Original Article
The reliability of individual maturity phase judged by dental age

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Abstract: The objective of this study was to investigate the reliability of using dental age to indicate the individual maturity phase. The samples were derived from the pretreatment digital panoramic radiographs and lateral skull cephalograms of 176 Chinese children, including 86 boys and 90 girls, aged 5-16 years. Maturity phase was evaluated by the cervical vertebral maturation (CVM) method. The mandibular second molars were chosen to assess the dental maturity using Demirjian’s method. The Spearman rank correlation coefficient was used to evaluate the correlation between the two maturation indicators. In addition, positive likelihood ratios were calculated to identify the reliability of dental stage to determine the maturity phase. Results: (1) The dental age had high correlations with bone maturity, especially in females. (2) The positive likelihood ratios in female was much higher than male’s. The positive likelihood ratios in female were 40 in stage D and 11.85 in stage E, indicating the stage D could identify initiation phase (CVM1) and stage E could identify the acceleration phase (CVM2) respectively. (3) In male: Stage D and stage H gave the positive likelihood ratios of 7.93 and 8.40 for identifying initiation phase (CVM1) and maturity phase (CVM5) respectively. Conclusion: Dental age had high correlation coefficients with bone maturities. In female, it was reliable to use dental age for the indication of individual maturity phase in clinical practice, with stage D standing for initiation phase and stage E for acceleration phase.

Keywords: Dental age, maturity phase, LR+

Introduction
Growth is an essential feature of organisms. It begins with fertilization and reach a peak until the individual grows into a fully mature body. In the history of human medical science, lots of pioneers have tried to find a method to evaluate the maturity phase [1] precisely. Confirming the pubertal growth spurt has great significance in pediatrics, anthropology, stomatology [2], and facilitates the interdisciplinary health care of the patients with various types of short stature, endocrine disorders, and/or metabolic diseases; its utility is well established for syndrome identification and forensics [3, 4]. In stomatological fields, evaluating children’s maturity phase precisely can help to identify the optimal time for orthopedic treatment [5].

Bone age is an important parameter which is widely used to evaluate the growth or physiologic maturation of patients. Initially we have used hand-wrist radiographs to assess maturity phase [6-9]. By now cervical vertebral maturation method (CVM) has been proved as valid as the hand-wrist bone analysis [5], with a lower radiation exposure for growing children [10].

Dental age [11-15] is another reliable signal for maturity assessment, which is less affected by external factors. So far, Demirjian’s method [16] has been accepted by all the dentists to assess dental age. This method is definite, however, it can’t indicate the maturity phase specifically.

The aim of the present study was to investigate the reliability of dental age forecast individual maturity phase.

Materials and methods
Subjects
The samples derived from the patients registered to the department of Orthodontics in the Stomatological Hospital of Shandong University,

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from July 2013 to July 2014. Pretreatment digital panoramic radiographs and lateral skull cephalograms were taken for diagnosis and treatment plan in 176 Chinese children aged 5-16 years, including 86 boys and 90 girls. Informed consents were obtained from all the patients, and the study protocol was approved by the ethical committee of the Stomatological hospital of Shandong University.

The samples were selected according to the following criteria: 1. No history of medical or surgical disease that could affect the presence and development of mandibular permanent teeth; 2. Integrity dentition; 3. No pulpitis or apical periodontitis and subsequent root canal treatment; 4. Digital radiograph with distinct images, especially images of the left mandibular second molars, the third and fourth cervical vertebra.

All above images were taken by ORTHOPHOS XG Plus DS Ceph (Sirona Dental Systems GmbH, Germany). In the present study, the mandibular second molars of left side were chosen to assess the dental maturity [17] through Demirjian [16] et al method. Maturity phase was evaluated according to the CVM method [1] (Figure 1). The morphology of the second cervical vertebra (C2), the third cervical vertebra (C3), and the fourth cervical vertebra (C4) were identified in 5 levels from cervical vertebral maturation 1 (CVM1) to cervical vertebral maturation 5 (CVM5), as Table 1.

80 radiographs were selected out and divided into 4 groups randomly, with 20 in each group. Group 1 was traced in the first week. In the second week, Group 2 was traced and Group 1 was traced again as a repeated trial. All of the 4 groups were traced in 5 weeks, with each group in the same way. The above radiographs were traced to evaluate the dental stage as well as the CVM stage twice. The agreement was calculated between two judgements. If a 95% agreement was not achieved, the cycle was repeated. This training program was supervised by an experienced orthodontist to ensure the intraobserver reliability.

Statistical analysis

The Spearman rank correlation coefficient was used to determine the correlation between the two maturation indictors. Additionally, in order to evaluate the diagnostic ability of dental stage, positive likelihood ratios were calculated [18]. These positive likelihood ratios could estimate how much a dental maturation stage changes the odds of a CVM stage. When the ratio was greater than 10, it was considered to have a satisfactory reliability, indicating that any dental maturation stage could be assessed for the identification of a CVM stage; when it was between 5 and 10, the reliability was ordinary; and when it was less than 2, the assessment was unreliable [19].

The statistical analysis was carried out using SPSS 17.0 software (SPSS Inc, Chicago, IL). Differences were considered statistically significant when P < 0.01.

Result

For whole sample

A total of 176 patients were involved in the investigation, aged from 5-16 (11.5±2.8), with a median age of 12.

Spearman rank-order correlation coefficients between the dental stages and CVM stages
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Table 1. The classification of CVM stages

<table>
<thead>
<tr>
<th>CVM stage</th>
<th>vertebral shape</th>
</tr>
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<tbody>
<tr>
<td>1 (Initiation)</td>
<td>C3 and C4 flat.</td>
</tr>
<tr>
<td>2 (Acceleration)</td>
<td>C3 concavity ≥1 mm; C4 flat.</td>
</tr>
<tr>
<td>3 (Pubertal peak)</td>
<td>C2, C3, and C4 concavity ≥1 mm; C3 and/or C4 tapered or horizontal rectangular.</td>
</tr>
<tr>
<td>4 (Deceleration)</td>
<td>C3 and/or C4 square; if C3 or C4 are not square, then horizontal rectangular.</td>
</tr>
<tr>
<td>5 (Maturation)</td>
<td>C3 and/or C4 vertical rectangular.</td>
</tr>
</tbody>
</table>

Flat: concavity < 1 mm. Tapered: C3up-C3lp to C3ua-C3la, or C4up-C4lp to C4ua-C4la ratio (PAR) > 1.20. Square: C3up-C3lp to C3ua-C3la, or C4up-C4lp to C4ua-C4la ratio (PAR) with 0.80-1.20; C3la-C3lp to C3ua-C3la, or C4la-C4lp to C4ua-C4la ratio (BAR) with 0.85-1.15. Horizontal rectangular: C3la-C3lp to C3ua-C3la, or C4la-C4lp to C4ua-C4la ratio (BAR) > 1.15. Vertical rectangular: C3la-C3lp to C3ua-C3la, or C4la-C4lp to C4ua-C4la ratio (BAR) < 0.85.

Table 2. The positive LHR for dental age for the identification of CVM stage (n=176)

<table>
<thead>
<tr>
<th>CVM stage</th>
<th>Dental Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.69**</td>
</tr>
<tr>
<td>2</td>
<td>0.81</td>
</tr>
<tr>
<td>3</td>
<td>0.09</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
</tr>
</tbody>
</table>

LHR, likelihood ratios; **numeric >10 have satisfactory reliability; *numeric is between 5-10 was considered the reliability is ordinary.

Table 3. The positive LHR for dental age for the identification of CVM stage in female (n=90)

<table>
<thead>
<tr>
<th>CVM stage</th>
<th>Dental Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40**</td>
</tr>
<tr>
<td>2</td>
<td>0.59</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
</tr>
</tbody>
</table>

LHR, likelihood ratios; **numeric >10 have satisfactory reliability.

was 0.692, and the correlation was statistically significant (P < 0.01). The positive likelihood ratios for each dental maturation stage for the identification of each CVM stage were shown in Table 2.

For females

There were 90 females in the study, aged from 5-16 (11.7±3.0), with a median age of 12.

Spearman rank-order correlation coefficients between the dental stages and CVM stages in females was 0.711, and the correlation was statistically significant (P < 0.01). The positive likelihood ratios for each dental maturation stage for the identification of each CVM stage in female were shown in Table 3.

For males

86 males participated in this study, aged from 5 to 16 (11.3±2.5), with a median age of 12.

Spearman rank-order correlation coefficients between the dental stages and CVM stages in males was 0.666, and the correlation was statistically significant (P < 0.01). The positive likelihood ratios for each dental maturation stage for the identification of each CVM stage in male were shown in Table 4.

Discussion

Maturity phase was one of the most important indicators in orthodontic treatment. Its identification could help the orthodontists to determine whether to recommend activator appliances, orthopedic force therapy, fixed appliances, extraction treatment or orthognathic sur-
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In previous studies [3, 17, 20-24], the correlation between dental and bone age had been analyzed for ranked data using Spearman's correlation coefficient. However, it could only indicate the agreement of two indicators but couldn't specify for more details due to the limitation of the analytical method. In the present study, the positive likelihood ratio based on Spearman's analysis was introduced to test whether there were one-to-one correspondence between dental age and CVM stage. The reliability of dental age to evaluate maturity phase could guide the clinical diagnosis and treatment plan.

In the exploratory study, we randomly selected 140 samples from 300 conforming to inclusion criteria, and analyzed them. We found a maldistribution in male that the sum of males was much smaller than females. The insufficient male samples limited some calculations. In order to achieve a more credible result, we specifically added more samples based on 400, improving the distribution in male and female. The main cause of lack samples in male is the different psychologic situation between male and female. Male adolescent are less concern about the aesthetic and health of teeth than females; and the rebellious emotion is more serious. They have bad compliance when parents want take them to receive orthodontic treatment.

In accordance with previous studies, there was a high correlation coefficient between dental age and bone age in this study, especially in females. This further suggested that somehow the dental age could reflect the maturity phase.

The correspondence between dental stages and CVM stages was tested by the positive likelihood ratios. This study showed the positive likelihood ratios were much higher in female than in male. In female, the stage D identified initiation phase (CVM1) in LR+ with 40 and stage E identified the acceleration phase (CVM2) in LR+ with 11.85. These numerical values indicated a satisfying diagnostic reliability, which could assist in the clinical diagnosis. On the other hand, in male; Stage D and stage H showed positive likelihood ratios of 7.93 and 8.40 for the identification of initiation phase (CVM1) and maturation phase (CVM5) respectively. These numerical values were less than 10, showing that it was not reliable enough to use the dental stages to demonstrate a specific bone stage. However, as a part of an integrated evaluation system, it was necessary to find other auxiliary methods to confirm.

Based on the above results, dental development period in female was longer than that in male. In male, it started later and ended earlier than in female, consequently the difference between dental and bone development in male is more obvious than the in female. In this study, it was more reliable to use dental age for identification of individual maturity phase in female than in male. For the total samples, the reliability of the above judgment was not enough in the clinical diagnosis, because of the difference between male and female. Although the results was not convenient in all of the maturity phase, but the capability of indicating maturity phase prompt us to learn more about dental maturation.

Despite the base samples that had been increased to 400 in this study, maldistribution in age and gender still existed. For the further investigation, the maldistribution needs to be solved to obtain a more comprehensive result with the improvement of the samples.

Conclusions

Dental age had quite relevance with bone maturities.

For female, it was reliable that a certain dental stage could reflect individual maturity phase clinically. Stage D of left mandibular second molars indicated the initiation phase, and stage E indicated the acceleration phase.

For male, it's a part of integrated assessment system applied dental age represent to the maturation.

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Disclosure of conflict of interest

None.

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