ABSTRACT

Objective: The assessment of skeletal maturation is of prime importance in diagnosis, treatment planning and retention after orthodontic treatment. This study was contemplated to find the correlation of improved version (CVMS) with older version (CVMI) of cervical vertebral maturation indicator and to correlate both these methods to stages of ossification of middle phalanx of third finger (MP3) and calcification stages of mandibular canine.

Materials and methods: The radiographs of 80 healthy children (40 males and 40 females) between the age group of 10 and 15 years were taken to assess the CVMS and CVMI stages using lateral cephalogram, stages of MP3 and the stages of development of mandibular right canine using dental (IOPA) X-ray film. Skeletal maturation was assessed from MP3, CVMS, CVMI and dental maturation was determined by Demirjian method.

Results: Overall, high significant correlation was found between CVMI and CVMS (r = 0.994) and lowest significant correlation was found between CVMS and DeMI (r = 0.653). Association between CVMS and CVMI indicated that stages 1, 2, 3 of CVMI correlated directly with CVMS 1, 2, 3; stages 4/5 of CVMI correlated with stage 4 of CVMS, and stage 6 of CVMI with stage 5 of CVMS.

Conclusion: The correlation between middle phalanx of 3rd finger (MP3) and cervical vertebral maturation method (CVMI and CVMS) was higher as compared to the correlation of either of the cervical vertebral maturation method or MP3 with dental maturation indicator.

Keywords: CVMI, CVMS, MP3, DeMI.


INTRODUCTION

Human growth is characterized by considerable variation in the rate of progress of different persons toward physiologic maturity. So, it becomes mandatory to assess the maturation status of the patient before planning orthodontic treatment and becomes even more important, when the treatment requires orthopedic correction. The developmental status of a child can be assessed by various growth indicators, including chronological age, dental development, height and weight, secondary sexual characteristics and skeletal age.1 The chronologic age may have little or no place in the assessment of maturational status of a child since it is governed by various factors, like genetic, epigenetic, environmental, nutritional, hormonal, etc.1 Assessment of height, weight and secondary sexual characters require long observation periods so they are not feasible in orthodontic practice. Various skeletal maturity indicators are used to determine the maturity level of an individual.2-8 Of these, bones of hand wrist and cervical vertebrae are very reliable parameters in assessing skeletal maturation. Dental calcification stages, though to a lesser degree than skeletal maturation indicators, correlate with the growth of an individual.2,3 In the present study, skeletal maturation was assessed by cervical vertebral maturation given by Hassel and Farman (CVMI),1 and by Baccetti and Franchi (CVMS),8 by middle phalanx of third finger (MP3) as given by Rajagopal and Kansal.6 Dental maturation was assessed by determining the calcification stages of mandibular right canine using Demirjian’s method as used by Coutinho and Buschang2,5 in their study. As the modified method of assessing cervical vertebrae maturation has not been correlated to the stages of MP3 or canine calcification stages earlier, the aim of the present study was to establish the correlation of the improved version of cervical vertebral maturation indicator with the ossification stages of MP3 and mineralization stages of mandibular canine and also to correlate older version with the improved version. Hence, an attempt was made not to validate the superiority of one method over the other but to establish correlation between the different methods available to assess skeletal maturation.

MATERIALS AND METHODS

The aim of this study was to see correlation in cervical vertebrae maturation stages (indicators), as seen on lateral cephalogram with calcification stages of mandibular canine.
as seen on IOPA X-ray and to compare them with maturation stages of MP3 as seen on IOPA X-ray. Eighty subjects (males and females) with age range of 10 to 15 years were selected randomly from patients visiting the Departments of Orthodontics, Pediatric Dentistry, and Oral Medicine and Radiology at Uttar Pradesh Dental College and Research Centre, Lucknow, and various schools.

Criteria for Case Selection

1. None of the subjects selected should have undergone orthodontic treatment.
2. All the subjects selected were moderately built and were in growing age with no history of bony deformities, bone diseases and major illnesses in the past.
3. None of the subjects showed any facial asymmetry.
4. No history of trauma or surgery in the dentofacial region.
5. The subjects with muscular dystrophy, congenital abnormalities affecting growth and development, traumatic lesions of cervical vertebrae, jaw, hand and wrist were excluded.

All the subjects were divided into two groups. Group I consisted of males, Group II consisted of females as shown in Table 1. Each group was further divided into two subgroups on the basis of their age.

Method: Standardized lateral cephalometric radiograph of each individual was taken with a Villa cephalostat. The films were exposed to 10 mA and 80 kV power for an average of 0.8 seconds with a tube to film distance of 6 feet. All the usual protective measures for radiographic exposure were followed in each patient.

Periapical radiograph for recording the stages of MP3 was taken by instructing the individual to place the right hand with the palm downward on a flat table, then middle finger was centered on a 31 × 41 mm periapical dental X-ray film, parallel with the long axis of the film. The cone of the dental X-ray machine was positioned in slight contact with the middle phalanx, perpendicular to the film. The film was exposed to 70 kV power and 8 mA for an average of 0.4 seconds.

Intraoral periapical radiograph of mandibular canine was taken using the bisecting angle technique with the film size 31 × 41 mm. The film was exposed to 8 mA and 70 kV power for an average of 0.3 seconds.

Radiographs of high clarity and good contrast were used. Interpretation of all radiographs was undertaken without referring to the clinical data of age of the patient.

The parts of the cervical vertebrae (C2, C3, C4) as seen on the lateral cephalogram were traced on matte acetate paper with 0.5 mm diameter pencil. These areas were selected because third and fourth cervical vertebrae could be visualized even when a thyroid protective collar was worn during radiation exposure. To assess the maturational stages of cervical vertebrae, visual assessment was done and stage of maturation was determined by both older (Fig. 1) and improved version methods (Fig. 2). For determination of stages of ossification of middle phalanx of 3rd (MP3) finger, it was traced on matte acetate paper and assessed by method given by Rajagopal and Kansal (Fig. 3). Calcification stages of right mandibular canine was determined by using Demirjian’s method as used by Coutinho and Buschang in their study after tracing mandibular right canine on matte acetate paper (Fig. 4).
The crown formation is completed down to the cemento-enamel junction.

- The superior border of the pulp chamber in the uniradicular teeth has a definite curved form, being concave toward the cervical region. The projection of the pulp horns, if present, gives an outline-shaped like an umbrella top.

- Beginning of root formation is seen in the form of a spicule.

- The walls of the pulp chamber now form straight lines whose continuity is broken by the presence of the pulp horn, which is larger than in the previous stage.

- The root length is less than the crown height.

- The walls of the pulp chamber now form a more or less isosceles triangle. The apex ends in a funnel shape.

- The root length is equal to or greater than the crown height.

- The walls of the root canal are now parallel and its apical end is still partially open.

- The apical end of the root canal is completely closed.

- The periodontal membrane has a uniform width around the root and the apex.

**Fig. 4:** Dental formation stages D-H of mandibular canine (adapted from Demirjian as used by Coutinho and Bushchang)

### Statistical Analysis: Mean Standard Deviation

**Error of measurement:** The test-retest method was used to assess the reliability. Repeat estimation of 20 randomly selected samples, 10 males and 10 females, from each of the two age groups were staged using different methods. As the assessments were done in form of grades/stages, kappa-statistic was calculated to match the interobservation reliability. Table 4 describes reliability chart to assess intraoperative error.

All the κ values were observed to be above 0.6, thereby indicating substantial agreement between two observations. Correlation between different systems was found Spearman rank correlation was performed and all the correlations were significant at p < 0.05.

### OBSERVATION AND RESULTS

Table 2 shows correlation between different systems irrespective of gender and age group. Table 3 shows overall correlations. Highest significant correlation was found between CVMS and CVMI with (r = 0.994) and lowest significant correlation was found between CVMS and DeMI

![Table 1: Subjects grouping](image)

<table>
<thead>
<tr>
<th>S.no.</th>
<th>Subgroup</th>
<th>Age years</th>
<th>No. of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>M₁</td>
<td>10-12</td>
<td>20</td>
</tr>
<tr>
<td>2.</td>
<td>M₂</td>
<td>13-15</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>F₁</td>
<td>10-12</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>F₂</td>
<td>13-15</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>40</td>
<td>Total 40</td>
</tr>
</tbody>
</table>

![Table 2: Overall correlation between different systems irrespective of gender and age group](image)

<table>
<thead>
<tr>
<th>10-12 (M + F)</th>
<th>13-15 (M + F)</th>
<th>10-12 F</th>
<th>13-15 F</th>
<th>10-12 M</th>
<th>13-15 M</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVMS &amp; CVMI</td>
<td>1</td>
<td>0.995</td>
<td>1</td>
<td>0.935</td>
<td>1</td>
</tr>
<tr>
<td>CVMS &amp; MP3</td>
<td>0.751</td>
<td>0.779</td>
<td>0.727</td>
<td>0.737</td>
<td>0.701</td>
</tr>
<tr>
<td>CVMI &amp; MP3</td>
<td>0.751</td>
<td>0.785</td>
<td>0.727</td>
<td>0.763</td>
<td>0.701</td>
</tr>
<tr>
<td>CVMS &amp; DeMI</td>
<td>0.690</td>
<td>0.458</td>
<td>0.378</td>
<td>0.402</td>
<td>0.329</td>
</tr>
<tr>
<td>CVMI &amp; DeMI</td>
<td>0.690</td>
<td>0.417</td>
<td>0.378</td>
<td>0.230</td>
<td>0.329</td>
</tr>
<tr>
<td>MP3 &amp; DeMI</td>
<td>0.612</td>
<td>0.550</td>
<td>0.383</td>
<td>0.461</td>
<td>0.351</td>
</tr>
</tbody>
</table>

![Table 3: Overall correlations](image)

- The crown formation is completed down to the cemento-enamel junction.
- The superior border of the pulp chamber in the uniradicular teeth has a definite curved form, being concave toward the cervical region. The projection of the pulp horns, if present, gives an outline-shaped like an umbrella top.
- Beginning of root formation is seen in the form of a spicule.
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- The walls of the root canal are now parallel and its apical end is still partially open.
- The apical end of the root canal is completely closed.
- The periodontal membrane has a uniform width around the root and the apex.
Baccetti and Franchi was used, as both of these methods were reliable predictors of sexual and somatic maturity as well. Both these methods are closely related to the stages of maturation of an individual as also shown in the previous longitudinal studies. Considering this fact, it was decided to use stages of ossification of MP3 given by Rajagopal and Kansal as seen on the intraoral periapical radiograph as it significantly reduced the radiation exposure. In this study, for the assessment of cervical vertebral maturation one method by Hassel and Farman and other modified version given by Baccetti and Franchi was used, as both of these methods analyze the shape of second, third and fourth cervical vertebrae, which can be seen even when protective radiation collar is worn. As both of these methods had not been correlated to each other in the past, hence, it was decided to establish the correlation of the improved version of cervical vertebral maturation indicator with older version by Hassel and Farman. Dental age assessed on the basis of eruption of teeth used as an indicator for maturity is a simple but not so accurate method because of wide variations in time of eruption of teeth so in this study a more reliable method based on tooth calcification was used as given by Demirjian. It has been found that relationships between the stages of tooth mineralization of the mandibular canine appear to correlate better with the ossification stages than the other teeth. Considering this fact, the calcification stages of right mandibular canine were used to assess the dental maturation of an individual in the present study. Therefore, the aim of the present study was to correlate the stages of maturation of cervical vertebral maturation, the stages of ossification of MP3 (in IOPAR) and stages of mineralization of mandibular canine-DeMI (in IOPAR) as a maturity indicator with each other and to correlate the older stages of ossification of MP3, (r = 0.653). All other correlation were also significant with (r = 0.783) for CVMS and MP3, (r = 0.775) for CVMI and MP3, (r = 0.664) for CVMI and DeMI, (r = 0.664) MP3 and DeMI.

### DISCUSSION

In orthodontics and dentofacial orthopedics, the assessment of skeletal age and pubertal growth spurt in particular are of prime importance in diagnosis, treatment planning and retention after orthodontic treatment. The key issue with any of these growth assessment methods is reliability. Although dental age has a statistically significant low correlation with the skeletal age, the skeletal maturity of the bones of the hand and wrist and the cervical vertebrae, on the other hand, is closely related to growth of the craniofacial region, and skeletal maturity indices are reliable predictors of sexual and somatic maturity as well. Both these methods are closely related to the stages of maturation of an individual as also shown in the previous longitudinal studies. Considering this fact, it was decided to use stages of ossification of MP3 given by Rajagopal and Kansal as seen on the intraoral periapical radiograph as it significantly reduced the radiation exposure. In this study, for the assessment of cervical vertebral maturation one method by Hassel and Farman and other modified version given by Baccetti and Franchi was used, as both of these methods analyze the shape of second, third and fourth cervical vertebrae, which can be seen even when protective radiation collar is worn. As both of these methods had not been correlated to each other in the past, hence, it was decided to establish the correlation of the improved version of cervical vertebral maturation indicator with older version by Hassel and Farman. Dental age assessed on the basis of eruption of teeth used as an indicator for maturity is a simple but not so accurate method because of wide variations in time of eruption of teeth so in this study a more reliable method based on tooth calcification was used as given by Demirjian. It has been found that relationships between the stages of tooth mineralization of the mandibular canine appear to correlate better with the ossification stages than the other teeth. Considering this fact, the calcification stages of right mandibular canine were used to assess the dental maturation of an individual in the present study. Therefore, the aim of the present study was to correlate the stages of maturation of cervical vertebral maturation, the stages of ossification of MP3 (in IOPAR) and stages of mineralization of mandibular canine-DeMI (in IOPAR) as a maturity indicator with each other and to correlate the older stages of ossification of MP3, (r = 0.653). All other correlation were also significant with (r = 0.783) for CVMS and MP3, (r = 0.775) for CVMI and MP3, (r = 0.664) for CVMI and DeMI, (r = 0.664) MP3 and DeMI.

### CONCLUSION

Within the limitations of this cross-sectional study, the following conclusions can be drawn:

1. We may say that the correlation between MP3 and cervical vertebral maturation method (CVMI and CVMS) was higher as compared with the correlation between either of the cervical vertebral maturation method and MP3 with dental maturation indicator.

2. The maturation of the MP3, cervical vertebrae and the mandibular right canine progress with age were more advanced in females in comparison to males. There was a statistically significant difference between the two age groups for different indicators and also for both the genders independently.

3. Recording MP3 stages on the intraoral periapical radiograph is an equally reliable choice as a maturation indicator whenever repeated radiographs are required for the assessment of peak in pubertal growth or when lateral cephalogram is not needed at that time. MP3 on IOPA radiograph significantly reduces radiation exposure to the patient and requires less elaborate armamentarium.

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**Table 4: Reliability chart (for intraoperative error)**

<table>
<thead>
<tr>
<th>Method</th>
<th>( \kappa )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVMI</td>
<td>0.722</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CVMS</td>
<td>0.649</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MP3</td>
<td>0.743</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DeMI</td>
<td>0.710</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

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**Figure 1: Correlation of Improved Version of Cervical Vertebral Maturation Indicator with Other Growth Maturity Indicators**

<table>
<thead>
<tr>
<th>Method</th>
<th>( \kappa )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVMI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CVMS</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
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<tr>
<td>DeMI</td>
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</tr>
<tr>
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<td>&lt;0.001</td>
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4. Association between CVMS and CVMI indicated that stages 1, 2, 3 of CVMI correlated directly with CVMS 1, 2, 3; stages 4/5 of CVMI correlated with stage 4 of CVMS and stage 6 of CVMI correlated with stage 5 of CVMS. Therefore, we can suggest that the results of older version can be applied to the newer version of cervical vertebral maturation index. (i.e. percentage of growth remaining by CVMI method and mandibular growth potential by CVMS method can be used interchangeably).

REFERENCES