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Evaluation of skeletal and dental maturity indicators and assessment of cervical vertebral maturation stages by height/width ratio of third cervical vertebra

Madhur Navlani [a,*], *P.G. Makhija* [b]

[a] *Reader, Department of Orthodontics & Dentofacial Orthopedics, Modern Dental College & Research Centre, Indore, India*
[b] *Professor & Head, Department of Orthodontics & Dentofacial Orthopedics, Modern Dental College & Research Centre, Indore, India*

Keywords:
CVMI
Hand-wrist radiograph
Mandibular canine developmental stages
Ratio of cervical vertebrae
MP3

ABSTRACT

Objectives: This study was designed to evaluate: Relationship between skeletal maturity indicators and a dental maturity indicator for assessment of pubertal growth in patients and; Feasibility and reliability of using height/width ratio of the third cervical vertebra for objective assessment of CVMI stage.

Methods: The study was conducted on 120 children in the age group of 8–16 years, comprising of 60 males and 60 females. Informed consent and due precaution for radiation safety were followed. Lateral cephalogram for assessment of cervical vertebrae maturation stages, OPG for evaluating mandibular canine developmental stages, Radiograph of middle phalanx of middle finger of right hand for MP3 maturation were recorded. Height/Width ratio of third cervical vertebra in all subjects was also calculated.

Results: Significant correlation was observed between MP3 stages and CVMI stages, whereas no correlation was observed between skeletal maturity indicators and dental developmental stages of mandibular canines. A highly significant correlation was observed between CVMI stage and height/width ratio of C3 vertebra in all subgroups of total population.

Conclusions: Skeletal maturity indicators show significant correlation amongst them but not with dental maturity indicator used in the study. CVMI stage can be assessed objectively by calculating the height/width ratio of C3 vertebra.

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1. Introduction

Clinical decisions in Orthodontics and Dentofacial Orthopedics regarding use of extraoral forces, functional appliances, extraction versus non-extraction treatment or Orthognathic surgery are at least partially based on growth considerations.[1] Skeletal maturation staging from radiographic assessment is a widely used approach to predict timing of pubertal growth, to estimate growth velocity and to estimate proportion of growth remaining.[2]

* *Corresponding author*. 'Devi-Kunj', 27, Triveni Colony Extension, Indore, M.P. 452004, India.
E-mail addresses: drmadhurnavlani@gmail.com, info@theperfect32.com (M. Navlani).

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http://dx.doi.org/10.1016/j.jpfa.2013.11.001

Initially, bone age was assessed by the stage of development of osseous centers in several regions of the body and compared with standards. For the hand, suitable standards include those of Todd, Flory and Greulich and Pyle.[3] Later, Fishman developed a system of skeletal maturation indicators (SMIs) using four stages of bone maturation at six anatomic sites and eleven indicators on hand and wrist radiograph.[4] In an attempt to reduce the radiographic exposure, assessment of maturity from the Hand-wrist radiographs was further simplified by observation of progressive ossification of the MP3 (Middle phalanx of 3rd finger) as described by Hagg and Taranger[5] and later by Kansal & Rajagopal[6] on a dental film.

Usefulness of lateral cephalometric radiographs by studying the maturation of the cervical vertebrae to assess skeletal maturation as initially described by Lamparski (1972) and elaborated later by Hassel and Farman[7], has the potential advantage of reducing the radiation exposure to the patient, as it eliminated the need for additional radiographs and assessment could be done even when patient wore a thyroid collar by analyzing the bodies of second, third and fourth cervical vertebrae.

Ease of recognizing dental developmental stages, together with the availability of intraoral or panoramic radiographs in most orthodontic dental practices, are practical reasons for attempting to assess physiologic maturity of an individual by using dental age which may be assessed either by tooth eruption dates or by the progress of tooth calcification. Demirjian, Goldstein and Tanner developed a method for estimating dental maturity or dental age, by reference to the radiological appearance of the seven teeth on the left side of the mandible.[8] Coutinho, Buschang and Miranda studied the relationship between mandibular canine calcification stages and skeletal maturity and concluded dental calcification stage of the mandibular canine provide readily available and easily recognized indicator of the maturity status of a person.[9]

Clinically, the timing of dento-facial orthopedic therapy can be determined by all of these factors, but neither chronological age nor the level of dental development alone can demonstrate growth status of an individual therefore sufficient correlation with skeletal maturation indicators is required to provide an adequate basis for the timing of therapy. It is also important to evaluate whether skeletal maturity indicators can be used interchangeably.

All these methods for growth assessment also have an inherent disadvantage of being subjective since they rely mostly on perceptible changes in the morphology of bones or teeth.

So, this study was designed to evaluate the relationship between skeletal maturity indicators i.e. MP3 and CVMI staging and dental maturity indicator i.e. mandibular canine developmental stages for assessment of pubertal growth spurts in patients. Secondly, to evaluate the feasibility and reliability of using height/width ratio of the third cervical vertebra for objective assessment of CVMI stage.

2. Material & methods

The study was conducted on 120 children selected from those who approached the Department for Orthodontic treatment in the age group of 8–16 years, comprising of 60 males and 60 females both of which were further divided into four subgroups on basis of age with 15 subjects each. This age group selection is supported by various studies done by O'Reilly and Yanniello[10], Moore[1] and Hellman on skeletal maturity assessment emphasizing the inclusion of subjects in age group who usually approach to Orthodontic clinics.

After informed consent from all subjects, following radiographs were taken with due precaution for radiation safety:

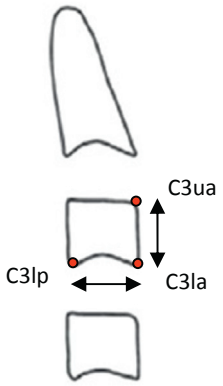


Fig. 1 – Cephalometric landmarks drawn on third cervical vertebrae to aid in measurement of height and width

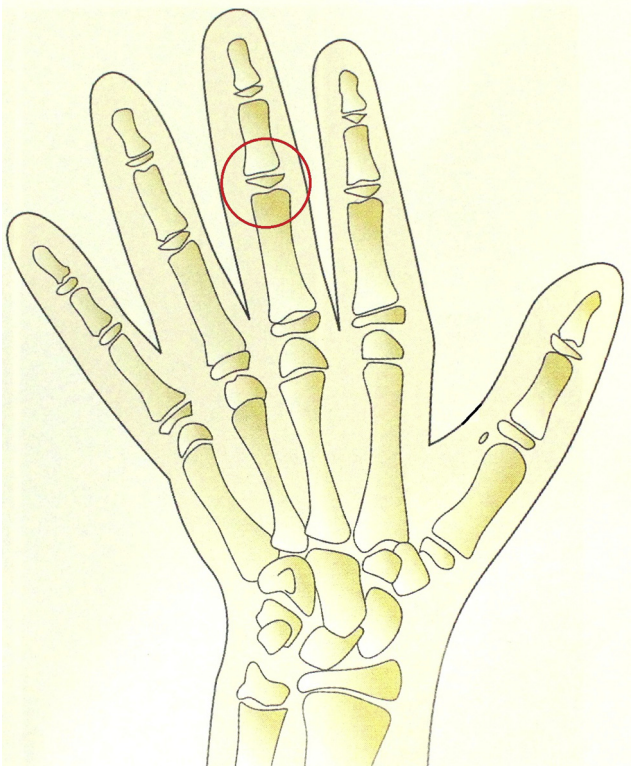


Fig. 2 – Highlighted area showing the middle phalanx of the third finger of the hand assessed in the study.

1. Lateral cephalogram for assessment of cervical vertebrae maturation stages.
2. OPG for evaluating mandibular canine developmental stages.
3. Radiograph of middle phalanx of middle finger of right hand for assessment of MP3 maturation.

Interpretation of cervical vertebrae maturation stages was done by method as given by Baccetti, Franchi, Mcnamara Jr.[11] Further, on the body of third cervical vertebra, points C3ua (superior most point of the anterior border), C3lp (posterior most point on the lower border) and C3la (anterior most point on the lower border) were traced and anterior height was measured in millimeters from point C3ua to C3la and lower border width was measured from point C3lp to C3la (Fig. 1) till two decimal points using a digital Vernier Caliper and then anterior height/lower border width ratio was calculated.

Interpretation of mandibular canine development stages was done by the method described by Demirjian et al[8] in 1973 for tooth development. The stages ascribed to tooth development in this study ranged from Stage D to Stage H.

For interpretation of MP3 radiograph, method introduced by Hagg and Taranger[5] was used. It consists of five stages of ossification for middle phalanx of third finger (MP3) of the hand (Fig. 2).

Fig. 3 shows comparative diagrammatic & radiological illustration of five stages used in our study for interpretation of cervical vertebrae, Mandibular canine root formation and MP3 radiograph.

To evaluate the magnitude of error in the measurement of CVMI, mandibular canine development and MP3, a double

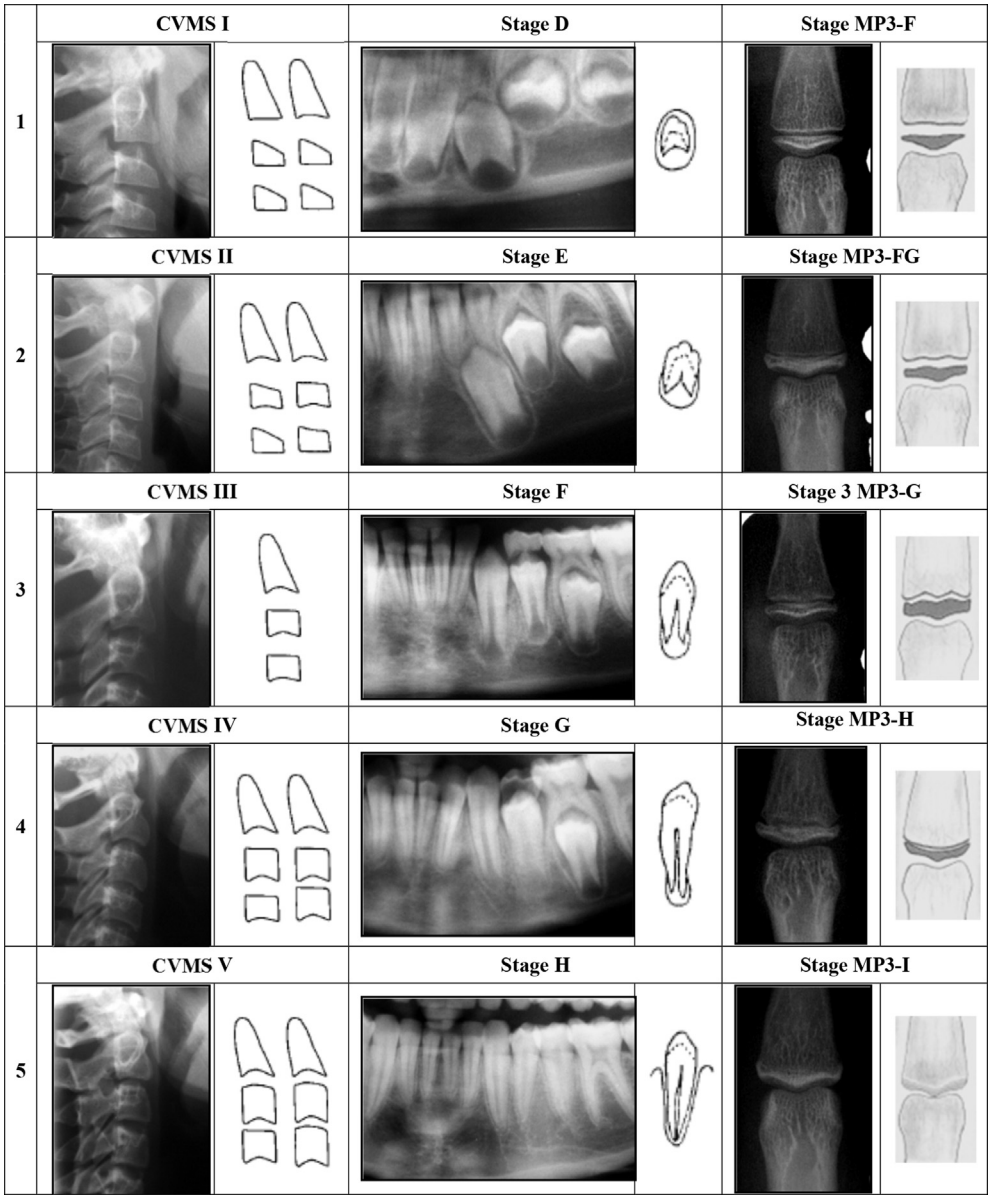


Fig. 3 – Comparative diagrammatic & radiological illustration of five stages used in our study for Interpretation of cervical vertebrae, mandibular canine root formation and MP3 radiograph.

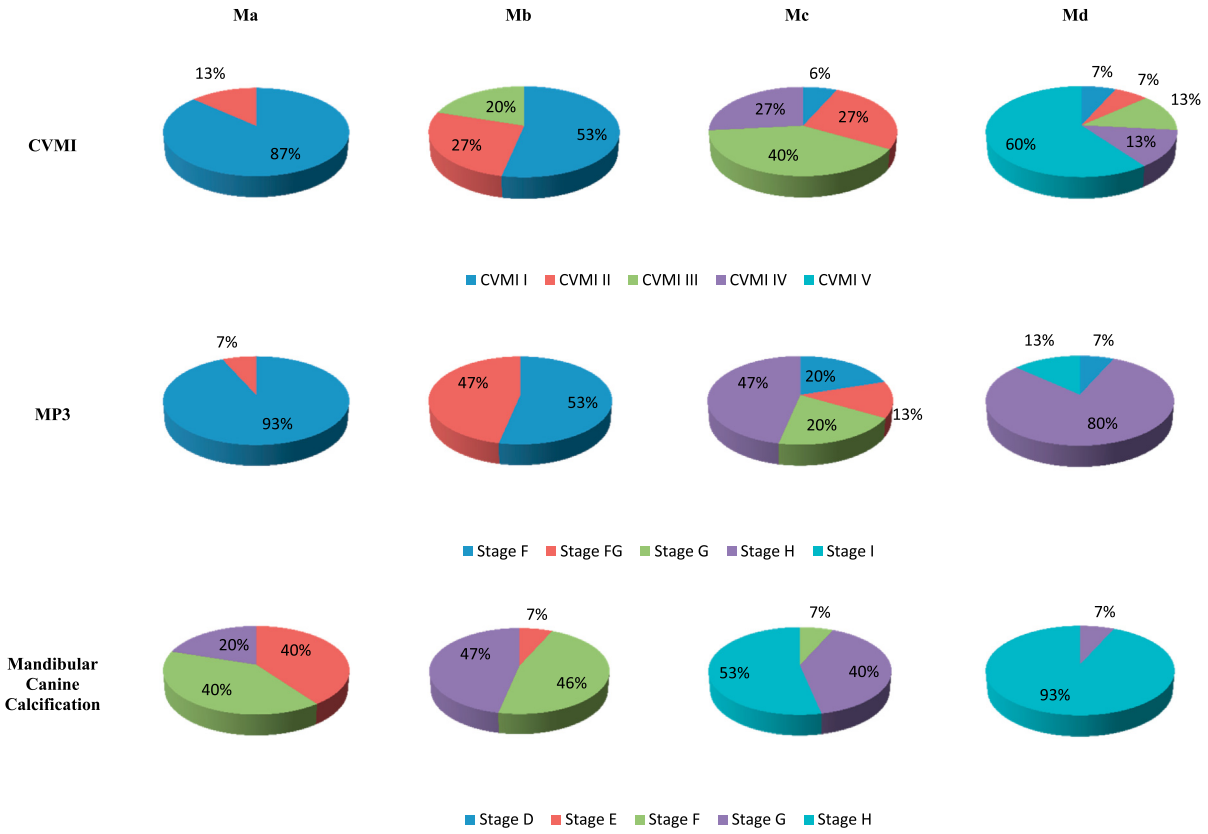


Fig. 4 – Pie diagrams showing distribution of Variables in Male Subjects of different subgroups

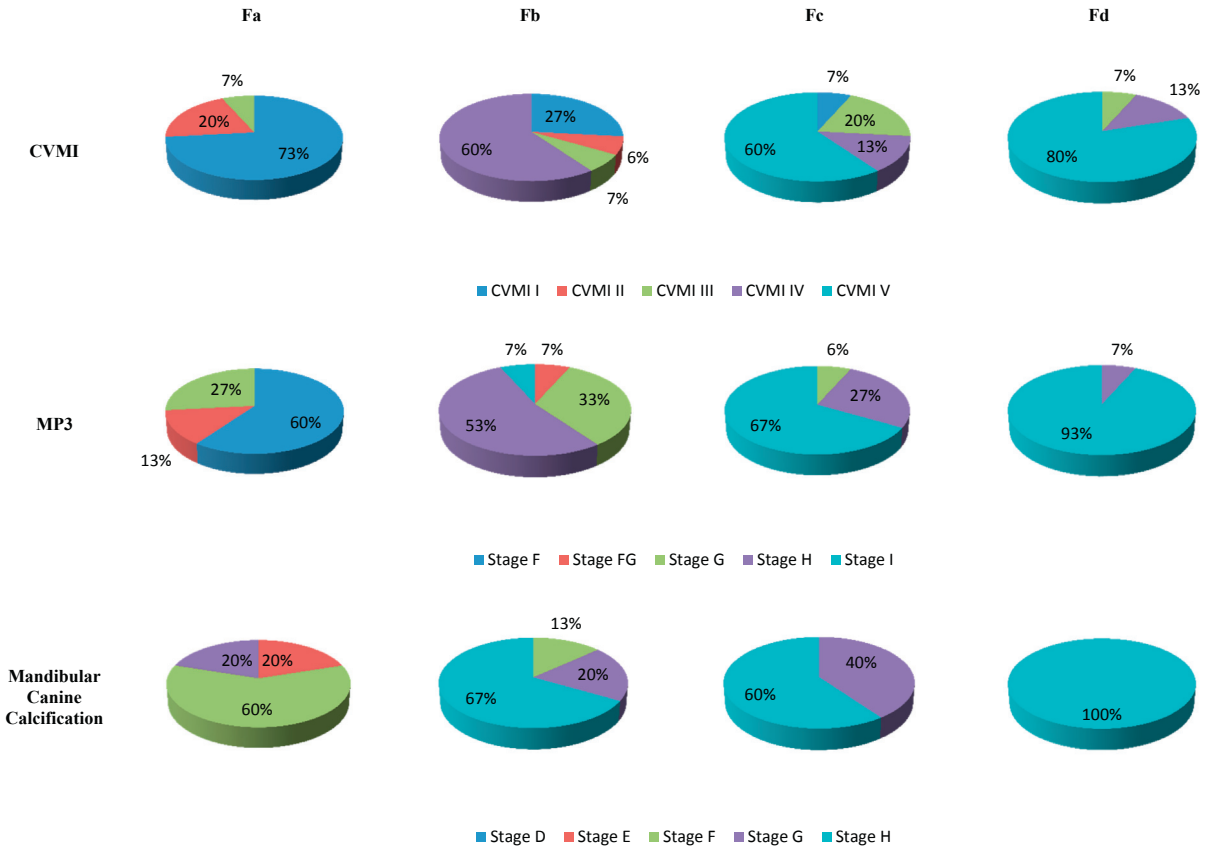


Fig. 5 – Pie diagrams showing distribution of Variables in Female Subjects of different subgroups

Table 1 – Showing mean, standard deviation, range and significance of CVMI stage for all subgroups in male and female subjects.

Sub group ($n = 15$ per subgroup)	Male				Female				't' value	p value
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.		
08–10 (a)	1.13	0.35	1.00	2.00	1.33	0.62	1.00	3.00	1.090	0.284NS
10–12 (b)	1.67	0.82	1.00	3.00	3.00	1.36	1.00	4.00	3.250	0.003**
12–14 (c)	2.87	0.92	1.00	4.00	4.20	1.21	1.00	5.00	3.400	0.002**
14–16 (d)	4.13	1.30	1.00	5.00	4.73	0.59	3.00	5.00	1.62	0.115NS

* = Significant, ** = highly significant.

determination was carried out on 40 individuals by same operator after one month. These tracings were analyzed separately and averages of readings were used for statistical evaluation.

3. Results

The data obtained on assessment of the above radiographs was sorted into various tables based upon the parameters of this study and was subjected to statistical analysis for obtaining correlation between MP3, CVMI and Mandibular canine developmental stages.

Figs. 4 and 5 show distribution of variables i.e. CVMI stage, Mandibular canine development and MP3 stage in respective subgroups of male and female subjects in the entire sample.

The mean, standard deviation (SD), range and significance of CVMI stage, Mandibular canine developmental stage, MP3 stage and Height/Width ratio of C3 vertebra for all subgroups of male and female subjects are presented in Tables 1–4.

The mean, standard deviation (SD), range and significance of CVMI stage for male and female subjects belonging to different subgroups (a-d) has been shown in Table 1. It can be seen that there are gradually increasing stages of CVMI with age. On comparing the mean CVMI stage of the males and females, it is observed that no significant differences are present in subgroup a and d and highly significant differences are present in subgroup b and c. In all the subgroups CVMI stages are more advanced in females than in males.

The mean, standard deviation (SD), range and significance of developmental stage of mandibular canine for male and female subjects belonging to different subgroups (a–d) has been shown in Table 2. It can be seen that there are gradually increasing stages of developmental of mandibular canine with age. On comparing the mean developmental stage of mandibular canine of the males and females, it is observed that no significant differences are present in subgroup a, c and d and significant differences are present in subgroup b. In all the subgroups developmental stage of mandibular canine are more advanced in females than in males.

The mean, standard deviation (SD), range and significance of MP3 stage for male and female subjects belonging to different subgroups (a–d) has been shown in Table 3. It can be seen that there are gradually increasing MP3 stages with age. On comparing the mean MP3 stage of the males and females, it is observed that significant differences are present in subgroup a and highly significant differences are present in subgroup b, c and d. In all the subgroups MP3 stage are more advanced in females than in males.

The mean, standard deviation (SD), range and significance of height/width ratio of C3 vertebra for male and female subjects belonging to different subgroups (a–d) has been shown in Table 4. It can be seen that there are gradually increasing height/width ratio of C3 vertebra with age. On comparing the mean height/width ratio of C3 vertebra of the males and females, it is observed that significant differences are present in subgroup a and d and highly significant differences are present in subgroup b and c. In all the subgroups height/width ratio of C3 vertebra are more advanced in females than in males. Fig. 6 shows the mean Height/Width ratio of third cervical vertebrae for all subgroups in male and female subjects of the study.

The Spearman's rank correlation coefficient (r) values for correlation between chronological age with CVMI stages, mandibular canine developmental stages and MP3 stage in male, female and total population are presented in Table 5. Highly significant correlation is found between the three variables and the chronological age in male, female and total population. However, for male subjects CVMI stage shows the maximum correlation followed by mandibular canine developmental stage and then by MP3 stage. In female subjects CVMI stage shows the maximum correlation followed by MP3 stage and then by mandibular canine developmental stage.

Table 2 – Showing mean, standard deviation, range and significance of mandibular canine developmental stage for all subgroups in male and female subjects.

Sub group ($n = 15$ per subgroup)	Male				Female				't' value	p value
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.		
08–10 (a)	2.80	0.77	2.00	4.00	3.00	0.65	2.00	4.00	0.763	0.451NS
10–12 (b)	3.40	0.63	2.00	4.00	4.53	0.74	3.00	5.00	4.497	0.000*
12–14 (c)	4.47	0.64	3.00	5.00	4.60	0.51	4.00	5.00	0.632	0.532NS
14–16 (d)	4.93	0.26	4.00	5.00	5.00	0.00	5.00	5.00	0.118	0.912NS

* = Significant.

Table 3 – Showing mean, standard deviation, range and significance of MP3 Stage for all subgroups in male and female subjects.

Sub group ($n = 15$ per subgroup)	Male				Female				't' value	p value
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.		
08–10 (a)	1.07	0.26	1.00	2.00	1.67	0.90	1.00	3.00	2.482	0.019*
10–12 (b)	1.47	0.52	1.00	2.00	3.60	0.74	2.00	5.00	9.183	0.000**
12–14 (c)	2.93	1.22	1.00	4.00	4.60	0.63	3.00	5.00	4.681	0.000**
14–16 (d)	3.93	0.88	1.00	5.00	4.93	0.26	4.00	5.00	4.206	0.000**

* = Significant, ** = highly significant.

When the total population is considered CVMI stage shows the maximum correlation followed by mandibular canine developmental stage and then by MP3 stage.

The Spearman's rank correlation coefficient (r) values for correlation between CVMI stages, mandibular canine developmental stages, MP3 stages and height/width ratio of C3 vertebra for all subgroups of male and female subjects are in presented in Table 6. When correlation is observed between CVMI and mandibular canine developmental stage, significant correlation exists in male subjects in age group of 12–14 years.

When correlation is observed between CVMI stage and MP3 stage, highly significant correlation exists in male subjects in age groups of 12–14 years, 14–16 years and in female subjects in age group of 12–14 years and a significant correlation exists in male and female subjects in age group of 10–12 years.

When correlation is observed between CVMI stage and height/width ratio of C3, highly significant correlation exists in male subjects in age groups of 12–14 years, 14–16 years and in female subjects in age group of 8–10 years, 10–12 years and 12–14 years.

When correlation is observed between mandibular canine developmental stage and MP3 stage, highly significant correlation exists in male subjects in age groups of 12–14 years and significant correlation exists in female subjects in age group of 10–12 years and 12–14 years.

Table 7 shows regression equations to calculate CVMI Stage on basis of H/W ratio of C3 for male, female and total population. A high value of multiple R for estimation of CVMI on basis of H/W ratio of C3 is indicative of its reliability and clinical applicability.

4. Discussion

As Orthodontists, we are expected to diagnose and treat individuals undergoing three-dimensional facial growth, the magnitude, rate and direction of which depends typically on the fourth dimension, i.e. time. In a given orthodontic case the selection of the treatment modality is therefore reliant on the stage of the growth of maxillofacial structures, thus, making its evaluation imperative.

The results of this study reveal that the maturation of the cervical vertebrae, mandibular canine development, maturation of middle phalanx of third finger and height/width ratio of C3 progresses with age but at a different rate.

In all subgroups, the CVMI and MP3 stages were more advanced in females than in males. This is in agreement with findings of Fishman,[4] Hagg and Taranger,[5] Chapman,[12] Leite et al,[13] Kalinowska.[14]

On comparing the male and female subgroups for mandibular canine development it was found that, there was significant difference in all subgroups between boys and girls but no significant differences in the rate of development between boys and girls as supported by Nolla. This can be attributed to the fact that in girls dental development started and completed early.

To find out the relationship between different skeletal and dental variables, Spearman's Rank correlation coefficient was applied between these variables according to age and sex. In males and females on comparing CVMI and MP3 with mandibular canine non-significant correlation was obtained in most subgroups. Results in this study show significant to highly significant association between MP3 and CVMI in both the genders in most of the subgroups indicating that either of the indicators can be used reliably and interchangeably to assess the skeletal maturity. These results are similar to that of that of Rajagopal and Kansal,[6] Wong et al,[15] Negi et al.[16]

A highly significant correlation exists between CVMI with length/breadth ratio of C3 in both the genders and in entire population in this study. This indicates that applicability of height/width ratio of C3 in determining pubertal status is comparable to CVMI stage.

Table 4 – Showing mean, standard deviation, range and significance of height/width ratio of C3 vertebra for all subgroups in male and female subjects.

Sub group ($n = 15$ per subgroup)	Male				Female				't' value	p value
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.		
08–10 (a)	0.48	0.06	0.39	0.57	0.56	0.10	0.39	0.76	2.629	0.013*
10–12 (b)	0.52	0.03	0.45	0.57	0.72	0.14	0.51	1.05	5.236	0.000**
12–14 (c)	0.62	0.13	0.42	0.87	0.77	0.14	0.50	0.98	3.147	0.003*
14–16 (d)	0.84	0.23	0.54	1.28	0.99	0.15	0.73	1.27	2.120	0.043*

* = Significant, ** = highly significant.

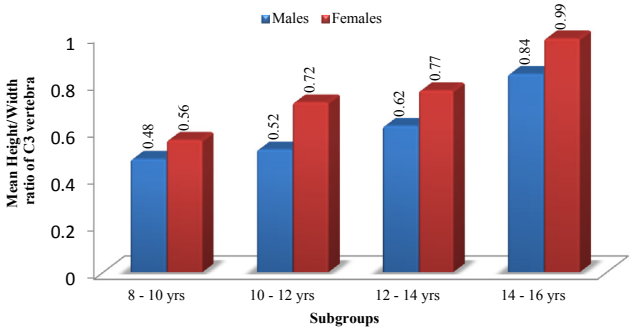


Fig. 6 – Mean height/width ratio of C3 vertebra for all subgroups in male and female subjects.

Table 5 – Showing correlation coefficient between chronological age of subjects with CVMI Stage, mandibular canine developmental stage and MP3 Stage in male, female and total population.

Parameters	Male	Female	Total
Correlation coefficient between CVMI Stage and chronological age of subjects (*r*)	0.803**	0.859**	0.846**
Probability (*p*)	0.000	0.000	0.000
Correlation coefficient between Mandibular Canine Stage and chronological age of subjects (*r*)	0.793**	0.761**	0.829**
Probability (*p*)	0.000	0.000	0.000
Correlation coefficient between MP3 Stage and chronological age of subjects (*r*)	0.773**	0.799**	0.765**
Probability (*p*)	0.000	0.000	0.000

* = Significant, ** = highly significant.

It must be remembered that skeletal and dental maturation is a continuous process. Skeletal maturity indicators in the hand-wrist and the cervical vertebrae and dental developmental stages are categorized by distinct events in this continuum. Each stage of maturation blends into the next, and it is sometimes difficult to differentiate the shape in borderline cases.[17] Therefore, to increase the objectivity of assessing the CVMI stages regression formulas were calculated for CVMI staging on basis of length/breadth ratio of C3 for males, females and total population.

Table 7 – Showing regression equation for calculating CVMI stage on basis of height/width ratio of C3 vertebra.

Regression equation for calculating CVMI Stage based on H/W ratio of C3:		
Male	CVMI = −1.396 + 0.0825 L/B ratio	Multiple *R* = 0.826
Female	CVMI = −1.625 + 0.0809 L/B ratio	Multiple *R* = 0.810
Total	CVMI = −1.463 + 0.0831 L/B ratio	Multiple *R* = 0.831

With the use of these formulas it would be possible to objectively assess the CVMI stage and all values of CVMI stage between 2 and 3 hold clinical relevance to predict the peak of growth of mandible for dentofacial orthopedic treatment. Alternatively, it can also be stated on the basis of formulas derived for total population in our study that all values of height/width ratio of C3 between 0.53 and 0.70 are suggestive of peak of growth of mandible and have clinical relevance.

5. Conclusion

Following conclusions were derived from this study:

1. A significant correlation is observed between MP3 stages and CVMI stages, whereas no correlation was observed between skeletal maturity indicators and dental developmental stages mandibular canines. Therefore, dental developmental stages cannot be used as a reliable indicator for assessment of pubertal growth status of an individual.
2. A highly significant correlation is observed between CVMI stage and height/width ratio of C3 vertebra in all subgroups of total population. This shows that there is a high

Table 6 – Showing correlation coefficient between different variables in all subgroups of male and female subjects.

Statistical parameter	Male				Female			
	CVMI & Mand. canine	CVMI & MP3	CVMI & H/W ratio C3	Mand. canine & MP3	CVMI & Mand. canine	CVMI & MP3	CVMI & H/W ratio C3	Mand. canine & MP3
08–10 years								
Correlation coefficient (*r*)	0.367	−0.105	0.467	−0.286	−0.177	0.343	0.710**	0.243
Probability (*p*)	0.177	0.710	0.077	0.301	0.528	0.209	0.003	0.383
10–12 years								
Correlation coefficient (*r*)	0.415	0.565*	0.116	0.044	0.212	0.569*	0.704**	0.548*
Probability (*p*)	0.122	0.027	0.681	0.877	0.448	0.026	0.003	0.033
12–14 years								
Correlation coefficient (*r*)	0.601*	0.693**	0.787**	0.773**	0.490	0.861**	0.825**	0.579*
Probability (*p*)	0.017	0.004	0.000	0.001	0.062	0.000	0.000	0.023
14–16 years								
Correlation coefficient (*r*)	0.028	0.691**	0.692**	−0.021	−0.124	0.342	0.273	−0.071
Probability (*p*)	0.920	0.004	0.004	0.941	0.658	0.211	0.323	0.800

* = Significant, ** = highly significant.

feasibility of using height/width ratio of C3 for assessment of pubertal status.
3. CVMI stage can be calculated on the basis of height/width ratio of C3 vertebra.

If orthodontic treatment of cases of malocclusion were initiated during the period of maximum growth, results should be obtainable in shorter time, with less effort of the orthodontist, more comfort to the patient, and greater satisfaction to all.[18]

Conflicts of interest

All authors have none to declare.

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