

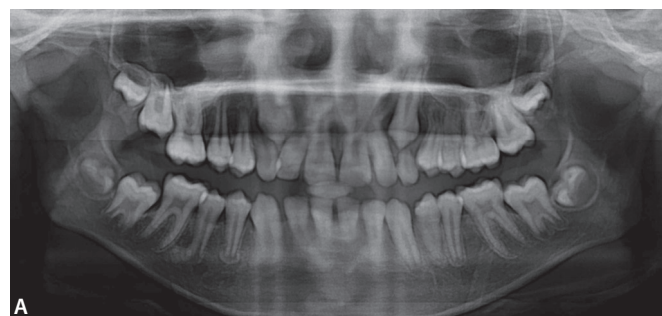
and dentofacial orthopedics, KM Shah Dental College, and Hospital, Sumandeep Vidyapeeth, Piparia, Gujrat, India. Lateral cephalogram and OPG of the participant included in the study were collected on the same day. All the Cephalograms and OPGs of participants included in the study were taken from Kodak 8000c digital panoramic and cephalometric system. A fixed distance of 5 feet with an exposure time of 1 second, 78 KVP and 12–15 MA were maintained during the exposure of the radiographic film. A participant information sheet was provided to the patient and informed consent was obtained from all the patients included in the study. Patients who had no history of medical or surgical disease affecting the presence and development of all teeth till second molars were included in the study. Patients with a history of serious illness, systemic disease, bone disease or deformities, trauma or disease to face, and/or neck, etc. were excluded from the study.

These 264 participant's lateral cephalograms and OPGs were further subdivided into 6 groups having a chronologic age group interval of 2 years each (7 years 1 month to 8 years 11 months, 9 years 1 month to 10 years 11 months, 11 years 1 month to 12 years 11 months, 13 years 1 month to 14 years 11 months, 15 years to 16 years 11 months, 17 years to 18 years 11 months). Each group comprised of 44 cephalograms having an equal gender distribution.

The staging of lower left permanent canine and the second molar was based on Demirjian Index. Both lower left permanent canine and second molars of an individual patient were traced on a tracing paper with the help of OPG, (Fig. 1A). The traced teeth were matched to the most nearing stage of maturation, (Fig. 1B). The CVBA was calculated as per the regression equation is given by Mito et al.⁷ The measurements of the height and width of the third and fourth cervical vertebra was measured by the principal investigator (NK) with the help of 'IC measure' software (Germany), (Fig. 2). The co-investigator (BD) who recorded the CVBA was blinded for the staging of lower left permanent molar and canine. All the measurements of third and fourth cervical vertebrae and the staging of permanent lower left canine and the second molar was recorded on the Microsoft Excel sheet and subjected to statistical analysis.

Statistical Analysis

Mean and standard deviation of age and cervical vertebral bone age were calculated. ANOVA test was utilized to determine the significance between age groups, gender, CVBA, CMS, and MMS. Tukey's post hoc test was also used to compare the importance of CVBA, CMS, and MMS. Spearman's correlation coefficient was utilized to derive the correlation among CVBA to CMS and MMS. The statistical analysis was carried out with the help of SPSS 21 version software.



OBSERVATION AND RESULTS

When the vertebral bone age was evaluated on an overall, it was observed that as the chronologic age increased, the CVBA also increased. Significant morphologic changes of the third and fourth cervical vertebra were observed between the age groups of 13–15 and 15–17 years' age group of individuals (Table 1). Among both males and females, it was observed that the change in the dimensions of the third and fourth cervical vertebra was gradual until 13 years. A major difference was observed in the age group of 13 to 15 years (Table 1).

The CVBA was also evaluated as per the CMS and MMS. It was observed that as the CMS and MMS increased, the CVBA also increased. A higher value of CVBA was observed with MMS. There was a statistically significant difference observed when the CVBA was compared as per the stages of CMS and MMS (Table 2).

The frequency of distribution of maturation stages of lower left permanent canine and the second molar was also analysed. Among various stages of maturation, a frequency distribution of 43.6% for stage H was observed. However, stage E and F had equal distribution representing 16.3% of the total participants (Table 3).

The appraisal of maturation of lower left permanent second molar revealed a maximum number of participants with stage H having a frequency distribution of 29.2% while the lowest number of participants were seen in stage C (0.8%) (Table 4).

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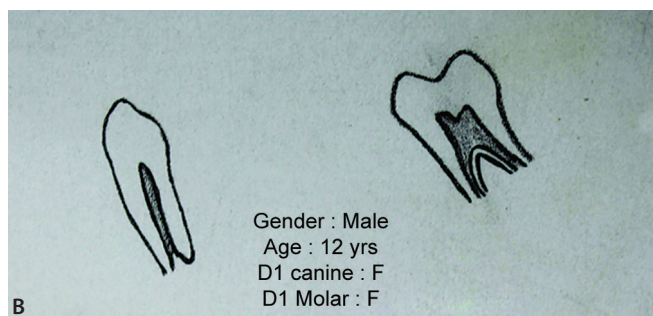
The CMS and MMS were also compared for the CVBA, a significant difference was observed, with maturation stages of F to G and G to H as shown in Graphs 1 and 2.

The correlation between CVBA and CMS and MMS was appraised. Both canine and second molar revealed a strong positive relationship. However, the canine revealed a higher value in comparison to the second molar.

DISCUSSION

Each individual has its rhythm of growing, and according to it, growth can be rapid, normal or late. The most useful method to evaluate biological maturity is the estimation of the skeletal age because the changes that bones experience during their maturation process are very similar in all individuals and each ossification center goes through many morphological changes that can be easily identified.⁸

It has long been recognized that an individual's chronologic age does not necessarily correlate well with his maturation age.



Figs 1A and B: Illustration for determining the Demirjian Stage of maturation of lower left permanent canine (CMS) and second molar (MMS); (A) Panoramic radiograph (OPG); (B) Tracing of canine and second molar.



Fig. 2: Illustration of measurements used to determine cervical bone age

Skeletally, one may be retarded or advanced in various degrees of deviation from the actual chronological age.^{9,10}

The hand-wrist radiograph is one of the most reliable radiographs to assess skeletal development. However, due to the complex anatomy and need for an extra radiograph, analysis of the skeletal maturity indicators such as hand wrist and cervical vertebra maturation index have various shortcomings. Hence the decline of utilization of the hand wrist radiograph and the increase in cervical vertebrae maturation for growth assessment has become pragmatic.⁸

Many investigators have suggested that the size and shape of the cervical vertebrae change from birth to full maturity at each level of skeletal development.² Baccetti et al. showed that only the shape changes of C2, C3, and C4 were enough to show skeletal maturation.¹¹ Further Perinetti et al. suggested that regular training is necessary to obtain high diagnostic accuracy and intra-rater repeatability in the visual assignment of the CVMI stages.¹²

Literature suggested that digital methods of evaluation of cervical vertebra can be employed in the analysis of maturation of CVMI. The ability of the software to measure the dimensions of the cervical vertebra in decimals enhanced the diagnostic accuracy of the CVBA of an individual. Hence the digital method of assessment was employed.

Kumara et al., Perinetti et al. and Kiran et al. suggested that the CMS and MMS can be used for assessment of growth maturation of an individual.^{2,12,13}

It was observed in the literature that no study correlated the CVBA to the CMS and MMS. Hence this study was carried out to evaluate and compare CVBA with CMS and MMS.

Table 1: Cervical vertebral bone age distribution as per age group and gender

Calculated CVBA						
Gender	Age group	N	Minimum	Maximum	Mean	Std. deviation
Male	7–9 years	22	9.35	12.53	11.19	1.01
	9–11 years	22	10.96	14.81	12.71	1.00
	11–13 years	22	10.45	16.09	12.46	1.44
	13–15 years	22	10.82	19.63	15.75	2.82
	15–17 years	22	14.72	19.93	17.72	1.49
Female	7–9 years	22	9.45	13.60	11.93	1.14
	9–11 years	22	10.66	15.23	12.41	1.06
	11–13 years	22	9.02	17.79	13.63	2.32
	13–15 years	22	12.65	19.41	16.42	1.63
	15–17 years	22	14.51	23.25	18.99	2.45
	17–19 years	22	15.45	19.80	18.09	1.17

Table 2: Cervical vertebral bone age distribution as per maturation stages of canine and second molar

Stage of maturation	N	Std. deviation		N	Mean		Std. deviation	Sum of squares	Df	Mean square	F	Sig.
		Canine	Molar		Canine	Molar						
Stage C	–	–	–	2	11.41	1.35	–	–	–	–	–	–
Stage D	23	11.45	1.13	43	11.93	1.21	–	–	–	–	–	–
Stage E	43	12.20	1.16	45	12.90	2.01	1751.056	4	437.764	108.788	0.000	–
Stage F	43	12.67	1.48	44	13.33	2.18	1042.216	259	4.024	–	–	–
Stage G	40	14.69	2.86	53	16.27	3.11	2793.272	263	–	–	–	–
Stage H	115	17.78	2.19	77	18.17	1.75	–	–	–	–	–	–

Table 3: Frequency distribution of various stages of maturation of canine

Maturation stage of canine (CMS)	Frequency	Percentage (%)
Stage D	23	8.7
Stage E	43	16.3
Stage F	43	16.3
Stage G	40	15.2
Stage H	115	43.6
Total	264	100.0

Table 4: Frequency distribution of maturation stages of second molar

Maturation stage of second molar	Frequency	Percentage
Stage C	2	0.8
Stage D	43	16.3
Stage E	45	17.0
Stage F	44	16.7
Stage G	53	20.1
Stage H	77	29.2
Total	264	100.0

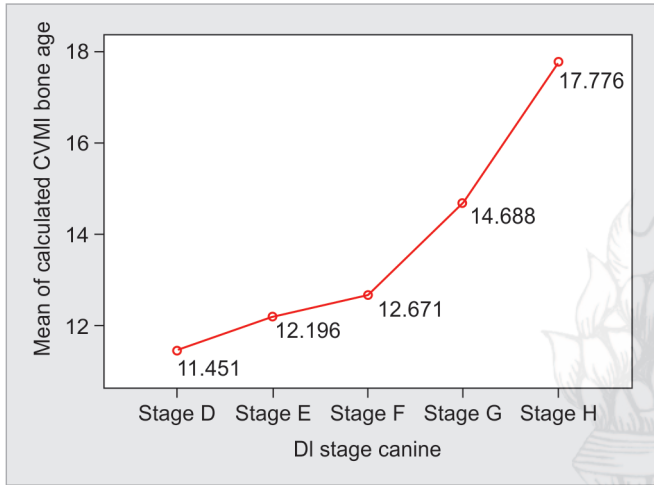
Kumar, Agarwal, Mehrotra did a study on evaluation of skeletal maturity in North Indian subjects using an objective method based on CVBA and assessment of its reliability as compared to hand wrist radiographic method and found that the process of objectively evaluating skeletal maturation is reliable and can be applied in orthodontic diagnosis and treatment planning.¹⁴

The mean vertebral bone age of various age groups was 11.56 for 7 years 1 month–8 years 11 months, 12.56 for 9 years 1 month–10 years 11 months, 13.04 for 11 years 1 month–12 years 11 months, 16.08 for 13 years 1 month–14 years 11 months, 18.36 for 15 years 1 month–16 years 11 months and 18.50 for 17 years 1 month–18 years 11 months for the samples included in this study.

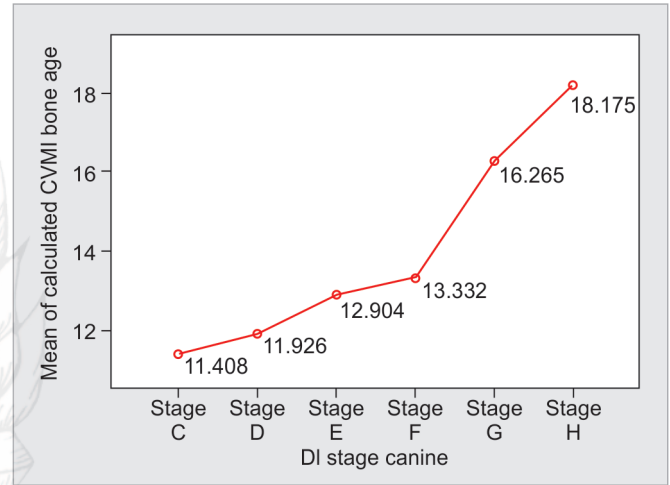
When the vertebral bone maturation was compared among girls and boys, it was found that at the same age, girls showed greater maturation than the boys (Table 1). This suggested that

females achieved growth maturation earlier than males. This observation is similar to the study done by Srkoc et al.¹⁵ On observing the distribution of CVBA as per CMS and MMS it was observed that statistically significant values were obtained when correlated with the transition stages of DI from F to G and G to H in both canine and molar. Stages G and H revealed a CVBA of 14.69 ± 2.86 and 17.78 ± 2.19 , respectively. Whereas, the molar revealed a CVBA of 16.27 ± 3.11 and 18.17 ± 1.75 for stage G and H respectively as shown in Graphs 1 and 2. These results obtained from this study were found to be similar to the results obtained in the study done by Rozylo-Kalinowska et al.¹⁶

In the study done by Chen J et al. it was found that 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 ($p < 0.05$). In girls, the



Graph 1: Correlation of cervical vertebral bone age and maturation stages of canine



Graph 2: Correlation of cervical vertebral bone age and maturation stages of permanent second molar

Table 5: Correlation between maturation stage of canine, molar and cervical vertebral bone age

		Spearman correlations				
		DI Stage canine	DI stage molar	Calculated CVMI bone age	Chronologic age	
Spearman's RHO	DI stage canine	Correlation coefficient	1.000	0.887**	0.769**	0.496
		p value	–	0.000	0.000	0.5
		N	264	264	264	264
	DI stage molar	Correlation coefficient	0.887**	1.000	0.734**	0.437
		p value	0.000	–	0.000	0.5
		N	264	264	264	264
	Calculated CVMI bone age	Correlation coefficient	0.769**	0.734**	1.000	0.345
		p value	0.000	0.000	–	0.5
		N	264	264	264	264
	Chronological age	Correlation coefficient	0.496	.437	0.345	1.000
		p value	0.5	0.5	0.5	–
		N	264	264	264	264

**Correlation is significant at the 0.01 level (2-tailed).

mandibular second molar had the highest, and the canine revealed the lowest correlation. In boys, the canine had the highest and the first premolar the lowest correlation.¹⁷

In this present study, CVBA was also correlated with CMS and MMS. The correlation coefficient for DI stage canine and CVMI bone age was 0.769 and for second molar it was 0.734 ($p \leq 0.01$) (Table 5). However, the correlation between the two may not hold as the skeletal age, and chronological age was found to have a moderate non-significant co-relation (Table 5).

The results of the present study should be interpreted cautiously as the design of the study was cross-sectional which accepts the limitation of investigating the growth of an individual. It is also observed that only subjective method of evaluation of maturation stages of canine was observed which is subject to one's own opinion of recognizing the traits. A further longitudinal study can be planned to derive an objective method that could help in identifying the level of dental maturation.

CONCLUSION

Chronologic age had a moderate correlation with CVBA. The CVBA was significant for all the stages of maturation of CMS and MMS. Females revealed a higher level of maturation. A substantial difference in the vertebral bone age was observed in the transition of stage F to G and G to H of dental maturation of canine and molar. Both CMS and MMS revealed a significant strong positive correlation with CVBA. Digital appraisal of vertebral measurements enhanced the precision of determining the CVBA.

CLINICAL SIGNIFICANCE

Cervical vertebral bone age can be utilized as an adjunct in identifying the stages of dental maturation of lower left permanent canine and second molar.

This research was approved by the Research and Ethics Committee of Sumandeep Vidyapeeth University (SVIEC/on/dent/PhD/15004).

REFERENCES

- Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. *Am J Orthod. Dentofac Orthop* 1995;107:58-66
- Kiran S, Sharma VP, Tandon P, et al. To establish the validity of dental age assessment using Nolla's method on comparing with skeletal age assessed by hand-wrist radiographs. *J Orthod Res* 2013;1:11-15
- Suri S, Prasad C, Bryan T et al. Longitudinal comparison of skeletal age determined by the Greulich and Pyle method and chronologic age in normally growing children, and clinical interpretations for orthodontics. *Am J Orthod Dentofac Orthop* 2013;143:50-60.
- Goyal S, Goyal S, Gugnani N. Assessment of skeletal maturity using the permanent mandibular canine calcification stages. *J Orthod Res* 2014;2:11-16.
- Uysal T, Sari Z, Ramoglu S, et al. Relationship between dental and skeletal maturity in Turkish subjects. *Angle Orthod* 2004;74(5):657-664.
- Larry J Green. The interrelationships among height, weight and chronological, dental and skeletal ages. *Angle Orthod.* 1961;31(3):189-193.
- Mito T, Sato K, Mitani H. Cervical vertebral bone age in girls. *Am J Orthod Dentofacial Orthod* 2002;122:380-385.
- Caldas MP, Ambrosano GM, Haiter Neto F. Computer-assisted analysis of cervical vertebral bone age using cephalometric radiographs in Brazilian subjects. *Brazilian oral research.* 2010;24(1):120-126.
- Bambha JK. Longitudinal cephalometric roentgenographic study of face and cranium in relation to body height. *The Journal of the American Dental Association* 1961;63(6):776-799.
- Fishman LS. Chronological versus skeletal age, an evaluation of craniofacial growth. *The Angle Orthodontist* 1979;49(3):181-189.
- Baccetti T, Franchi L, McNamara Jr JA. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. *The Angle Orthodontist* 2002;72(4):316-323.
- Perinetti G, Caprioglio A, Contardo L. Visual assessment of the cervical vertebral maturation stages: A study of diagnostic accuracy and repeatability. *The Angle Orthodontist.* 2014 Mar 25;84(6):951-956.
- Kumar S, Singla A, Sharma R, et al. Skeletal maturation evaluation using mandibular second molar calcification stages. *The Angle Orthodontist* 2011;82(3):501-506.
- Kumar S, Agarwal N, Mehrotra AK. Evaluation of skeletal maturity in North Indian subjects using an objective method based on cervical vertebral bone age and assessment of its reliability as compared to hand wrist radiographic method. *Journal of Indian Orthodontic Society* 2016;50(1):3.
- Srkoc T, Mestrovic S, Anic-Milosevic S, et al. Association between dental and skeletal maturation stages in Croatian subjects. *Actaclinica Croatica* 2015;54(4):445-452.
- Rozylo-Kalinowska I, Kolasa-Rączka A, Kalinowski P. Relationship between dental age according to Demirjian and cervical vertebrae maturity in Polish children. *The European Journal of Orthodontics* 2010;33(1):75-83.
- Chen J, Hu H, Guo J, et al. Correlation between dental maturity and cervical vertebral maturity. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology.* 2010 Dec 1;110(6):777-783.