

AGE RELATED CHANGES IN THE MORPHOLOGY OF CERVICAL VERTEBRAE IN ADOLESCENT PERIOD OF DEVELOPMENT

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ABSTRACT

Cervical vertebrae shape has been proposed as a diagnostic factor for assessing skeletal maturation in orthodontic patients, while Chronologic age is considered a poor indicator of adolescent development. The aim of the study was to correlate the chronologic age with maturational changes in cervical vertebral morphology. The study was conducted on 100 patients (36 males and 64 females) in the age range of 9 to 15 years (mean age 12.77 ± 1.54). To define vertebral stages, morphological evaluation of three cervical vertebrae (2nd to 4th) was done. The modified version of CVMS (Stage I-V) was used in the study. The spearman rank correlation between chronologic age and cervical vertebral maturation stages was 0.690 ($P < .001$). CVM method is more predictable than chronological age alone in establishment of appropriate timing and types of orthodontic treatment.

Key words: Chronologic age, Cervical vertebral maturation, skeletal maturation

INTRODUCTION

The issue of optimal timing for dentofacial orthopedic is linked to the identification of period of accelerated or intense growth that can contribute significantly to the correction of skeletal imbalance in a patient.^{1,2} The timing of growth for facial bones and the periods of accelerated or intense physiologic growth must be individualized to better exploit bone remodeling for correcting skeletal discrepancies in orthodontic patients.^{2,3} During growth every bone goes through a series of changes that can be seen radiologically. The sequence of changes is relatively constant for a given bone in every person but the timing of changes varies because each person has his/her own biological clock.^{4,5} Chronological age is not a valid instrument to calculate the speed of growth and skeletal maturation.²⁻⁵ Although chronological age commonly used to gauge a patient's position on his/her growth trajectory, but it does not address the difference in timing, duration, and extent of adolescence between the sexes and among the individuals within the same sex. When

physiological age is used instead of chronological age, the prediction of growth potential of the patient becomes more individualized.⁶ Physiological age is the registry of the rate of progress towards maturity that can be estimated by somatic, sexual, skeletal, and dental maturity.

Children exhibit great variations in tempo of their postnatal growth. At any given chronological age children differ in their progress towards adulthood, which is to say that they vary in their physical maturity.^{7,8} One may be skeletally accelerated or delayed in terms of maturational development.⁹ There is a wide variation in the chronological age of persons pertaining to the onset and duration of the adolescent growth spurt for both boys and girls. The major issue confronting the clinician is that each child does not grow at the same time, in the same direction, nor at the same rate. The chronological age of children with uncertain birth records are often estimated by evaluating the individual's somatic maturity. Since Chronologic age is such a poor indicator of the stage of adolescent develop-

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ment, we seek a more accurate measure, a “biologic age”. In practice we may distinguish among four physiologic or developmental indices: somatic, skeletal, dental and sexual maturity. Theoretically, strong relationship among indices implies a concordance of controlling mechanism that serves clinician in diagnosis and treatment planning.¹⁰ It has been shown that individualizing prediction by assessing maturational development rather than chronologic age can greatly increase the accuracy of prediction by significantly reducing much physiologic variability among children of the same chronologic age.¹¹

The evaluation of changes in size and shape of the cervical vertebrae in growing subjects have gained increased interest in the last decades as a biological indicator of individual skeletal maturity. One of the main reasons for the rising popularity of the method is that the analysis of cervical vertebral maturation is performed on the lateral cephalogram of the patient, a type of film used routinely in orthodontic diagnosis. It is well known that the morphology of the cervical vertebral bodies change with growth, as seen in lateral cephalogram.¹² Skeletal maturity can be evaluated in a detailed and objective manner on the cephalometric radiograph by determining the cervical vertebral bone age.¹³

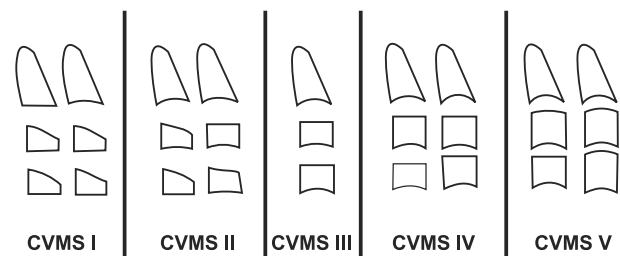
The relation of cervical vertebral maturation with skeletal maturation and peak growth in the mandible has been established^{2,14}. But little is known about the relation of chronologic age and changes in the morphology of cervical vertebrae in adolescent. The aim of this study was to investigate the relation ship between chronologic age and maturation of cervical vertebrae in local population.

METHODOLOGY

Study was carried out on 100 patients of age range 9 to 15 years. The entire sample was selected from the Orthodontic department Khyber College of Dentistry Peshawar. The patients and their parents were explained about the purpose and procedure of the study. The chronological age was recorded according to the actual date of birth confirmed by the parents. All lateral cephalometric radiographs were taken on the same machine by the same operator using identical source-subject and subject-film distances. To standardize the spinal position all radiograph were obtained with the patient positioned at the Frankfurt horizontal plane

parallel to the floor and the X-ray beam was perpendicular to the head. Radiographic techniques were standardized as much possible. Radiographs were exposed and developed using the standard developer and fixer in a dark room by the same operator to eliminate errors. Radiographs of high clarity and good contrast were used. Any radiograph that had poor contrast was discarded. Since relative measurement and not absolute measurement was used in the study, magnification was of minimal concern.

All assessments were performed in a darkened room with a radiographic illuminator to ensure contrast enhancement of the bone images. The tracings of the films were done using 4H lead pencil and 0.003-inch matte acetate tracing paper. In the lateral cephalograms,



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|-----------------|--|
| CVMS I | The lower borders of all the three vertebrae are flat, with the possible exception of a concavity at the lower border of C2 in almost half of the cases. The bodies of both C3 and C4 are trapezoid in shape. |
| CVMS II | 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. |
| CVMS III | Concavities at the lower borders of C2, C3, and C4 are present. The bodies of both C3, C4 are rectangular horizontal in shape. |
| CVMS IV | The concavities at the lower borders of C2, C3, and C4 are still present. At least one of the bodies of C3 and C4 is squared in shape. If not squared, the body of the other cervical vertebra is rectangular horizontal. |
| CVMS V | The concavities at the lower borders of C2, C3, and C4 still are evident. At least one of the bodies of C3 and C4 is rectangular vertical in shape. If not rectangular vertical, the body of the other cervical vertebra is squared. |

Fig 1: The newly improved CVM Method (five developmental stages, CVMS I through CVMS V).²

three parts of the cervical vertebrae were traced; these entities include the dens odontoid process – C2, body of the third cervical vertebrae – C3 and the body of the fourth cervical vertebrae – C4. These areas were selected because C3 and C4 could be visualized even when a thyroid protective collar was worn during radiation exposure.

Cervical Vertebral Maturation Stages (CVMS)

Lateral cephalogram was assessed for skeletal maturation according to the improved modified version of Bacetti (CVMS I - CVMS V)

Statistical analysis

Statistical analysis was performed with the help of SPSS (Version 13). Elementary statistics included sample distribution of skeletal maturation stages by age and gender obtained by cervical vertebral maturation method. Frequency and percentage were presented for discrete variable like gender and means $\pm$ SD were calculated for age. The outcome of data for radiographic assessment was ordinal and Spearman rank order correlation coefficient test was used to judge the strength of the relationship between the maturation stages of cervical vertebrae and chronological age. P value equal to or less than 0.05 was taken as statistically significant.

RESULTS

This study was conducted on total 100 orthodontic patients, comprising of 36 males and 64 females with the mean age of the patients 12.77 ± 1.54 years (Fig 2).

Frequency distribution of patients according to age in each cervical vertebral maturation stage is shown in Fig 3, table 1. CVMS I was most frequent in 9-10 years. CVMS II was most frequent in 10-11 years. CVMS III was most frequent in 11-13 years. CVMS IV and CVMS V was the most frequent in 13-15 years. Due to high percentage of female subjects in 14 years CVMS V was most frequent in this age as compared to 15 years age subjects. The spearman rank correlation between chronological age and cervical vertebral maturation stages was 0.690 ($P < .001$) statistically significant.

Frequency distribution of cervical vertebral maturation stages (CVMS) in different age groups was also plotted (table 2). In 9 -11 years age the most frequent stage was CVMS I (56%) followed by III and II. In 12-13 years age group, the most common stage was CVMS III (43%) followed by II and IV. In age group 14-15 years all the maturational stages were present except stage I, the most frequent was CVMS V (47%) followed by IV.

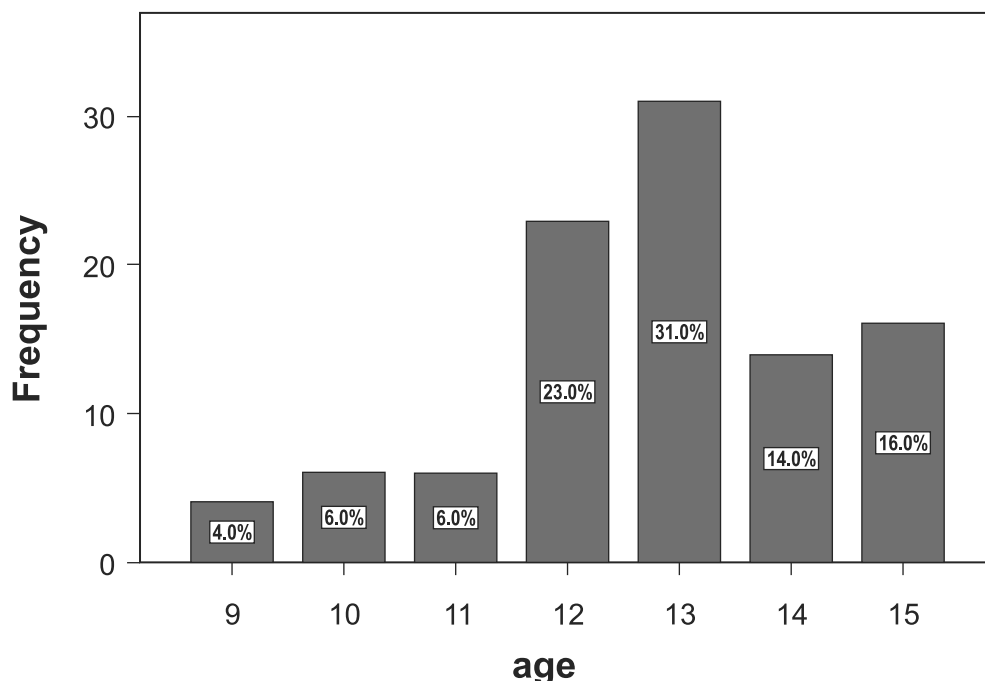


Fig 2: Frequency distribution of patients by age

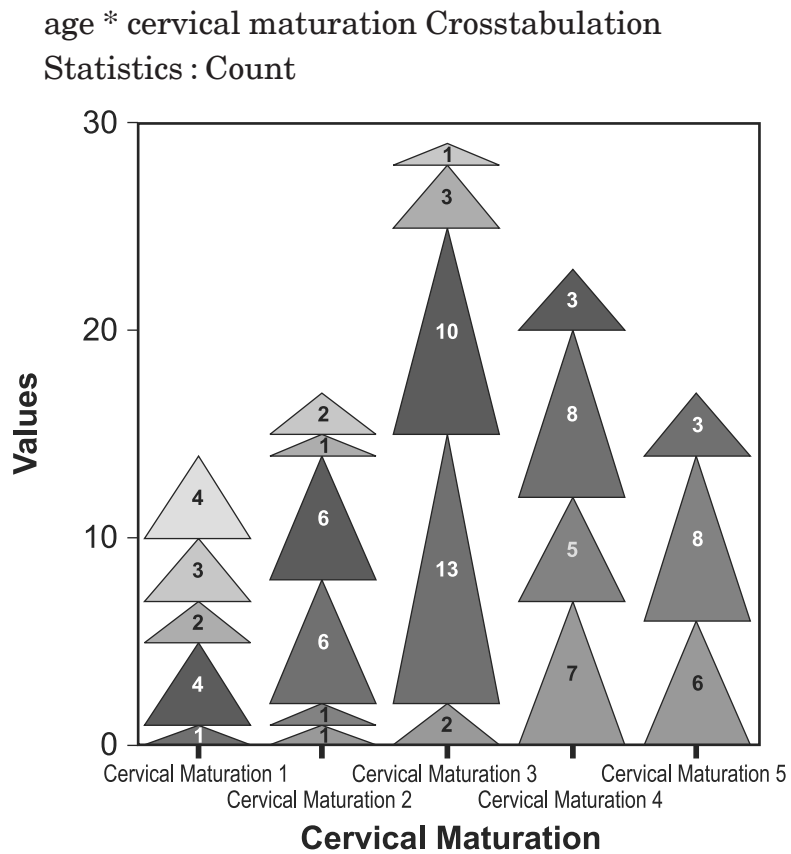


Fig 3: Age versus cervical vertebral maturation

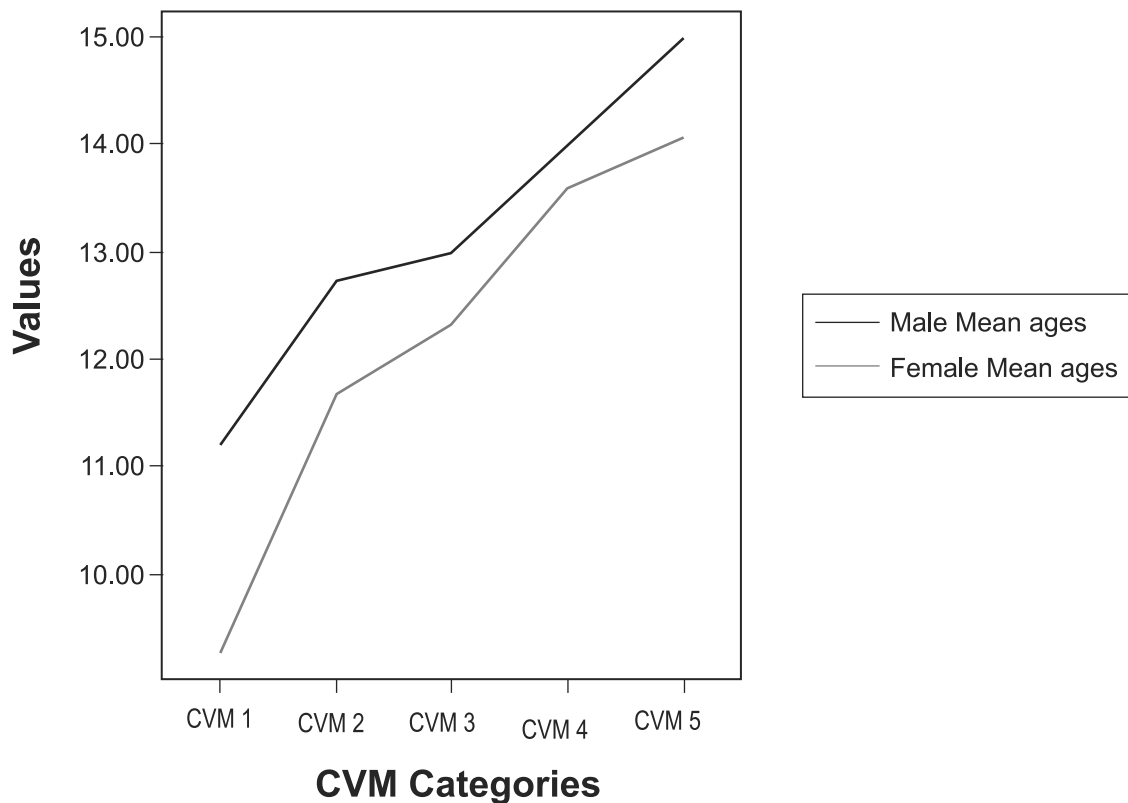


Fig 4: Gender difference in chronological age in cervical vertebral maturation

TABLE 1: AGE VERSUS CERVICAL MATURATION STAGES CROSS TABULATION
AGE * CERVICAL MATURATION CROSS TABULATION

Age	Cervical Maturation				
	CVMS I	CVMS II	CVMS III	CVMS IV	CVMS V
9.00	4	0	0	0	0
10.00	3	2	1	0	0
11.00	2	1	3	0	0
12.00	4	6	10	3	0
13.00	1	6	13	8	3
14.00	0	1	0	5	8
15.00	0	1	2	7	6
Total	14	17	29	23	17

Symmetric Measures

Ordinal by Ordinal	Spearman Correlation	Value	Std.Error	Approx. Sig.
		.690	.054	.000(c)
N of Valid Cases	100			

Spearman correlation (r) = 0.690

P < .001 (highly significant)

TABLE 2: AGE INTERVAL VERSUS CERVICAL VERTEBRAL MATURATION STAGES
CROSSTABULATION

Age Intervals	Cervical vertebral maturation stages					Total
	CVMS I	CVMS II	CVMS III	CVMS IV	CVMS V	
9-11	9	3	4	0	0	16
12-13	5	12	23	11	3	54
14-15	0	2	2	12	14	30
Total	14	17	29	23	17	100

Spearman correlation (r) = 0.689

P < .001 (highly significant)

TABLE 3: MEAN AGE DIFFERENCE IN BOTH
GENDERS IN CERVICAL VERTEBRAL
MATURATION STAGES

CVMS Stages	Male Mean ages	Female Mean ages	Difference in age
CVMS I	11.20	9.25	1.95
CVMS II	12.73	11.67	1.06
CVMS III	13.00	12.32	0.68
CVMS IV	14.00	13.59	0.41
CVMS V	15.00	14.07	0.93

CVMS: Cervical Vertebral Maturation Stage.

Similarly the mean chronological age of males and females showed gender dimorphism in each cervical vertebral maturation stage. The females were advance than males in each stage and the mean chronological age of females in each cervical vertebral maturation stage was less than male subjects (Fig 3). The mean chronological age of males and females and their difference in each stage is shown in table 3. The major difference in mean age in both the gender was seen in CVMS I and II. The mean difference in chronological age in males and females was 1.00 year.

DISCUSSION

An important objective of orthodontic treatment during adolescence is to take advantage of growth in patients with skeletal discrepancies.¹⁵ Maturational status can have considerable influence on diagnosis, treatment goals, treatment planning, and the eventual outcome of orthodontic treatment. Clinical decisions regarding functional appliances or orthognathic surgeries are modulated by the patient's degree of physiological maturity. That is why prediction of the time and the amount of active growth is an important issue. Houston et al^{16,17} observed that if advantage is to be taken of growth spurt, it is necessary to predict its timing at least one or two years in advance of peak height velocity. Hence it would be desirable to have a reliable way of forecasting when the maximum growth of the jaw bone at puberty will occur in a patient.

Baccetti et al² in 2002 modified the original Hassel and Farman CVM method. He reviewed lateral cephalometric of 706 subjects from the files of the University of Michigan Elementary and Secondary School Growth Study. Two sets of variables were analyzed.

- 1 Presence of a concavity at the lower border of the body of C2, C3, C4
- 2 Shape of the body of C3 and C4 (trapezoidal, rectangular horizontal, square, rectangular vertical)

We used the modified system, which comprised of five maturational stages (CVMS I - CVMS V). The new system has the following advantages

- 1 Appraises three vertebrae only.
- 2 Restricts the stages of growth.
- 3 Uses simpler and easily individualized cephalometric points.

Generally, chronological age is considered a poor indicator for estimating the degree of skeletal maturity due to significant individual growth variations among children of the same chronological or calendar age groups.¹⁸⁻²² Sierra²³ found that the relationships between chronologic age and skeletal age assessment proved to have relatively high correlation (0.58 to 0.71). In our study, the correlation between chronologic age and skeletal maturation assessed by the cervical vertebrae method was 0.690 – higher than those reported by

Sierra, but lower than those reported by Uysal²⁴ (0.72 and 0.79) and Al Hadiaq²⁵ (r value = 0.80). In general, the differences reported in the present study in relating the mean chronological age to the skeletal maturity stage for samples from different populations can be attributed to differential racial backgrounds, distinct environmental conditions, and/or some research methodology disparity associated with the sample size and/or sample distribution. Further studies are inevitable by increasing the sample size and by improving the sample distribution among the gender. The more representative sample will help to establish distinct maturity standards for the Pakistani population.

Gender is an important factor which influences the timing of adolescent growth spurt.^{8,9} The females are advance than male in skeletal maturation. This is supported by the previous studies of Tanner⁸, Nanda²⁶, Bowden²⁷, Hägg and Taranger²⁸. Hunter²⁹ and Kamal⁴ in separate studies found similar results. The outcome of the present study showed difference of one year in males and females in attaining the same level of maturation in Pakistani subjects. Shamsheer⁵ documented 1.2 years difference in local population previously. However, according to skeletal maturation, the sex differences were steadily significant at the skeletal maturity corresponding to about 12 years in the males and 10 years in the females (Table III). Our results are in accordance with the findings of Kimura K¹⁹ that was conducted in Japanese population and concluded the same. The age difference in the onset of the pubertal growth spurt adds to the sexual diversity in physiological maturity. Fishman⁹ stated that when growth is examined on maturational age basis rather than chronological age, the gender and racial differences are eliminated

Hunter²⁹ found that girls were usually advance by an average of 2.4 years than boys for the onset of puberty, with a mean value of 12.8 years for boys and 10.4 years for girls. While our results showed 11.4 years for boys and 9.4 years for girls with a mean difference of 2 years. This shows that Pakistani subjects are advance in attaining skeletal maturity stages. Shaikh A, Rikhasor R, Qureshi A.³⁰ also documented it previously.

Zhang and Wang³¹ estimated skeletal age from the cervical vertebrae on lateral cephalogram. They con-

cluded that the appearance of the sesamoid of hand and the concavity of the second vertebral body at the same time showed the beginning of rapid growth period, which was equally estimated from the cervical vertebrae on lateral cephalogram. The present study revealed that concavity in C2 appeared in mean chronological age of 12.7 years in males and 12 years in females. According to Baccetti Adolescent growth was accelerating at CVMS II. This indicates that CVMS II was closely related to the age of accelerating growth velocity. According to Bacetti CVMI III is peak growth age. So the CVM method is highly reliable for identification of adolescent growth peak but poor reproducibility by inexperienced person as reported by Gabriel³² is the only limitation of the method. Seedat and Forsberg³³ Studied black subjects for the morphologic changes observed radiographically in the body of C3 at different age groups on lateral cephalogram according to the criteria set by Hassel & Farman. The results showed that radiographically, the body of C3 displayed morphological changes consistent with normal skeletal maturation that are consistent with our results.

The study results suggest that along with chronological the CVM appraisal is a valuable aid to improve orthodontic diagnosis and therapeutic decisions. The techniques simplicity and ease of use should encourage more orthodontists to use this method to assess skeletal maturation. Small sample size is the limitation of the study. Further study with large sample size is recommended.

CONCLUSION

- A wide variation in chronological age for different maturity levels suggests that chronological age is a poor indicator of maturity.
- Skeletal maturity indicators provide a more valid basis than chronological age for growth status of individuals.

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