

RESEARCH ARTICLE

A Correlative Study between Hand-Wrist Maturation and Cervical Vertebrae for the Assessment of Skeletal Age

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ABSTRACT

Aim: To correlate cervical vertebrae maturation and hand-wrist maturation using radiographs, to eliminate the need of hand-wrist radiograph and to reduce patient's additional exposure and cost.

Materials and methods: The sample consists of 100 subjects aged between 9 and 18 years divided into 50 males and 50 females. Every individual was subjected for a left hand-wrist radiograph and a lateral cephalogram, manually processed, illuminated and were traced. Assessment of skeletal maturation index (SMI) from hand-wrist radiograph and assessment of cervical vertebrae maturity index (CVMI) from lateral cephalogram was made. The SMI and CVMI scores were compared with each other and their correlation was established statistically.

Results: When Wilcoxon signed-rank test was applied to know the statistical difference between CVMI and SMI, the p-value of 0.715 among study population which are statistically not significant ($p > 0.05$), suggesting that the difference between the two methods is not significant. On Spearman correlation coefficient was computed, a very good association was found between CVMI and SMI methods, with r-value of +0.95, where $p < 0.001$, suggestive of statistically highly significant.

Conclusion: There is no significant difference between the two methods, and the correlation was found to be statistically significant. It is beneficial to use lateral cephalogram for skeletal age assessment and eliminate the need of hand-wrist radiograph.

Keywords: Skeletal maturation, CVMI, SMI, Radiographic assessment.

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INTRODUCTION

As an oral radiologist concerned to the fraternity of oral medicine and radiology, a broad knowledge of skeletal growth patterns and their physiology of different growth spurts during the development of the jaw bones, and the related growth in formation of teeth at different stages of development is essential to correlate, compare, diagnose, plan of treatment and to analyze the prognostic component of various diseases and the abnormalities.

In orthodontic treatment planning, knowledge of facial growth, velocity and percentage of facial growth remaining, is very important for effective growth modification interventions.

Staging of human skeletal development has been assessed using physiological parameters, including peak growth velocity in standing height, pubertal markers (such as voice changes in males, menarche in females, breast development, appearance of pubic hair and appearance of axillary hair), radiographic assessment of bone maturation, chronological age and staging of dental development.^{1,2}

More recently, Fishman³⁻⁵ developed a system for assessment of skeletal maturation on the basis of 11 discrete 'skeletal maturity indicators' covering the entire period of adolescent development.

Cervical vertebrae maturation (CVM) method was described by Hassel and Farman,⁶ where vertebral bodies (C2, C3 and C4) were used to perform the staging.

The hand-wrist radiographs have been used routinely in orthodontics to assess the peak of the growth spurt.^{7,8} However, there are concerns about the extra radiation exposure from the hand-wrist radiography.⁷ One obvious advantage of using the CVM method is that the lateral cephalometric radiograph is routinely required for orthodontic diagnosis and treatment planning; therefore, no additional radiograph is required.⁷

Because of this, CVM in the lateral cephalometric radiographs was evaluated for its correlation with skeletal maturity as an alternative to the hand-wrist maturation.⁹

Therefore, in this study, it has been investigated the correlation between the cervical vertebrae maturation index (CVMI) method and the hand-wrist maturity index (SMI), by including only the subjects near or within the pubertal growth spurt.

AIM AND OBJECTIVES

To determine whether the morphological changes in the cervical vertebrae are equally useful to determine the growth stages assessed by hand-wrist radiographs in male and female subjects of different age groups and to eliminate the need of hand-wrist radiograph, to reduce patient's additional exposure and cost.

MATERIALS AND METHODS

The study was conducted in Department of Oral Medicine and Radiology, SVS Institute of Dental Sciences, Mahabubnagar district, Andhra Pradesh, India. The sample consists of 100 subjects aged between 9 and 18 years, constituting

50 males and 50 females. After obtaining the written consent of the parent, every individual was subjected for a left hand-wrist radiograph with ‘palm down’, hand flat on the cassette with fingers slightly separated (Fig. 1) using exposure parameters of 50 kVp and 6 mA with exposure time of 0.6 sec. using Mediotronics, X-ray machine—Indian made. Then a lateral cephalogram (Fig. 2) was made using Villa conventional cephalostatic radiographic machine—Italian made with exposure parameters of 70 to 80 kVp, 8 mA and time of 0.8 sec. Both the films were manually processed, illuminated and were traced on 36 micron matte acetate using a 0.3 mm diameter lead pencil.

- **Assessment of skeletal maturation index (SMI) from hand-wrist radiograph:** SMI is assessed by Fishman’s eleven grade system—skeletal maturity indicators interpreted on hand-wrist radiographs, found at six anatomical sites located on thumb, third finger, fifth finger and radius (Fig. 3).

The sequence of the four ossification stages is evaluated through the ossification of the adductor sesamoid of the thumb, epiphyseal widening on selected phalanges, the capping of selected epiphysis over their diaphysis and the fusion of selected epiphysis and diaphysis (Fig. 4). Based on the observation scheme (Fig. 5), individual maturity stages were scored, as SMI from one to eleven.

- **Assessment of CVMI from lateral cephalogram:** Using Hassel and Farman system, an observational scheme for cervical vertebrae was noted on the lateral cephalogram, where the second (C2), third (C3) and fourth (C4) cervical vertebrae were traced.

The shapes of the vertebrae, tapering of the superior border, height and the concavities of the inferior border were assessed, and an individual score was provided

based on the cervical vertebrae stage (CS) (Fig. 6) of the bodies as CVMI scores from one to six.

- **Correlation of the SMI and CVMI:** CVM is related to the skeletal maturation for further assessment of growth.

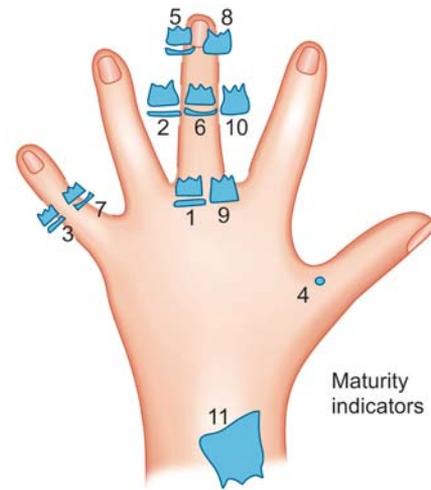


Fig. 3: Fishman’s eleven discrete indicators six anatomical sites³

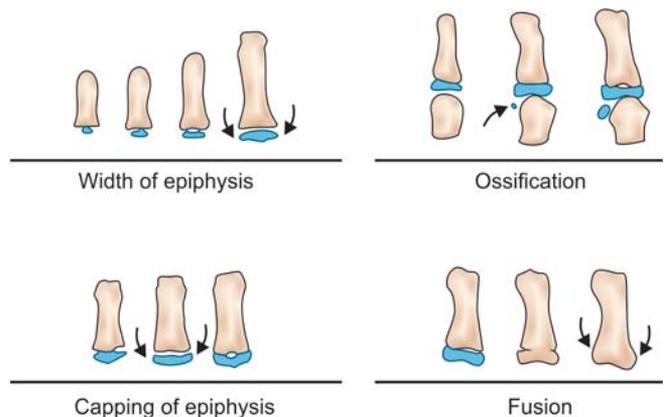


Fig. 4: Four ossification stages³



Fig. 1: Hand-wrist radiograph



Fig. 2: Cropped image showing cervical vertebrae 2, 3 and 4 on lateral cephalogram

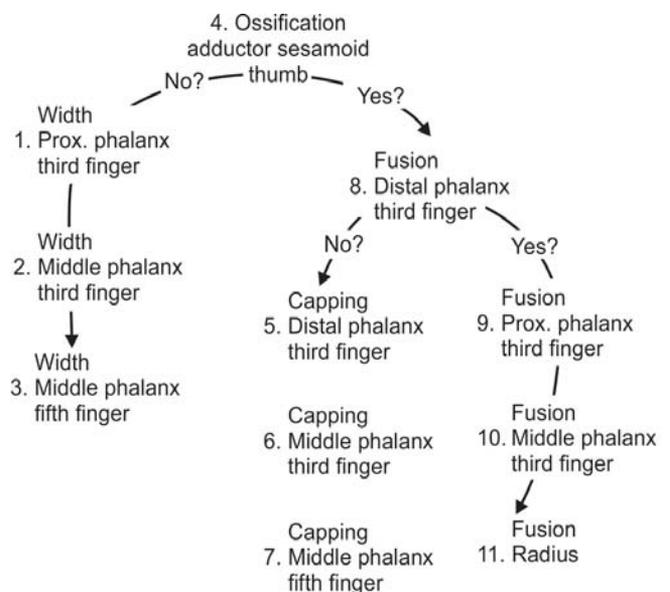


Fig. 5: Hand-wrist observational scheme³

The SMI and CVMI were compared with each other and their correlation was established statistically.

The obtained data was statistically analyzed using the software ‘Statistical Package for Social Sciences’ SPSS for Windows (version 16.0) (SPSS Inc, 1999 New York).

- *Assessment of growth:* Percentile of pubertal growth remaining is assessed based on the maturation indicators⁶ (Table 1).

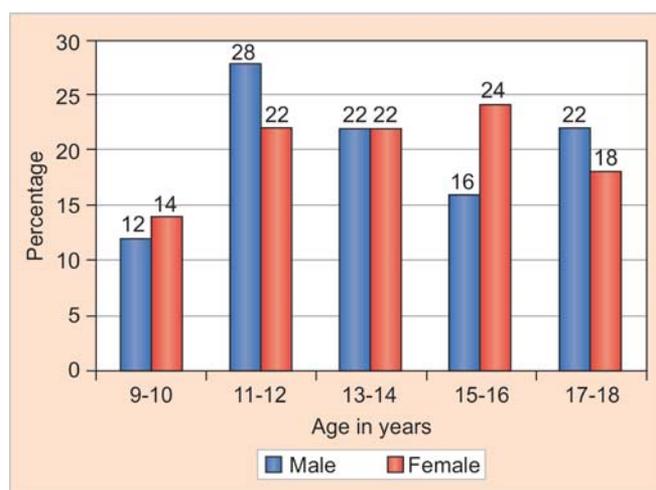
RESULTS

The sample consists of 100 subjects aged between 9 and 18 years divided into 50 males and 50 females.

- *Age group and gender distribution of the study population (Graph 1):* A p-value of 0.84 was obtained; the difference observed was statistically not significant as $p > 0.05$.
- *Distribution of SMI according to age group among the study population (Graph 2):* The difference between chronological age, and SMI was statistically highly significant ($p = 0.000$).
- *Distribution of CVMI according to age group among the study population (Graph 3):* The difference between chronological age, and CVMI was statistically highly significant ($p = 0.00$).
- *Distribution of SMI according to gender among the study population (Graph 4):* The difference in the SMI scores between males and females was statistically significant ($p = 0.00$).
- *Distribution of CVMI according to gender among the study population (Graph 5):* The difference between males and females with the CVMI scores was statistically significant ($p = 0.001$).

- *Comparison of SMI vs CVMI among the study population (Table 2):* When Wilcoxon signed rank test was applied to know the statistical difference between CVMI and SMI, the difference was -0.365 , and the p-value of 0.715 among study population, which was statistically not significant ($p > 0.05$) suggesting that the difference between the two methods is not significant.

When Spearman correlation coefficient was computed; a very good association was found between CVMI and SMI methods, where value was 0.95, and p-value < 0.001 suggesting that the correlation is of statistically highly significant.



Graph 1: Age group and gender distribution of the study population

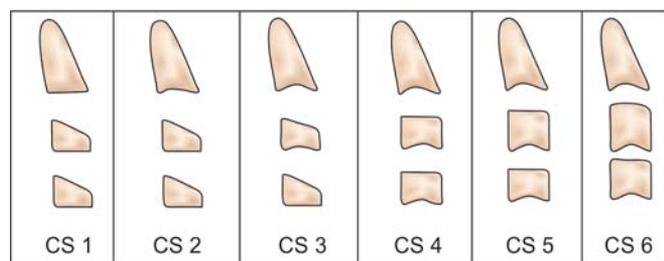
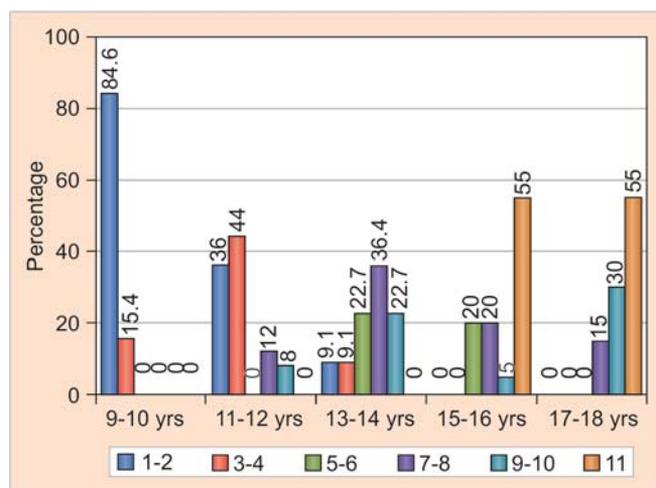
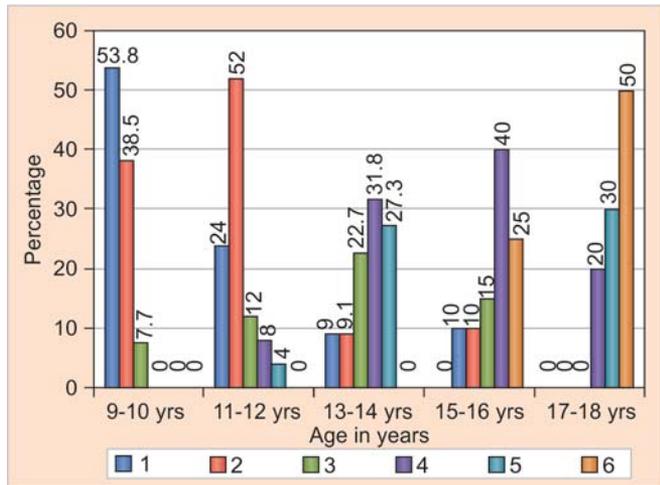


Fig. 6: Cervical vertebrae stages (CS)⁷

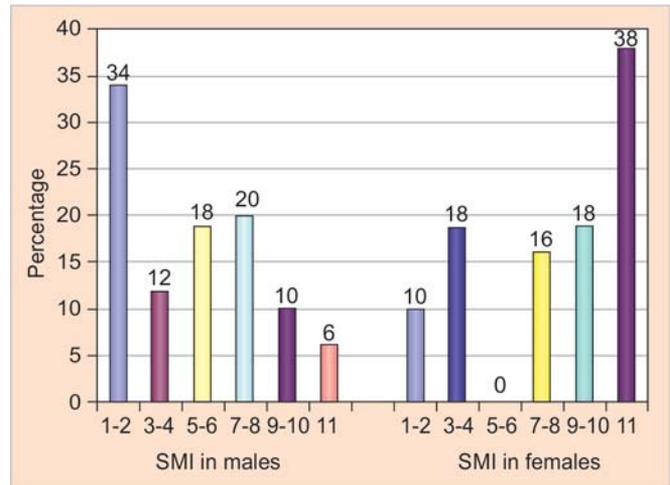


Graph 2: Distribution of SMI according to age group among the study population

Hand-wrist indicator (SMI)	Cervical vertebrae stage (CVMI)	Percentile of pubertal growth remaining (%)
1-2	1. Initiation	85-100
3-4	2. Acceleration	65-85
5-6	3. Transition	25-65
7-8	4. Deceleration	10-25
9-10	5. Maturation	5-10
11	6. Completion	0



Graph 3: Distribution of CVMI according to age group among the study population



Graph 4: Distribution of SMI according to gender among the study population

DISCUSSION

Chronological age is not a valid predictor of skeletal growth velocity or skeletal maturity.^{2,10-12,14} Sexual dimorphism is well documented^{15,16} and there is a wide range of individual variability in timing of periods of increased growth velocity.⁵

Fishman³ reported that there was a rapid acceleration to peak growth velocity and a more progressive decline. This observation was more pronounced in females. The growth curves included in the Moore et al¹⁷ article show similar acceleration and deceleration, but the correlation between skeletal maturity and overall facial growth was not significant in females and only weakly correlated in males.

If advantage is to be taken of the growth spurt, it is necessary to be able to predict the onset several years in advance. The prediction improves as the age of the growth spurt is approached, which may necessitate repeated radiographic evaluation.¹²

Hand-wrist radiographic assessment of skeletal maturity is a valuable tool in orthodontic research. Analysis approaches, such as the one described by Fishman,³⁻⁵ which are based on relative growth velocity and percentage of growth remaining are more useful than analysis that yields a skeletal age.¹³

Pancherz and Szyska found that the cervical vertebral maturation method has level of reliability comparable to the hand and wrist method.¹⁸

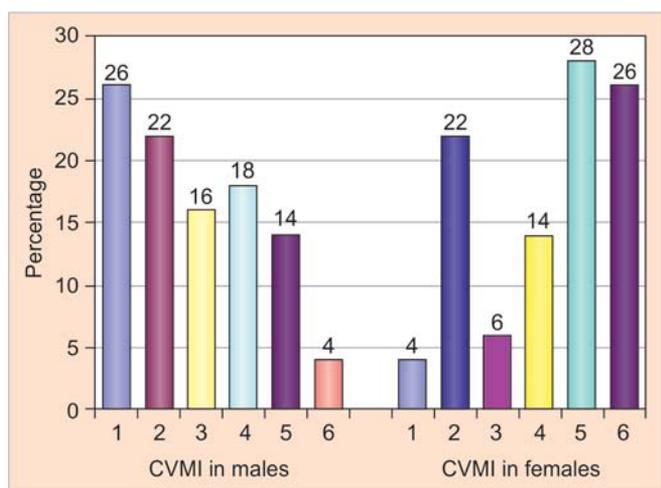
A definite concavity at the lower border of C2 is present in 80% of the subjects at cervical stage 2. The appearance of a visible concavity at the lower border of the third cervical vertebra is the anatomic characteristic that mostly accounts for the identification of the stage (cervical stage 3), immediately preceding the peak in mandibular growth.¹⁹

According to the present study, when the tables and graphs are observed; it can be inferred that the scores either SMI or CVMI vary significantly with age, especially at the ages between 11 and 16 years for both males and females; suggesting that chronological age is a poor indicator of

Table 2: Comparison of SMI vs CVMI among study population

SMI		CVMI						Total
		1	2	3	4	5	6	
1-2	No.	15	6	1	0	0	0	22
	%	68.20	27.30	4.50				100.00
3-4	No.	0	14	1	0	0	0	15
	%		93.30	6.70				100.00
5-6	No.	0	2	7	0	0	0	9
	%		22.20	77.80				100.00
7-8	No.	0	0	2	13	3	0	18
	%			11.10	72.20	16.70		100.00
9-10	No.	0	0	0	3	10	1	14
	%				21.40	71.40	7.10	100.00
11	No.	0	0	0	0	8	14	22
	%					36.40	63.60	100.00
Total	No.	15	22	11	16	21	15	100
	%	15.00	22.00	11.00	16.00	21.00	15.00	100.00





Graph 5: Distribution of CVMI according to gender among the study population

maturation and did not correlate with skeletal maturation indicators (SMI and CVMI). These results are in confirmation with studies conducted by Bjork and Helm,¹⁶ Fishman (1979, 1982, 1987)^{4,5,11} and Hagg and Taranger (1982).⁸

It can be predicted that as the age increases, the corresponding scores also gradually increased and linearly increases. A p-value of less than 0.001 is suggestive of statistical significance.

It can also be inferred that male subject's skeletal maturity is much slower as compared to female subjects of same age group; as higher maturity scores are noted in early ages of females when compared to males. Similarly, this general trend was observed from the previous studies.

CONCLUSION

There is no significant difference in skeletal age assessed by cervical vertebrae maturational method and hand-wrist maturational method for growing patients. The two methods were statistically similar for both genders. As lateral cephalogram is routinely made to assess the maxilla-mandibular relation, the same would be sufficient for skeletal age assessment, thereby we can eliminate the need of hand-wrist radiograph. Based on ALARA (as low as reasonably achievable) principle, this can reduce the radiation exposure as well and cost effective. Further studies with a larger sample size should be encouraged.

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