Comparative study between cervical vertebrae and hand-wrist maturation for the assessment of skeletal age

Estudo comparativo entre maturação de vértebras cervicais e da mão e punho para a determinação da idade esqueletal

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Abstract

Objectives: The aim of the study was to compare the cervical vertebrae maturity, using a lateral cephalogram, which is routinely taken before orthodontic treatment and is included as a part of the patient's record, with hand-wrist maturation method. **Materials and methods**: The study group comprised of sixty subjects of Bangalore, Indian, origin, aged between 9-18 years. Hand wrist radiograph and lateral cephalograms were taken for these subjects. Assessment of skeletal maturation was done using Skeletal Maturity Indicators (SMI's) from hand-wrist radiograph and Cervical Vertebrae Maturity Indicators (CVMI's) from lateral cephalogram. A pair wise comparison for skeletal age assessment stages was done using Wilcoxon sign rank test and proportions was compared using *Chi-Square* test for statistical analysis. **Results**: Skeletal maturity assessed using the cervical vertebrae maturation index (CVMI) method and hand-wrist skeletal maturational index (SMI) method showed no statistical significant difference for males and females. However, females showed maturation at an early age as compared to males. **Conclusions**: Since properly utilized cervical vertebrae assessment provided a reliable assessment of pubertal growth spurt, it would be beneficial to use a lateral cephalogram for skeletal maturity assessment and thereby

eliminate the need for an additional radiograph (hand-wrist radiograph). This is cost effective and will also reduce the radiation exposure to the patient.

Keywords: Skeletal maturation. Hand-wrist and cervical vertebrae radiograph. Cervical vertebrae maturational indicator. Skeletal maturational indicator.

Resumo

Objetivos: *O objetivo do presente estudo foi comparar a maturidade das vértebras cervicais, por meio de um cefalograma lateral, que é rotineiramente obtido antes de tratamentos ortodônticos, com um método de medição de maturação de mão e punho.* ***Materiais e métodos***: *O grupo estudado consistiu de sessenta indivíduos da região de Bangalore, Índia, com idades entre 9 e 18 anos, de ambos os sexos. Radiografias de mão e punho e cefalogramas em norma lateral foram obtidos. A determinação da maturação esquelética foi determinada com o uso de Indicadores de Maturidade Esquelética para radiografias de mão e punho e Indicadores de Maturidade de Vértebras Cervicais para cefalogramas em norma lateral. A comparação por pareamento para determinação da idade esqueletal foi feita utilizando o teste de ranqueamento de Wilcoxon e as proporções comparadas pelo teste* Qui-Quadrado *para análise estatística.* ***Resultados***: *A maturidade esquelética determinada pelo índice de maturação esquelética não mostrou diferença estatística significante para homens e mulheres. Entretanto, em mulheres a maturação ocorreu em idade mais precoce quando comparadas com os homens.* ***Conclusões***: *Uma vez utilizado adequadamente, o método de determinação da maturidade das vértebras cervicais proporciona um indicativo confiável do crescimento no estirão da puberdade, o qual pode ser útil no estabelecimento da maturidade esqueletal por meio de cefalogramas laterais, eliminando assim a necessidade de radiografias adicionais de mão e punho. Essa eliminação das radiografias de mão e punho é custo-efetiva e igualmente reduz a exposição do paciente à radiação ionizante.*

Palavras-chave: *Maturação esquelética. Radiografia de mão e punho e de vértebras cervicais. Indicador de maturidade de vértebras cervicais. Maturação esquelética.*

Introduction

It is a routine procedure for orthodontists to take both hand wrist radiograph for assessing skeletal maturation and cephalometric radiograph to analyze skeletal morphology and direction of growth patterns (1). Although minimal radiation is associated with a hand-wrist radiograph, it would be ideal to assess the growth stage without additional radiography. The usefulness of lateral cephalometric radiographs to assess skeletal maturation has been studied. Scant data are available suggesting that the cervical vertebrae may be good indicators of skeletal maturity.

Considering the above, a study was proposed to compare cervical vertebrae and hand-wrist maturation for the assessment of skeletal age, which could eliminate the need for an additional radiograph. This would be both an economical and convenient benefit for the patient.

The objective of the study was to determine whether the morphological changes seen in the cervical vertebrae are equally useful to determine the growth stages as the maturation stages assessed by hand-wrist radiographs in male and female subjects of different age groups and to thereby eliminate the need of an additional radiograph (hand-wrist radiograph) which will be cost effective and will reduce radiation exposure to the patient.

Materials and methods

This study was conducted in department of Oral Medicine and Radiology, R.V. Dental College and Hospital, Bangalore, India. 60 subjects of Indian origin, aged between 9-18 years, were selected for the study. The subjects were divided into 3 groups on the basis of their ages ranging from I (9-11 years), II (12-14 years) and III (15-18 years) for both males and females. Patients presenting with congenital or acquired malformations affecting cervical vertebrae or hand wrist or patients presenting with

developmental alterations of cervical vertebrae or hand wrist were excluded from the study. A hand-wrist radiograph and a lateral cephalogram were made for each of the subjects after duly obtaining consent. An ethical clearance was obtained with regard to the radiographic exposure of the subject. Prior to exposure to radiation, suitable patient protection devices were used. Hand wrist radiograph and lateral cephalograms were taken on a Gendex™ "Orthoralix 9200 Plus".

The hand-wrist radiograph and lateral cephalogram were taken. They were traced on 36-micron matte acetate with a 0.3 mm diameter lead pencil using a radiographic illuminator. Three parts of the cervical vertebrae were traced. These were the *dens* (odontoid process), the body of the third cervical vertebra (C3), and the body of the fourth cervical vertebra (C4). Radiographs of high clarity and good contrast were used. Any radiographs that showed motion unsharpness or had poor contrast were discarded from the evaluation.

To evaluate the maturational patterns of the indicators in the hand-wrist, Fishman's eleven-grade system was used. This system uses only four stages of bone maturation; all found at six anatomical sites located on the thumb, third finger, fifth finger and the radius. Eleven discrete adolescent skeletal maturational indicators (SMI's), covering the entire period of adolescent development are found on these six sites (2).

Cervical vertebrae development of the sample was evaluated by Hassel and Farman's (modification of Lamparski's criteria) method, which assesses maturational changes of the second, third and fourth cervical vertebrae (3). Six distinct stages of growth can be related to the skeletal maturity indicators developed by Fishman. The *dens* (odontoid process) of C2, the body of the third cervical vertebra (C3), and the body of the fourth cervical vertebra (C4) were observed and used to indicate maturity.

Cervical vertebrae maturation indicators (CVMI) can be described as follows:

I. *Initiation stage* (*CVMI – 1*)
   Very significant amount of adolescent growth expected
   C2, C3, and C4 inferior vertebral body borders are flat
   Superior vertebral borders are tapered posterior to anterior

II. *Acceleration stage* (*CVMI – 2*)
   Significant amount of adolescent growth expected
   Concavities developing in lower borders of C2 and C3
   Lower border of C4 vertebral body is flat
   C3 and C4 are more rectangular in shape

III. *Transition stage* (*CVMI – 3*)
   Moderate amount of adolescent growth expected
   Distinct concavities in lower borders of C2 and C3
   C4 developing concavity in lower border of body
   C3 and C4 are rectangular in shape

IV. *Deceleration stage* (*CVMI – 4*)
   Small amount of adolescent growth expected
   Distinct concavities in lower borders of C2, C3, and C4
   C3 and C4 are nearly square in shape

V. Maturation stage (CVMI – 5)
   Insignificant amount of adolescent growth expected
   Accentuated concavities of inferior vertebral body borders of C2, C3, and C4
   C3 and C4 are square in shape

VI. Completion stage (CVMI – 6)
   Adolescent growth is completed
   Deep concavities are present for inferior vertebral body borders of C2, C3, and C4
   C3 and C4 heights are greater than widths

Hand-wrist and cervical vertebrae maturation stages can be correlated according to Table 1 (4).

Pair wise comparison for skeletal age assessment stages was done using Wilcoxon Sign rank test and proportions were compared using *chi-square* test. The data was analyzed using SPSS (Statistical Package for Social Science™, version 10.5) package.

Results

The CVMI readings and SMI readings of the study subjects were tabulated and compared (Table 2 and 3).

Table 1 - Hand-wrist and cervical vertebrae maturation stages

Hand-Wrist indicator	Cervical Vertebrae Stage	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%

Table 2 - Comparison of SMI vs CVMI among males

SMI	CVMI						Total
	1	2	3	4	5	6	
1-2	9	3					12
	75.0%	25.0%					100.0%
3-4		8					8
		100.0%					100.0%
5-6			1				1
			100.0%				100.0%
7-8				3			3
				100.0%			100.0%
9-10					4	1	5
					80.0%	20.0%	100.0%
11						1	1
						100.0%	100.0%
Total	9	3					12
	75.0%	25.0%					100.0%

Table 3 - Comparison of SMI vs CVMI among females

SMI	CVMI						Total
	1	2	3	4	5	6	
1-2	1	3					4
	25.0%	75.0%					100.0%
3-4	1	8					9
	11.1%	88.9%					100.0%
5-6			1				1
			100.0%				100.0%
7-8			1	3			4
			25.0%	75.0%			100.0%
9-10				1	6	1	8
				12.5%	75.0%	12.5%	100.0%
11					1	3	4
					25.0%	75.0%	100.0%
Total	2	11	2	4	7	4	30
	6.7%	36.7%	6.7%	13.3%	23.3%	13.3%	100.0%

The mean chronological age of the subjects was 13 with a standard deviation of 2.73 and with an age range of 9-18 years. A significant association was observed between SMI and CVMI stages. The difference between the SMI and CVMI scores was statistically not significant (p=0.248) (Figure 1). A very good similarity was seen in males when SMI and CVMI stages were compared. There was 100% similarity in CVMI stage of 2 and SMI stage of 3-4, CVMI stage of 3 and SMI stage of 5-6, CVMI stage of 4 and SMI stage of 7-8, and CVMI stage of 6 and SMI stage of 11 (Figure 2). Among the females, except in CVMI stage 1, similarity in other stages was found to be ≥ 75% (Figure 3)

Discussion

The present study was conducted with an aim of assessing the skeletal age of an individual by interpretation of the cervical vertebrae, as seen in the lateral cephalogram and to correlate the size and shape of the cervical vertebrae with the skeletal maturity index on a hand-wrist radiograph. Various methods to assess the growth have been suggested

by many authors but the important factor is reliability and reproducibility of the method. The present scenario in dental and maxillofacial orthopedics requires an accurate method with well-defined and easily identifiable stages which could be interpreted in a cross sectional study without requiring long observation periods.
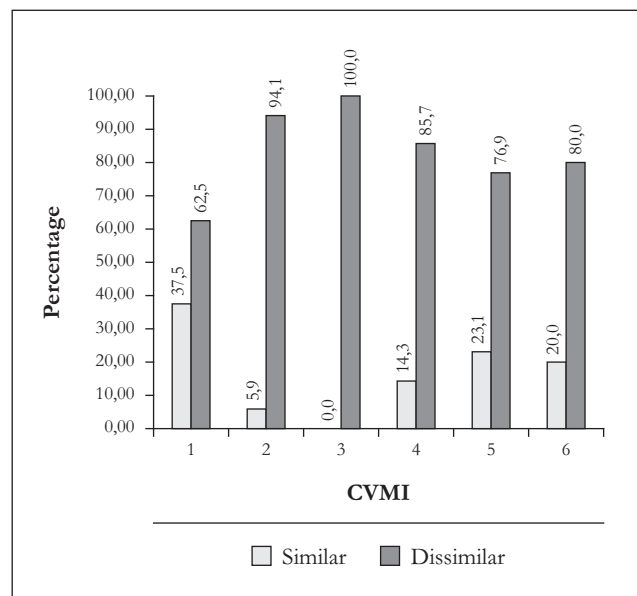

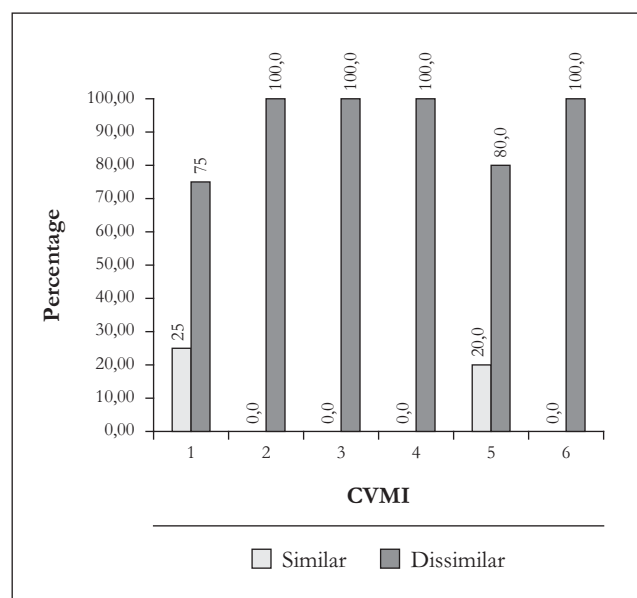**Figure 1** - Comparison of SMI vs CVMI among the study population
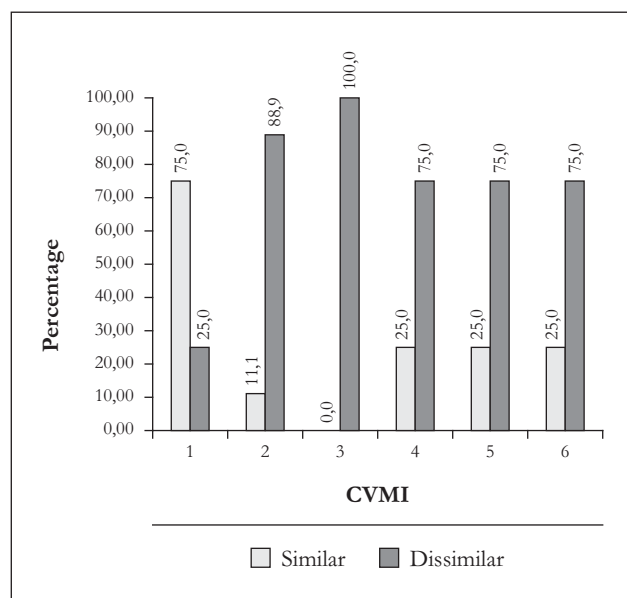

Figure 2 - Comparison of SMI vs CVMI among males

Figure 3 - Comparison of SMI vs CVMI among females

In this study, chronological age proved to be a poor indicator of maturity. The common practice of comparing an individual cephalometric measurement to chronological age provides no biologically sound basis for growth evaluation, prediction or treatment timing. A wide variation between chronological age with skeletal age was observed in the present study. The chronological age showed large differences in comparison with SMI, especially in the age group of 11-14 years and 17-18 years (Figure 4). Similar results were seen when subjects were assessed using developmental stages in cervical vertebrae (Figure 5) as a biological indicator. Here subjects in all the age groups demonstrated wide variation in their maturational development. These results are in confirmation with similar studies performed previously (5-8).

Though skeletal maturation assessed on hand-wrist radiograph has been considered the best indicator of assessment of skeletal maturity stage; however, routine use of hand-wrist radiographs has lately been questioned from radiation safety point of view.

Lamparski (9) first suggested the use of cervical vertebrae to determine skeletal maturity. This was later modified by Hassel and Farman in 1995 (3). They developed six stages of CVMI by using lateral profiles of second, third and fourth cervical vertebrae. It significantly corresponds to eleven SMI stages proposed by Fishman. Many authors have

confirmed this hypothesis (1, 3, 4, 10). An important feature was that in the male subjects skeletal maturity was much slower as compared to female subjects. Similar results were seen in a Swedish study (7). A significant association was also observed between SMI and CVMI stages (Figure 1). The difference between the SMI and CVMI scores was statistically not significant (p=0.248). Similar results were found in a study in which there was high correlation between SMI and CVMI scores was seen (p<0.001).[3] Further it is evident that the lower the SMI stages, lower were the CVMI stages and as the SMI stages increased, CVMI stages also increased almost linearly.

A very good similarity was seen in males when SMI and CVMI stages were compared (Figure 2). There was 100% similarity between CVMI stage 2 and SMI stage 3-4, CVMI stage 3 and SMI stage 5-6, CVMI stage 4 and SMI stage 7-8, and CVMI stage 6 and SMI stage 11. Among females, except for CVMI stage 1, similarity in all other stages was found to be ≥ 75% (Figure 3). A similar study showed that at the ages of 9,14,16,17 and 18 years, 100% of patient's showed similar values for cervical vertebrae and hand-wrist evaluations.[4] The patient population showed 85.7% similarity for both techniques at 10 years, 90.9% at 11 years, 84.6% at 12 years, 91.6% at 13 years and 93.3% at 15 years.
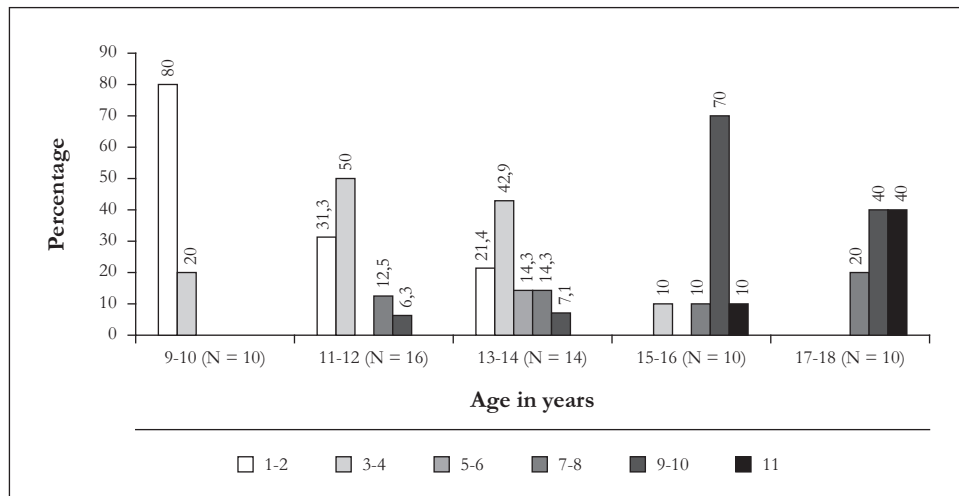

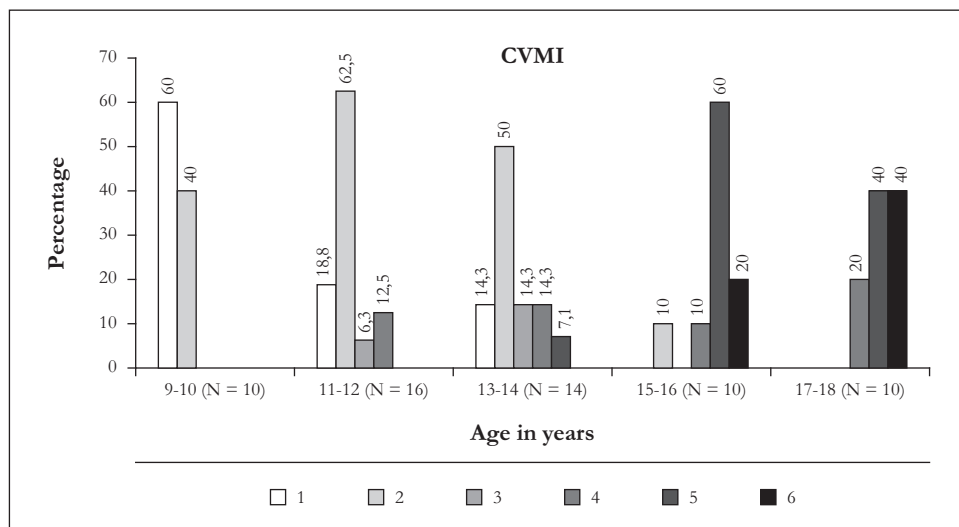**Figure 4** - Comparison of SMI vs CVMI among the study population

Figure 5 - Distribution of CVMI according to age group among the study population

A very good correlation was found between CVMI method and SMI method with a Pearson correlation value of 0.964. Among males, the correlation value was 0.975 whereas among females the value was 0.947.

The growth factor is a critical variable in orthodontic treatment. A treatment plan can vary from orthognathic surgery to extraction of teeth to non-extraction of teeth, depending on the growth factor. By observing at the cervical vertebrae on a lateral cephalometric radiograph the orthodontist can evaluate skeletal maturity of the patient. A reasonable idea of how much growth should be factored into anticipated treatment can be obtained.

Conclusion

An effort was made to assess the skeletal maturation by using Hassel and Farman's method (3) based on morphological characteristics of the cervical vertebrae and Fishman's method for hand-wrist radiographs. From this study, it was found that there was no significant difference in skeletal age assessed by cervical vertebrae maturational method and hand wrist maturational method for growing patients and the two methods were statistically similar for both genders.

Since properly utilized cervical vertebrae may provide a reliable assessment of the pubertal growth spurt, it would be beneficial to use lateral cephalogram projections for skeletal age assessment and thereby eliminate the need for an additional radiograph (hand-wrist radiograph). This would be cost effective and will reduce the radiation exposure to the patient.

Conflict of interest

The authors declared no conflict of interest in this manuscript.

Ethics commitee

This research was approved by the Ethic Commitee and the consent forms and all documents are kept in the archives of the Institution.

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