A comparison between cervical vertebrae and modified MP3 stages for the assessment of skeletal maturity

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Abstract

Objective: Evaluation of skeletal maturity in human individuals is an important aspect in orthodontics and dentofacial orthopedics because, growth guidance and fundamental structural changes are essential for treatment of skeletal discrepancies in all the three planes. Among various growth assessment methods, cervical vertebra maturation stages and hand wrist have been correlated with the individual growth changes during puberty. The purpose of this study is to determine correlation of the CVM index with the modified median phalanx index (MP3) as described by Rajagopal and Kansal. **Materials and Methods:** 200 subjects (100 males and 100 females) of Nellore, Indian origin boys aged between 10 to 19 years and girls of 8 to 16 years were selected for the study. The subjects are selected randomly from patients visiting the Departments of Orthodontics and Dentofacial Orthopedics, Pediatric dentistry and Oral medicine and Radiology at Narayana Dental College and Hospital. Nellore. Radiographs of left hand MP3 and lateral cephalogram were taken. **Results:** Cohen's kappa statistic was used to assess the agreement between the two measurements based on categorical variables. **Conclusions:** There was a good concordance between 6 stages of CVMI (Hassel and Farman) and the 6 stages of MP3 (Rajagopal and Kansal). Physiological maturity was earlier in females than in males when compared to the individuals of opposite sex of same chronological age. Chronological age was not a valid predictor of assessing the skeletal maturity because of significant variations in the distribution of CVMI and MP3 stages with respect to individual chronological age distribution.

Key words: Cervical vertebrae, middle phalynx of third finger (MP3), skeletal maturation

INTRODUCTION

Growth is the result of biologic processes by means of which living matter normally gets larger and it is not uniform throughout the life. Adolescence is a period during which the rate of growth acceleration reaches a peak velocity and then decelerates until adulthood is achieved. This pattern can be found in all individuals, but there are marked individual variations in the initiation, duration, rates and amount of growth during this period of life.[1]

One of the objectives of orthodontic treatment during adolescence, in cases with skeletal discrepancies is to take advantage of the patient's growth changes.[2] Maturational status can have a considerable influence on diagnosis, treatment goals, treatment planning and the eventual outcome of orthodontic treatment. This is especially true when treatment considerations are based strongly on the facial growth such as the use of extra oral traction, functional appliances, selection of orthodontic retention and orthognathic surgery.[3]

The maturity status of a child is best estimated relative to specific stages of physiologic maturity than chronological

age, being not a reliable indicator. Physiologic age is estimated by the maturation of one or more tissue systems. Physiologic age can be estimated by somatic, sexual, skeletal and dental maturity.[4]

The technique for assessing skeletal maturity consists of visual inspection of the developing bone, their initial appearance and their subsequent ossification related changes in shape and size. Various areas of the skeleton have been used like frontal sinus, the foot, the ankle, the hip, the elbow, the hand - wrist and the cervical vertebrae.[5]

It is a routine procedure for the orthodontist to take both hand - wrist radiograph for assessing the skeletal maturation and cephalometric radiograph to analyze skeletal morphology and direction of growth patterns. Cervical vertebral analysis for the assessment of skeletal maturity is correlating and is as reliable as hand - wrist radiographic method of assessment. A series of investigations performed in different parts of the world have confirmed the validity of the cervical vertebral maturation (CVM) method, mostly by comparing it with the hand – wrist method.[6]

Hagg and Taranger have described five stages of MP3 (Middle phalanx of the Middle finger) growth, based primarily on epiphyseal changes for the assessment of skeletal maturity. Skeletal maturity is evaluated by visible changes in the epiphyseal capping of the MP3. They are MP3 - F, MP3 - FG, MP3 - G, MP3 - H, MP3 - I stages.[7] Rajagopal and Kansal have added an additional bone stage between MP3 - H and MP3 - I, which they called the MP3 -HI stage. The modified six stages of MP3 can be easily compared with that of CVMI, which can be recorded on a standard periapical X-ray film and dental X-ray machine.[8,9] Considering the above, the objective of the present study is to determine the ossification events of the MP3 could be used to assess skeletal age with precision comparable to that of 6 CVMI stages and to assess the reliability of dental radiographic film for the assessment of skeletal maturity status.

The aim of this study was to determine whether the six modified MP3 stages described by Rajagopal and Kansal could be correlated with the six stages of cervical vertebrae maturation indices (CVMI), as described by Hassel and Farman. To evaluate the feasibility of recording MP3 stages using standard dental radiographic film for assessment of skeletal maturity. To assess the correlation among the chronological age, cervical vertebral maturity indicators and MP3 maturity stages.

MATERIALS AND METHODS

The subjects were selected randomly from the Departments of Orthodontics and Dentofacial Orthopedics, Pedodontics and Oral medicine and Radiology of Narayana Dental College and Hospital, Nellore. A sample of 200 subjects (100 males and 100 females) of Nellore, Indian origin boys aged between 10 to 19 years and girls aged between 8 to 16 years were selected for the study [Table 1]. All potential participants were explained the need and design of the study and the benefits if undergoing through clinical and radiographic investigations. Individuals who agreed to undergo this procedure were instructed to read and sign the consent form.

The samples were a mixed one consisting of patients with normal occlusion, malocclusion and those undergoing orthodontic treatment. The following subjects were not included in the study.
- Patients presenting with congenital or acquired malformations affecting cervical vertebrae or hand wrist.
- Patients presenting with developmental alterations of cervical vertebrae or hand - wrist bone.

Equipment used in the study
Villa Sistemi Medicali, Rotograph plus [Figure 1], Satelec dental radiographic machine [Figure 2] and 10 inches rigid cassette, Fuji radiographic films, Kodak IOPA films and Lead apron with thyroid shield were used.

Processing
Manual film processing.

Calibration device
36- micron matte acetate sheet, 0.5 mm diameter lead pencil and X- ray viewer.

Radiographic evaluation
In this study the radiographs of left hand Middle Phalanx of third finger - MP3 [Figure 3] and Lateral cephalogram [Figure 4] were taken under ideal conditions. Once skeletal maturation was assessed

Table 1: Percentage of growth estimation in correlation with MP3 and cervical vertebrae maturation stages

MP3 indicator	Cervical vertebrae stage	Percentile of pubertal growth remaining (%)
F Stage	Initiation	85-100
FG Stage	Acceleration	65-85
G Stage	Transition	25-65
H Stage	Deceleration	10-25
HI Stage	Maturation	5-10
I Stage	Completion	0

from the MP3 radiograph, the Lateral cephalogram was taken and three parts of the cervical vertebrae were traced. They were Dens Odontoid process, the 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. The method used by Rajagopal and Kansal was used to compare the modified MP3 stages [Figure 5 and Table 1]with that of the cervical vertebrae as growth indicator.

RESULTS

Age and gender distribution of the study population [Table 2].

The study population consists of 100 (50%) males and 100 (50%) females in the age range from 8 to 19 years.

Comparison of CVMI vs. MP3 among the study population:

Table 3 represents the comparison between MP3 and CVMI scores among the study population irrespective of age groups and gender.

Comparison of CVMI vs. MP3 among males.

Table 4 represents the comparison between CVMI and MP3 among males irrespective of age group.

Comparison of CVMI vs. MP3 among females.

Table 5 represents the comparison between CVMI and MP3 among females irrespective of age group.

Comparison of CVMI vs. MP3 among 8-9 years age group in study population [Figure 6]. The CVMI and MP3 among 8-9 years age in study population irrespective of gender had a CVMI score 1, 18 subjects (100.00%) were showing MP3 - F stage. With CVMI score 2, 1 subject (25.00%) was showing MP3 - F stage and 3 subjects (75.00%) were showing MP3 – FG stage. Strength of agreement was very good (K Value = 0.831).
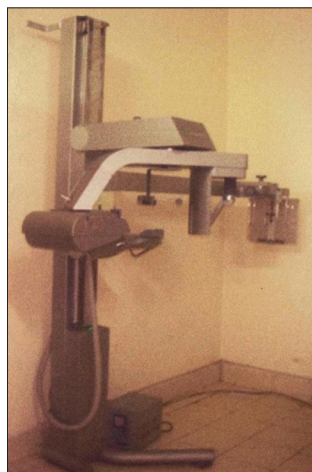

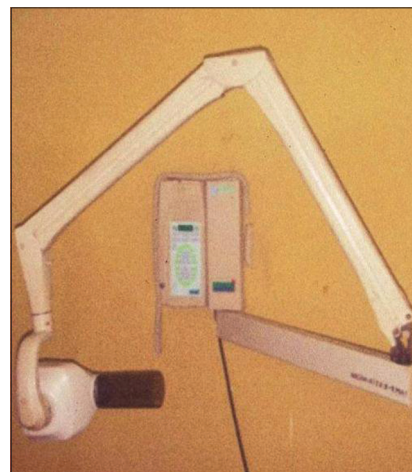**Figure 1:** Villa sistemi medicali, rotograph plus

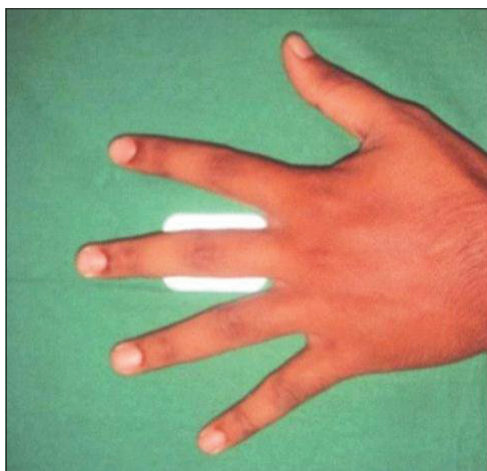**Figure 2:** Satelec dental radiographic machine

Figure 3: Radiograph of left hand middle phalanx of third finger

Figure 4: Lateral cephalogram machine

Comparison of CVMI vs. MP3 among 10-11 years age group in study population [Figure 7]. The CVMI and MP3 among 10-11 years age in study population irrespective of gender had a CVMI score of 1, 8 subjects (88.88%) were showing MP3 – F stage and 1 subject was showing MP3 - FG stage.

Comparison of CVMI vs. MP3 among 12-13 years age group in study population [Figure 8]. The CVMI and MP3 among 12-13 years age in study population irrespective of gender had a CVMI score of 1, 2 subjects (100.00%) were showing MP3 - F stage.

Comparison of CVMI vs. MP3 among 14-15 years age group in study population [Figure 9]. The CVMI and MP3 among 14-15 years age in study population irrespective of gender had a CVMI score of 1, 1 subject (100.00%) was showing MP3 - F stage.

Comparison of CVMI vs. MP3 among 16-17 years age group in study population [Figure 10]. The CVMI and MP3 among 16-17 years age in study population irrespective of gender had a CVMI score 5, 4 subjects (100.00%)

were showing MP3 - HI stage. With the CVMI score 6, 2 subjects (7.14%) were showing MP3 - HI stage and 26 subjects (92.85%) were showing MP3 - I stage. Strength of agreement was good (K Value = 0.651).

Comparison of CVMI vs. MP3 among 18-19 years age group in study population [Figure 11]. The CVMI and MP3 among 18-19 years age in study population irrespective of gender had a CVMI score 5, 1 subject (100.00%) was showing MP3 - HI stage. With the CVMI score 6, 1 subject (5.26%) was showing MP3 - HI stage and 18 subjects (94.73%) were showing MP3 - I stage. Strength of agreement was good (K Value = 0.643).

DISCUSSION

Optimal effectiveness in the use of orthodontic or orthopedic appliances has been associated with skeletal maturation. Functional appliances have shown to be more effective when used at peak mandibular growth rate rather than earlier.[2]

Table 2: Age and gender distribution of study population

Age	Gender		Total
	Male	Female	
8-9	0	22	22
10-11	20	22	42
12-13	20	22	42
14-15	20	22	42
16-17	20	12	42
18-19	20	0	20
Total	100	100	200

Table 3: Comparison of MP3 versus cervical vertebrae maturation indices among the study population

MP3 stages	CVMI stages						Total
	1	2	3	4	5	6	
F	29	2					31
%	14.5	1					15.5
FG	1	48	2		1		52
%	0.5	24	1		0.5		26
G		2	12	1		1	16
%		1	6	0.5		0.5	8
H				7	1		8
%				3.5	0.5		4
HI		1		4	13	5	23
%		0.5		2	6.5	2.5	11.5
I					6	64	70
%					3	32	35
Total	30	53	14	12	21	70	200
%	15	26.5	7	6	10.5	35	100
Total (Male+Female)					200		
K-value					0.823		
Agreement strength					Very good		

Figure 5: Correlation of cervical vertebrae with MP3 skeletal maturation stages

Table 4: Comparison of MP3 versus cervical vertebrae maturation indices among males

MP3 Stages	CVMI stages						Total
	1	2	3	4	5	6	
F	10	1					11
%	90.91	9.09					100.0
FG	1	32	2				35
%	2.86	88.57	5.71				100.0
G			6	1	1		8
%			75.00	12.50	12.50		100.0
H				4			4
%				100.0			100.0
HI					5	2	7
%					71.42	28.57	100.0
I					1	34	35
%					2.85	97.14	100.0
Total	11	33	8	5	7	36	100
%	11.0	33.00	8.00	5.00	7.00	36.00	100.0
Total Males				100			
K-value				0.727			
Agreement strength				Good			

Table 5: Comparison of MP3 versus CVMI among females

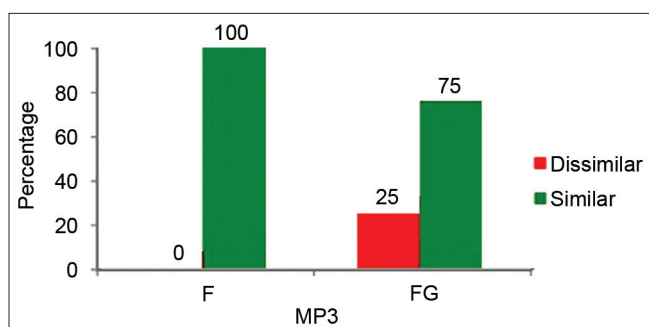| MP3 Stages	CVMI stages						Total
	1	2	3	4	5	6	
F	19	1					20
%	95.0	5					100.0
FG		17					17
%		100					100.0
G		2	6				8
%		25	75.0				100.0
H				4			4
%				100			100.0
HI				3	13		16
%				18.8	81.3		100.0
I					1	34	35
%					2.86	97.14	100.0
Total	19	20	6	7	14	34	100
%	19.0	20	6.0	7.0	14.0	34.0	100.0
Total Females				100			
K-value				0.91			
Agreement strength				Very good			

Figure 6: Comparison of CVMI versus MP3 among 8-9 years age group in study population
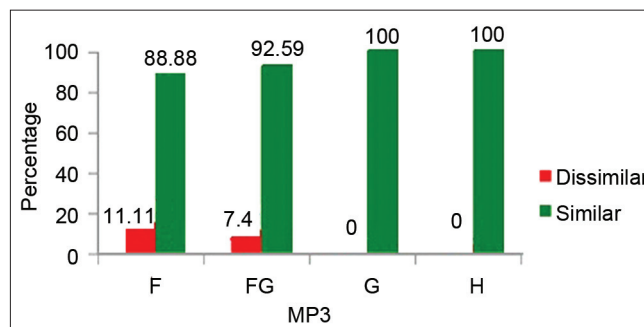

Figure 7: Comparison of CVMI versus MP3 among 10-11 years age group in study population

Chronologic age is an inaccurate indicator of the stages of development through adolescence to adulthood.[9] Dental age has a significantly low correlation with biological age.[4,10-12] Growth prediction based on the appearance of secondary sexual characterics requires a long observation period and frequent physical examinations. The skeletal maturity of the bones of the hand - wrist and cervical vertebrae, on the other hand, is closely related to that of the craniofacial
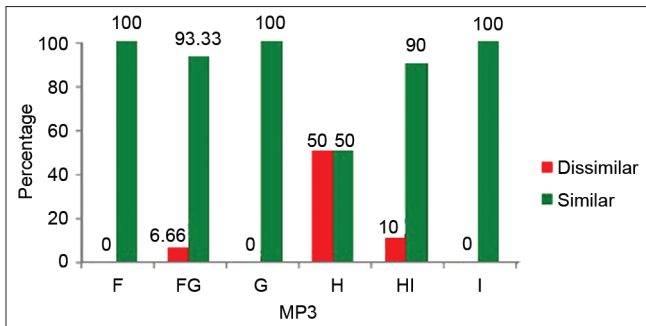
Figure 8: Comparison of CVMI versus MP3 among 12-13 years age group in study population
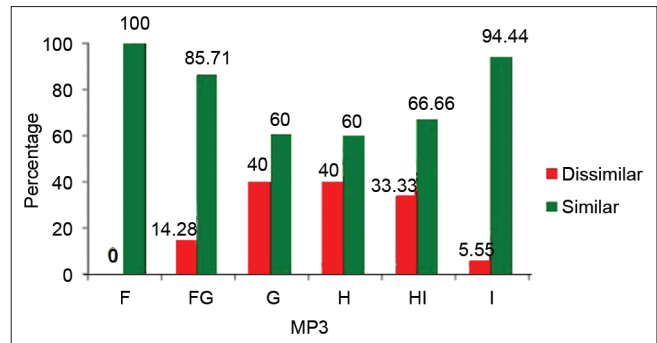

Figure 9: Comparison of CVMI versus MP3 among 14-15 years age group in study population
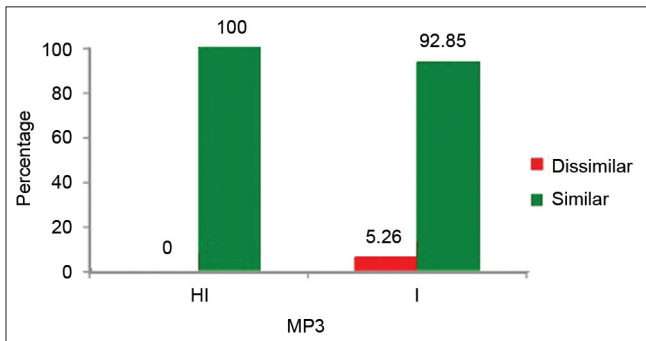

Figure 10: Comparison of CVMI versus MP3 among 16-17 years age group in study population
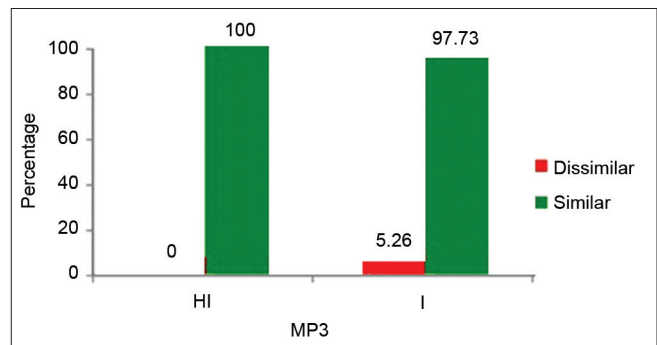

Figure 11: Comparison of CVMI versus MP3 among 18-19 years age group in study population

region development. The skeletal maturity indices are good reliable predictors of sexual and somatic maturity as well.[8]

A sample of 200 subjects ranging from 10 to 19 years for boys and 8 to 16 years for girls was taken to assess the stages of skeletal maturation through cervical vertebrae as well as MP3 stages. Two successive CVMI - MP3 groups were combined; it was considered that MP3 anatomic characters were unique to each of these groupings.

A very good Kappa correlation value of 0.82 [Table 3] was found in the study population between CVMI and MP3 stages Hassel and Farman - Rajagopal and Kansal analysis. Similar results were found in a previous study in which there was a high correlation between CVMI and MP3 scores. There was 90.9% similarity in MP3 - F stage and with a CVMI score of 1, 88.5% similarity in MP3 - FG stage and with a CVMI score of 2, 75.0% similarity in MP3 - G stage and with a CVMI score of 3, 100.0% similarity in MP3 - H stage and with a CVMI score of 4, 71.4% similarity in MP3 - HI stage and with a CVMI score of 5, 97.1% similarity in MP3 - I stage and with a CVMI score of 6. Kappa value 0.72 [Table 4] is slightly lower when compared to females 0.91 [Table 5]. The investigation from this study strongly correlates with the study by Rajagopal and Kansal.[8]

Females are more in the advanced maturity stages as compared to males, indicating that faster maturation occurs in females as compared to males. However, the difference in the SMI and CVMI scores between males and females are statistically not significant.[8]

The findings of this study showed that the agreement strength of CVMI versus MP3 among 8-9 years age group in the study population as in [Figure 6] was very good which means 95.45% in the sample size in the population coincided by CVMI and MP3. Similarly the agreement strengths of CVMI versus MP3 among 10-11, 12-13 age group was very good i.e., 0.8 and 0.86 [Figures 7 and 8], whereas 14-15, 16-17, and 18-19 years age groups showed good agreement 0.74, 0.64 and 0.64 [Figures 9-11].

CONCLUSION

From the present study, the following conclusions are made
- There was a good concordance between six stages of CVMI (Hassel and Farman) and the six stages of MP3 (Rajagopal and Kansal).
- Physiological maturity was earlier in females than in males when compared to the individuals of opposite sex of same chronological age.
- Chronological age was not a valid predictor of assessing the skeletal maturity because of significant variations in the distribution of CVMI and MP3 stages with respect to individual chronological age distribution.

Hence, MP3 indicator can be a better choice of predicting skeletal maturity of an individual because of its simplicity, reliability and reduced radiation exposure to an individual. There is a need for further study with a larger sample size and longitudinal study methodology, as this can show a better correlation between CVMI and MP3 than the observations made in this study.

To conclude, chronological age of an individual cannot be a reliable method of predicting the skeletal maturity and any kind of dentofacial orthopedics should be instituted at an early age in females when compared to males, because skeletal maturity is earlier in females. Therefore, any method that might help to identify growth acceleration or deceleration is helpful.

REFERENCES

1. Anibal MS, Leonard SF, Daniel SJ, Denise KK. Facial growth during adolescence in early, average and late maturers. Angle Orthod 1992;62:185-90.
2. Carlos FM, Corr AB, Mitchell C, Robert J, Micheal J, Pitcher R, *et al*. Correlation of skeletal maturation stages determined by cervical vertebrae and hand-wrist evaluations. Angle Orthod 2005;76:1-5.
3. Robert NM, Barbara AM, Linda MD. Skeletal maturation and craniofacial growth. Am J Orthod Dentofacial Orthop 1990;98:33-40.
4. Demirjian PH, Buschang RT, Kingnorth DP. Interrelationship among measures of somatic, skeletal, dental and sexual maturity. Am J Orthod Dentofacial Orthop 1985;88:433-8.
5. Heloisio RL, Maria TO, John MC. Skeletal age assessment with the first, second and third fingers of the hand. Am J Orthod Dentofacial Orthop 1987;92:492-8.
6. Paola G, Marta M, Federico A. A comparison of hand-wrist bone and cervical vertebral analysis in measuring skeletal maturation. Angle Orthod 2006;76:984-9.
7. Urban H, John T. Maturation indicators and the pubertal growth spurt. Am J Orthod Dentofacial Orthop 1982;82:299-309.
8. Rajagopal SK. A comparison of modified MP3 stages and the cervical vertebrae as growth indicators. J Clin Orthod 2002;36:398-406.
9. Torun O, Jalen DL, Senem YO. A practical method for determining pubertal growth spurt. Am J Orthod Dentofacial Orthop 2006;130:131-6.
10. Arthur BL. Comparison between dental and skeletal ages. Angle Orthod 1991;61:87-92.
11. Carlos FM, Brian N, Paul WM. Use of skeletal maturation based on hand-wrist radiographic analysis as a predictor of facial growth: A systematic review. Angle Orthod 2004;74:218-24.
12. Tancan U, Sabry LR, Faruk AB, Zafer S. Chronological and skeletal maturation of the cervical vertebrae and hand-wrist; is there relationship? Am J Orthod Dentofacial Orthop 2006;130:622-8.

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