Original Article

A Comparison of Modified MP3 Stages and the Cervical Vertebrae as Growth Indicators in Prepubertal and Pubertal Individuals: A Cross-Sectional Study

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Abstract

Background: An understanding of growth events is of primary importance in the practice of clinical orthodontics. A number of growth indicators are available to the orthodontist in day-to-day practice; changes in the cervical vertebra (CV) and middle phalanges (MP) of the middle finger (MP3) being the commonly assessed growth indicators. Apart from the five stages of MP3 growth based on epiphyseal changes, a new stage is developed. **Aim:** To compare the modified MP3 stages and the CV as growth indicators among prepubertal and pubertal individuals. **Materials and Methods:** Lateral cephalogram for CV and a standard intraoral periapical radiograph of middle phalanx of the third finger (MP3) were taken for 45 boys and girls aged between 9 years and 17 years and compared. **Results:** Both MP3 and CV maturation indices (CVMIs) stages were comparable and 100% similar to both sexes in 9, 12, 16, and 17 years of age. There were slight changes across both sexes in other age groups. The correlation between modified MP3 stages and CVMI stages was statistically analyzed using the Chi-square test. A highly significant correlation ($P < 0.0001$) was obtained between modified MP3 and CVMI stages in all the subjects examined. **Conclusions:** Modified MP3 stages can be used as a primary reliable method of skeletal maturity assessment which compare harmoniously with CVMI stages in all ages and sex studied. Modified MP3 stages can be used as an alternative to CVMI or hand wrist in assessing skeletal maturity in the orthodontic office. Recording MP3 using standard dental X-ray film is an accurate, simple, practical, and economical method of skeletal maturity assessment.

Keywords: Growth indicator, Cervical vertebrae maturation indices, Middle phalanges 3, Orthodontics.

Introduction

"*Growth was conceived by an anatomist, born to a biologist, delivered by a physician left on a chemist's doorstep and adopted by a physiologist. At an early age, she eloped with a statistician. Divorced him for a physiologist, and is now being wooed alternatively and concurrently by an endocrinologist, a pediatrician, a physical anthropologist, an educationalist, a biochemist, a physicist, a mathematician, an orthodontist, a eugenicist, and the children bureau*" – Krogman.[1]

One of the most challenging aspects of orthodontic treatment is that of being a mediator in the craniofacial growth process. A formal description of craniofacial growth can be of immense importance to orthodontists and other clinicians who are treating functional and aesthetic anomalies of the human face. The development of a satisfactory treatment plan is often contingent on predicting the outcome of growth in the absence of treatment and anticipating the product of the interaction between the desired treatment objective and craniofacial growth. The failure to anticipate the effects of growth in a long range treatment plan can result in a marked deterioration of the desired outcome overtime. On the other hand, postponing treatment until the head has stopped growing can have disastrous consequences for the patient's self-image and ability to engage in social interactions during a period of the life cycle when peer relationships have a profound impact on the ability to form other relationships in later years.

An understanding of growth events is of primary importance in the practice of clinical orthodontics. Maturational status can

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have a considerable influence on diagnosis, treatment goals, treatment planning, and the eventual outcome of orthodontic treatment.[2] Clinical decisions regarding the use of extraoral traction forces, functional appliances, extraction versus non-extraction treatment, or orthognathic surgeries are, at least partially, based on growth considerations. Growth prediction has been a controversial topic ever since it was advocated by Ricketts. The prediction would involve forecasting a change in the direction of different growth rates for two patients who were the same age, sex, and race on the basis of some prior knowledge and investigations.

A number of growth indicators are available to the orthodontist in day-to-day practice. Sexual maturation characteristics, chronologic age, dental development, height, weight, and skeletal development are some of the more common means that have been used to identify stages of growth. The selection of a growth indicator is mainly based on its reliability. Furthermore, the method should have a long observation period. A lot of growth indicators helping in the skeletal maturation assessment of a growing patient have been introduced. The most common method used is by Fishman[3-5] which uses a hand-wrist radiograph of its four stages of bone maturation at six anatomic sites. Hassel and Farman[5] utilized the cervical vertebrae and found them reliable and valid. Hagg and Taranger[7,8] introduced a method using the hand-wrist radiograph to correlate certain maturity indicators to the pubertal spurt and noted that the stage of ossification of the middle phalanx of the third finger of a hand (middle phalange MP3 follows the pubertal growth spurt from the onset to the end. They described five stages of MP3 growth based on epiphyseal changes.

Rajagopal and Kansal[9] added an additional bone stage between MP3 H (deceleration of the curve of the pubertal growth spurt) and MP3-I (end of a pubertal growth spurt), which was called the MP3-HI stage, resulting in a total of six stages of MP3 growth using a simple intraoral radiographic film. This introduction is sure to revolutionize clinical orthodontics for its ease and simplicity. To estimate the potential of this new technique, a study to assess the reliability of the skeletal maturity assessment using intraoral periapical (IOPA) film was taken up. The purpose of the present study is to determine whether the six modified MP3 stages correlate with the six stages of CVMI and to evaluate the possibility of recording MP3 stages using standard dental X-ray film.

Aims and objectives

The objectives of the study were as follows:

1. To evaluate the six modified MP3 stages as a method of skeletal maturation assessment
2. To compare six modified MP3 stages with six stages of cervical vertebrae maturation indices (CVMIs)
3. To determine whether a correlation exists between the modified MP3 stages and CVMI stages
4. To evaluate the possibility of recording MP3 stages using standard dental X-ray film for routine clinical applications.

Materials and Methods

The sample consisted of 45 males and 45 females aged between 9 and 17 years. The subjects were selected randomly from patients seeking and undergoing orthodontic treatments at the Departments of Orthodontics and Pedodontics, Government Dental College, Kozhikode.

The subjects were divided into nine groups based on age; each group consisted of 10 patients with an equal distribution of males and females.

Two radiographs, namely, lateral cephalogram and a standard IOPA radiograph of the middle phalanx of the third finger (MP3) were used for this study. Written consent was obtained from the parents of the patients before radiographic exposure. Ethics committee approval was also obtained before the commencement of the study.

Lateral cephalograms were taken using an extraoral radiographic machine (Planmeca Proline PM 2002cc., Finland) and radiographic film (and Kodak – extraoral film – USA) of size 8 × 10 inch. Exposure parameters were 72 kVp, 10 mA for 1.2 s. X-ray source to mid-sagittal plane distance was kept at 60 inches. Radiographs were taken in natural head position following standard procedure, with patients standing erect and instructed to look straight into their own eyes in a mirror placed on the wall in front.

MP3 region radiograph was taken using the standard dental radiographic machine (Planmeca Prostyle Intra, Finland) with exposure parameters (60 kVp, 8 mA for 6 s) and a No. 2 size IOPA film (Kodak-E-speed, 31x41 mm, Germany). The subjects were instructed to place the right hand with the palm down on a flat table. The middle finger was centered on a 31 mm × 41 mm periapical dental X-ray film parallel with the long axis of the film. The cone of the dental X-ray machine was positioned in slight contact with the middle phalanx, perpendicular to the film.

All radiographs were processed with standard processing technique, and radiographs of high clarity and good contrast were used. The records with the subject's name, age (specifying the month), and sex were first evaluated by the author (BKS) using an X-ray viewer as per the methods detailed below.[4,8] Retests were done by the second investigator (RR) to check the validity of the experiment. In 89 out of 90 samples, the observations were in agreement.

Evaluation of CVMI and MP3 Stages

The method proposed by Lamparski and modified by Hassel and Farman was used for the assessment of cervical vertebra, which assesses maturational changes on second, third, and fourth cervical vertebrae. The stages proposed by Hagg and Taranger[7,8] and modified by Rajagopal and Kansal[9] were used to assess MP3 growth. The six stages of MP3 growth are as follows. The comparison and correlation of the CVMI and modified MP3 stages were made with the below features as shown in Table 1.

Results

The sample consisted of 45 males and 45 females aged between 9 and 17 years, with a total of 90 patients. The subjects were divided into nine groups based on age (9–17 years); each group consisted of 10 patients with an equal distribution of males and females.

The method proposed by Lamparski[10] and modified by Hassel and Farman was used for the assessment of cervical vertebrae, which assesses maturational changes on second, third, and fourth cervical vertebrae. The stages proposed by Hagg and Taranger and by Rajagopal and Kansal were used to assess MP3 growth. The correlation and comparison between CVMI and modified MP3 stages were made. The relationship between CVMI MP3 stages was also assessed using Chi-square analysis.

As per Table 2, among the 45 males studied at 9, 10, 12, 14, 15, 16, and 17 years – the similarity of occurrence of MP3 stages with CVMI is 100%. At 11 and 13 years – the similarity of occurrence of MP3 stages with CVMI is 80%. Among the 45 females studied at 9, 12, 13, 16, and 17 years – the similarity of occurrence of MP3 stages with CVMI is 100%. At 10, 11, 14, and 15 years – the similarity of occurrence of MP3 stages with CVMI is 80%.

As per Table 3, among the 90 subjects studied, the similarity of occurrence of MP3 stages with CVMI was 100% in the age groups of 9, 12, 16, and 17 years. The similarity of occurrence of MP3 stages with CVMI was 90% in the age groups of 10, 13, and 14 years, while the similarity was 80% in the age groups of 11 and 15 years.

As per Tables 3 and 4, both MP3 and CVMI stages were comparable and 100% similar for both sexes in 9, 12, 16 as shown in the Tables 3 and 4, and 17 years of age.While there were slight changes across both sexes in other age groups as shown in the table. Among the males, 43 subjects showed similarity between modified MP3 stages and CVMI (95.6%). Two of the 45 subjects were dissimilar (4.4%). Among females, 41 subjects showed similarity between modified MP3 stages and CVMI (91.1%). Four of the 45 subjects were dissimilar (8.9%). Out of 90 subjects studied, 84 subjects showed

Table 1: The features of CVMI and MP3 stages

CVMI stages	Features	MP3 stages	Features
CVMI-1: Initiation stage of cervical vertebrae	C2, C3, and C4 inferior vertebral body borders are flat, and superior vertebral borders are tapered from posterior to anterior (A wedge shape), 80–100% of pubertal growth remains	MP3-F stage: Start of the curve of the pubertal growth spurt	The epiphysis is as wide as metaphysis, ends of epiphysis are tapered and rounded, metaphysis shows no undulation, radiolucent gap (representing cartilaginous epiphyseal growth plate) between epiphysis and metaphysis is wide
CVMI-2: Acceleration stage of cervical vertebrae	Concavities are developing in lower borders of C2 and C3, lower border of C4 vertebral body is flat, C3 and C4 are more rectangular in shape, 65–85% of pubertal growth remains	MP3-FG stage: Acceleration of the curve of the pubertal growth spurt	The epiphysis is as wide as metaphysis, distinct medial and/or lateral border of epiphysis forms line of demarcation at a right angle to the distal border, and metaphysis begins to show slight undulation, the radiolucent gap between metaphysis and epiphysis is wide
CVMI-3: Transition stage of cervical vertebrae	Distinct concavities are seen in lower borders of C2 and C3, and the concavity is developing in the lower border of C4, C3, and C4 are more rectangular in shape, 25–65% of pubertal growth remains	MP3-G stage: Maximum point of a pubertal growth spurt	Sides of epiphysis have thickened, and cap its metaphysis, forming a sharp distal edge on one or both sides, marked undulations in metaphysis give it a "Cupid's bow" appearance, the radiolucent gap between epiphysis and metaphysis is moderate
CVMI-4: Deceleration stage of cervical vertebrae	Distinct concavities are seen in lower borders of C2, C3, and C4, C3, and C4 are nearly square in shape; 10–25% of pubertal growth remains	MP3-H stage: Deceleration of the curve of a pubertal growth spurt	Fusion of epiphysis and metaphysis begins, one or both sides of epiphysis form an obtuse angle to the distal border, the epiphysis is beginning to narrow, slight convexity is seen under the central part of metaphysis, typical "Cupid's bow" appearance of metaphysis is absent, but slight undulation is distinctly present, the radiolucent gap between epiphysis and metaphysis is narrower
CVMI-5: Maturation stage of cervical vertebrae	Accentuated concavities of C2, 3, and C4 inferior vertebral body borders are observed, C3 and C4 are square in shape, 5–10% of pubertal growth remains	MP3-HI stage: Maturation of the curve of a pubertal growth spurt:	The superior surface of epiphysis shows smooth concavity, metaphysis shows smooth, convex surface, almost fitting into the reciprocal concavity of epiphysis, no undulation is present in metaphysis, the radiolucent gap between epiphysis and metaphysis is insignificant
CVMI-6: Completion stage of cervical vertebrae	Deep concavities are present in C2, C3, and C4 inferior vertebral body borders, C3 and C4 are greater in height than in width, pubertal growth is complete	MP3-I stage: End of a pubertal growth spurt	Fusion of epiphysis and metaphysis complete, no radiolucent gap exists between metaphysis and epiphysis, a dense, radiopaque epiphyseal line forms an integral part of the proximal portion of the middle phalanx

MP: Middle phalange

Table 2: No. of subjects in each stage based on the age-wise distribution

Stages	Sex M/F	No. of subjects in each stage based on the age-wise distribution (years)								
		9	10	11	12	13	14	15	16	17
CVMI- 1	M/F	5/3	2/0	2/1	2/0	2/0	-	-	-	-
MP3-F	M/F	5/3	2/1	2/1	2/0	3/0				
CVMI-2	M/F	0/2	3/5	3/1	1/0	1/0	-	1/0	-	-
MP3-FG	M/F	0/2	3/4	2/2	1/0			1/0		
CVMI-3	M/F	-	-	0/2	2/3	2/1	4/2	-	-	-
MP3-G	M/F	-	-	0/1	2/3	2/1	4/1			
CVMI-4	M/F	-	-	0/1	0/2	0/3	1/0	3/2	1/0	-
MP3-H	M/F	-	-	1/1	0/2	0/3	1/1	3/1	1/0	
CVMI-5	M/F	-	-	-	-	0/1	0/3	1/3	2/2	-
MP3-HI	M/F	-	-	-	-	0/1	0/3	1/4	2/2	
CVMI-6	M/F	-	-	-	-	-	-	-	2/3	5/5
MP3-I	M/F	-	-	-					2/3	5/5

MP: Middle phalange

Table 3: Frequency distribution and the correlation of modified MP3 stages according to CVMI stages in both sexes in all age groups

Stages	MP3-F	MP3-FG	MP3-G	MP3-H	MP3-HI	MP3-I
CVMI-1	13 (M) (92.9%)					
	4 (F) (80%)					
CVMI-2	1 (M) (7.1%)	7 (M) (100%)		1 (M) (16.7%)		
	1 (F) (20%)	7 (F) (87.5%)				
CVMI-3			8 (M) (100%)			
		1 (F) (12.5%)	6 (F) (100%)	1 (F) (12.5%)		
CVMI-4				5 (M) (83.3%)		
				7 (F) (87.5%)	1 (F) (10%)	
CVMI-5					3 (M) (100%)	
					9 (F) (90%)	
CVMI-6						7 (M) (100%)
						8 (F) (100%)

(M= Males, F = females). In males, Chi-square=205.48, DF=25, P<0.001; in females, Chi-square=182.25, DF=25, P<0.001. MP: Middle phalange

Table 4: Correlation between modified MP3 stages according to CVMI stages in all age groups

Stages	MP3-F	MP3-FG	MP3-G	MP3-H	MP3-HI	MP3-I	Total
CVMI- 1	17 (89.5%)						17 (18.9%)
CVMI-2	2 (10.5%)	14 (93.3%)		1 (7.1%)			17 (18.9%)
CVMI-3		1 (6.7%)	14 (100%)	1 (7.1%)			16 (17.8%)
CVMI-4				12 (85.7%)	1 (7.7%)		13 (14.4%)
CVMI-5					12 (92.3%)		12 (13.3%)
CVMI-6						15 (100%)	15 (16.7%)
Total	19 (21.1%)	15 (16.7%)	14 (15.6%)	14 (15.6%)	13 (14.4%)	15 (16.7%)	90 (100%)

Chi-square=385.54, DF=25, P<0.001 – highly significant, r=0.984. MP: Middle phalange

similarity between modified MP3 and CVMI (93.3%). Six of the 90 subjects were dissimilar (6.7%). The correlation between modified MP3 stages and CVMI stages was statistically analyzed using the Chi-square test. A highly significant correlation (P < 0.0001) was obtained between modified MP3 and CVMI stages in all the subjects examined.

Discussion

The evaluations of skeletal maturation levels provide a very useful means of identifying specific points along with adolescent growth, including facial growth. Dental, maturational, and chronological ages are related. It is common

for an orthodontist to see a patient who is tall in stature, advanced in age, but with retained deciduous teeth than normal tor this stage. However, a short child may be advanced more in skeletal maturation than a taller child because of a genetic pattern that predestines a short adult.

An understanding of growth events is of primary importance in the practice of clinical orthodontics. Maturational status can have a considerable influence on diagnosis, treatment goals, treatment planning, and the eventual outcome of orthodontic treatment. Clinical decisions regarding the use of extraoral traction forces, functional appliances, extraction versus non-extraction treatment, or orthognathic surgeries are, at least partially, based on growth considerations.

The skeletal maturity of bones of the hand and wrist and the cervical vertebrae is closely related, and skeletal maturity is more cervical reliable predictors of sexual and somatic maturity dental and chronological age. Hagg and Taranger[7,8] recommended using five stages of MP3 development as a reliable biological indicator. This is modified by Rajagopal and Kansal[9] by adding the MP3-HI stage between MP3-H and MP3-I, resulting in six stages of MP3 maturation. Chapman[11] was the first to use periapical X-ray film to evaluate ossification of the adductor sesamoid bone as a skeletal maturity indicator. Abdel-Kader[12,13] applied this idea for recording MP3 stages. Rajagopal and Kansal[8] also used IOPA film for recording modified MP3 stages.

The purpose of this study is to determine whether the six modified MP3 stages will be correlated with the six stages of CVMI. This study also evaluates the possibility of recording MP3 using standard dental X-ray film. The study consisted of 45 males and 45 females aged between 9 and 17 years, with a total of 90 patients.

In the present study, in 90 subjects, the six modified MP3 stages showed a high correlation with the six stages of cervical vertebrae, with an overall similarity of 95.3%. These results are supported by Rajagopal and Kansal.[8] The correlation between modified MP3 stages and CVMI stages was statistically analyzed using the Chi-square test. A highly significant correlation ($P<0.0001$) was obtained between modified MP3 and CVMI stages in all the subjects examined. This is supported by the finding of is Madhu *et al*.[14] and Tandon *et al*.[15]

Hence, the six modified MP3 stages and CVMI stages closely were related and can be used as reliable skeletal maturity indicators. This can also be used as an alternative method to hand-wrist and cervical vertebrae radiograph for assessing the skeletal maturity in an orthodontic office.

With the American Association of Orthodontists[15] current recommendations of first orthodontic consultation at 7 years of age and a lot of interest of professionals and public about early treatment, orthodontists will have to see many young patients. Treatment of these young children will call for a synchronized evaluation of chronological, skeletal, and dental ages. Hence, a simplistic and patient-friendly method of skeletal age evaluation will bring this method close to the methods of evaluating chronological age (date of birth) and dental age (shedding and eruption). Thus, the MP3 evaluation will occupy a higher significance in routine clinical practice and can be used for managing a large population.

Once practiced, it becomes easy and simple to read MP3 radiographs like routine periapical X-rays. Hence, this will be a time-saving method for orthodontist and pedodontist to be used in handling mixed dentition patients.

The present study also evaluated the possibility of using standard dental periapical radiographs and standard dental X-ray machine in recording the MP3 stages. The lateral cephalometric radiograph and hand-wrist radiograph use large film (20 cm × 25 cm). The whole hand and head, and neck are subjected to radiation exposure. Hence, there will be a large area of exposure, increased production of scattered radiation, and the exposure to radiation is in large quantity.

The size of the IOPA film is about 32 mm × 41 mm. Hence, when this film is used to record the middle phalanx of the third finger of a hand (MP3), the area of exposure is reduced because only that part of the finger is subjected to radiation, not the whole hand. Hence, the risk to the patient is less. In modern society, people are highly aware of health hazards and are cautious about radiation exposure. Therefore, any step is taken to reduce radiation dosage and exposure to vital structures of patients. This will also be highlighted before the ethics committee and was well appreciated.

Lateral cephalometric radiographs are one of the essential diagnostic aids in an orthodontic office. However, in small children, the thyroid collar used during radiography tends to mask the cervical vertebrae, so it was necessary to use an additional hand-wrist radiograph along with lateral cephalogram, causing high radiation exposure, being expensive and requiring elaborate equipment. By recording the MP5 using IOPA film, we can also assess the growth status of a patient that was previously done by hand-wrist radiograph.

The cost of the extraoral machine is above four lakhs, and the panoramic/cephalometric machine is about 40 lakhs. However, the standard dental X-ray machine is in the range of 50,000–150,000. Hence, any ordinary dental clinic can reasonably afford the machine eliminating the need to outsource. In addition, the cost of the extraoral film is more than a standard size IOPA film. Hence, the cost of the radiograph is much more than in the case of hand-wrist or lateral cephalometric radiographs. The developing solution used for radiograph is expensive. The developing IOPA film does not require a large amount of solution as compared to extraoral film. These also add up to the increased cost of hand-wrist or lateral cephalometric film.

Every radiographic machine requires safety recommendations. The safety recommendations are high for extraoral and panoramic/cephalometric machine. This is less in the case

of a standard dental X-ray machine. The maintenance cost of a standard dental X-ray machine is less compared to an extraoral and panoramic machine, which requires expensive maintenance.

In addition, the high degree of clarity of radiograph, the ease with which we can interpret MP3 stages, the simplicity of the method, and the significantly low patients radiation exposure highly recommend it as a practical and sensitive technique that meets the requirements of the clinician in the field of orthodontics. The equipment required is only the standard size periapical dental X-ray films and the standard dental X-ray machine, which is available in most clinics.[9,12,13]

In this study, all the six stages of modified MP3 and CVMI were reached earlier in females than in males. This is in agreement with the sexual dimorphism found in other studies.[3-7,11,14,16-18] Hence, growth modulation should be started in an earlier chronological age in females compared to males.

The results obtained from the limited sample size of this study cannot be generalized to the Malabar population. Hence, multicentric studies with large sample sizes with specific racial selection are possible in future to derive MP3 indices to the various age groups of boys and girls of the Malabar population to predict skeletal maturation standards for boys and girls. MP3 evaluation can be a primary method of skeletal evaluation in a dental clinic because of its simplicity, safety, and cost-effectiveness. However, supplemental and more sensitive and elaborate methods of skeletal maturity evaluation, namely, hand-wrist or CVMI, can be used where additional information or confirmation is required.

Summary and Conclusions

The present study was done on 90 subjects between the age group of 9–17 years to compare and correlate the newer methods assessment of skeletal maturity, namely, the middle phalanx of the third finger (MP3) and the CVMI draws the following conclusions which are limited due to the small sample size: Modified MP3 stages can be used as a primary reliable method of skeletal maturity assessment which compare harmoniously with CVMI stages in all ages and sex studied. A highly significant correlation exists between modified MPŠ stages and CVMI stages in the age group of males and females studied. Thus, modified MP3 stages can be used as an alternative to CVMI or hand wrist in assessing skeletal maturity in orthodontic office. Recording MP3 using standard dental X-ray film is an accurate, simple, practical, and economical method of skeletal maturity assessment.

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