The developmental stages of the middle phalanx of the third finger (MP3): a sole indicator in assessing the skeletal maturity?

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Assessment of skeletal maturity is an integral part of interceptive diagnosis and treatment planning. The present day methods of skeletal maturity assessment like the hand-wrist radiographs or cervical vertebrae radiographs are expensive, require elaborate equipment and accounts for high radiation exposure, especially for growing children. The present study was thus undertaken to provide a simple and practical method of skeletal maturity assessment using the developmental stages of the middle phalanx of the third finger (MP3) as seen on an IOPA film taken using a standard dental x-ray machine. The results of the study showed that this simple method was highly reliable and could be used as an alternative method to assess the skeletal maturity of growing children.
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INTRODUCTION

The role of interceptive orthodontics in recognizing and eliminating potential irregularities and malpositions in the developing dentofacial complex is well documented. The scope ranges from interception of dental anomalies like crossbite, abnormal habits, space maintenance etc. to interception of developing skeletal malocclusion. Among the different treatment modalities for skeletal malocclusion, growth modification is the interceptive procedure undertaken in a growing child.[1]

For the growth modification to be successful, it is absolutely essential that it should be initiated at the right time.[2,3] Since chronological age is not a reliable indicator in assessing the skeletal maturity, other indicators like dental age, skeletal age, sexual maturity, body height and weight can be used for the purpose.[4,5] Among them the clinically relevant and reliable method is the assessment of skeletal maturity.[6-9]

Hand wrist maturity assessment has been used as a reliable method of assessing the skeletal maturity. Lamparski in 1972 concluded that even cervical vertebrae as seen on lateral cephalogram could be used for this purpose.[10] But in a pediatric patient, the use of thyroid collar while taking the radiograph, tends to mask the cervical vertebrae. Hence it was necessary to use additional hand-wrist radiographs along with lateral cephalogram, which had the disadvantages of being expensive, causing high radiation exposure and requiring elaborate equipment.

Goto *et al*.[11] have used the ossification of the distal phalanx of the first digit as an indicator of the skeletal maturity and determination of late mandibular growth of the patient and of the potential for further growth. Previous studies by Goto have shown that fusion of the epiphysis and the diaphysis of the distal phalanx of the first digit occurs from 1 to 3 years after the pubertal growth maximum in Japanese women. This method can be helpful in determining residual mandibular growth potential in Japanese female patients with Class III malocclusions and mild skeletal discrepancies.

Hagg and Taranger[12] noted that the stages of ossification of the middle phalanx of the third finger (MP3) follow the pubertal growth spurt. They described five stages of development of MP3 region namely MP3F, MP3FG, MP3G, MP3H, and MP3I.

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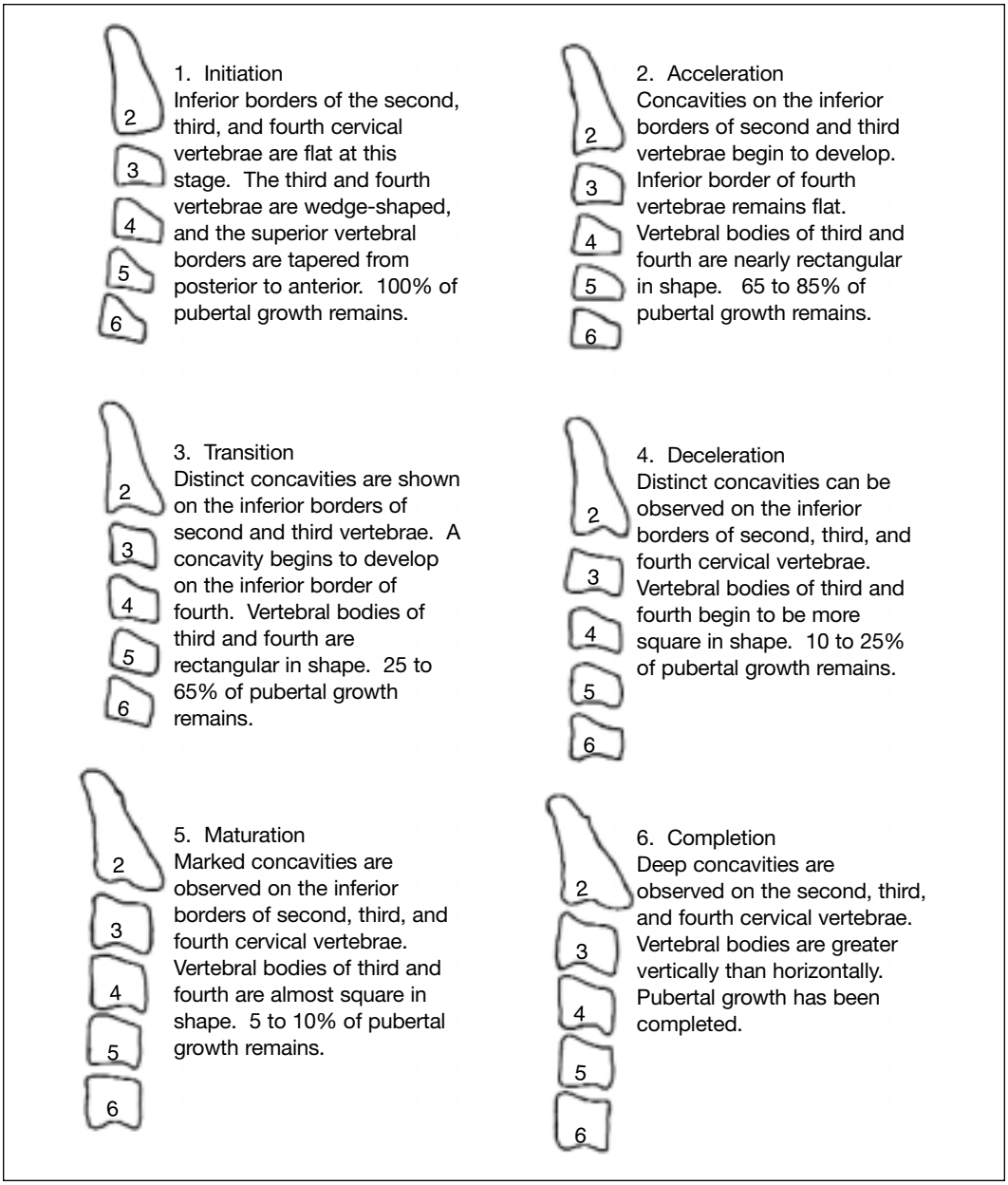

Figure 1. Maturation stages of cervical vertebrae as described by Lamparski[10] and modified by Hassel and Farman[14].

Abdel-Kader[13] in his clinical study used these MP3 stages as seen on IOPA films, for assessing skeletal maturity. This method also fulfills the principle of ALARA, which states that the patient should be subjected to only that amount of radiation that is absolutely needed for the diagnostic purpose.[13]

Abdel-Kader[14] evaluated the reliability of using a recent advance in clinical radiographic technique, digital dental radiography, in recording two growth indicators: the adductor sesamoid and MP3 stages. With an exposure time five times less than that used in the conventional approach, this method shows greatest flexibility in providing a high quality digitized radiographic images of the two growth indicators under investigation.

However, no study could be found in the literature, which assessed the reliability of this method in a standardized manner comparing it with a known standard method or assessing the inter- or intra-examiner error associated with this method.

Hence the aim of the present study was to assess the reliability of the proposed method in a standardized manner, comparing it with a known standard method like CVMA (Cervical vertebrae maturity assessment),[10,15] assessing the inter and intra examiner error and categorizing the MP3 stages into clinically relevant categories like pre peak, peak and post peak stages respectively.

Figure 2. CVMI 1

Figure 3. CVMI 2

Figure 4. CVMI 3

Figure 5. CVMI 4

MATERIALS AND METHODS

Sixty-seven (67) patients, (35 boys, 10 to 18 years and 32 girls, 8 to 16 years), who required skeletal maturity assessment, from the Department of Pedodontics and Preventive Children Dentistry, A.B. Shetty Memorial Institute of Dental Sciences, Mangalore, were selected for the study. Two radiographs namely lateral cephalogram and MP3 region radiograph using an IOPA film were used for the study. Written consent was obtained from the parents of the children prior to radiographic exposure.

Lateral cephalograms were taken using extra-oral radiograph machine (Planmeca Proline PM 2002cc, Finland) and the radiographic film (Kodak X-omat™ - China) of size, 8x10 inches. Exposure parameters were 72 Kvp, 10 mA and 1.2 sec. Source to mid sagittal plane distance was kept at 60 inches.

The method proposed by Lamparski[10] and modified by Hassel and Farman[14] was used for the assessment of cervical vertebrae (Figures 1 to 7). CVMI stages were further categorized into pre-peak, peak and post-peak stages according to method proposed by Kucukkeles *et al*.[16]

Figure 6. CVMI 5

Figure 7. CVMI 6

Figure 8. Technique of taking MP3 radiograph

Figure 9. Technique of taking MP3 radiograph

MP3 region radiograph was taken using the standard dental radiograph machine, (Villa – Sistemi Medicali, Explore, Italy) with exposure parameters 70Kvp, 8mA and 0.4sec and a No 2 size IOPA film (32x41 millimeter, Kodak E-speed).

The patients were instructed to place the left hand on a flat table. Third finger was kept straight with long axis of IOPA film in contact with the MP3 region. The cone of the dental radiograph machine was positioned in light contact with the middle phalanx of the third finger perpendicular to the IOPA film[13] (Figures 8, 9). Stages proposed by Hagg and Taranger[12] were used for the assessment of MP3 developmental stages (Figures 10 to 15). Only radiographs of the high clarity and good contrast were used for the study. All the radiographs were traced on a matte acetate paper of 0.003-inch thickness with 3H pencil.

To assess the inter- and intra-examiner variability, radiographs of 10 cases (5 boys and 5 girls) were examined by 3 observers A, B and C initially and reevaluated

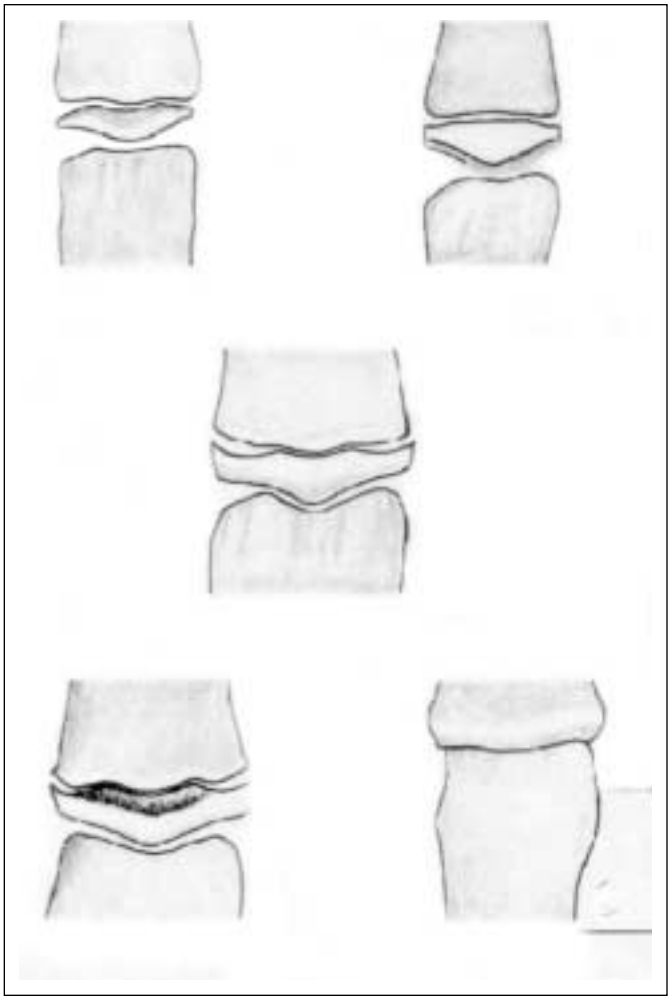

Figure 10. The developmental stages of the midddle phalnx of the third finger.

Figure 11. MP3F

Figure 12. MP3FG

Figure 13. MP3G

Figure 14. MP3H

Figure 15. MP3I

Table 1. Inter examiner error according to Kruskul-Wallis test

	CVMI stages	MP3 stages
H	1.325	0.142
P	0.516 *	0.932 *

* not significant

Table 2. Intra examiner error according to Wilcoxon's signed rank sum test

EXAMINER		CVMI	MP3
A	Z	-0.312	-0.46
	P	0.755*	0.963*
B	Z	-0.159	-0.182
	P	0.874*	0.855*
C	Z	-0.87	-0.445
	P	0.931*	0.657*

* not significant

3 weeks later. The results were statistically analyzed and found not to be significant (Tables 1 and 2). Least variability was found with the observations of examiner B. So the whole study was conducted by him.

Fig.1 Maturation stages of cervical vertebrae as described by Lamparski[10] and modified by Hassel and Farman[14]

RESULTS

Table 3 gives the correlation between MP3 stages and CVMI stages. The correlation was statistically analyzed using Chi-Square test with Yates correction for continuity and was found to be of very high significance.

Table 4 gives the distribution of MP3 stages into pre-peak, peak, and post-peak stages. The correlation was statistically analyzed using Chi square test, which was found to be of very high significance. Further, it

Table 3. Correlation between MP3 and CVMI stages.

	CVMI1	CVMI2	CVMI3	CVMI4	CVMI5	CVMI6	TOTAL
MP3F	4 18.2%	17 77.3%	1 4.5%	-	-	-	22 100%
MP3FG	-	5 62.5%	1 12.5%	-	2 25.0%	-	8 100%
MP3G	-	-	6 60.0%	3 30.0%	1 10.0%	-	10 100%
MP3H	-	1 14.3%	1 14.3%	2 28.6%	3 42.9%	-	7 100%
MP3I	-	-	-	-	4 57.1%	3 42.9%	7 100%
TOTAL	4 7.4%	23 42.6%	9 16.7%	5 9.3%	10 18.5%	3 5.6%	54 100%

Table 4. Distribution of MP3 stages into pre-peak, peak, and post-peak stages.

	MP3F	MP3FG	MP3G	MP3H	MP3I	TOTAL
Pre peak (CVMI1, 2)	21 77.8%	5 18.5%	-	1 3.7%	-	27 100.0%
Peak (CVMI3, 4)	1 7.1%	1 7.1%	9 64.3%	3 21.4%	-	14 100.0%
Post peak (CVMI5, 6)		2 15.4%	1 7.7%	3 21.1%	7 53.8%	13 100.0%
TOTAL	22 40.7%	8 14.8%	10 18.5%	7 13.0%	7 13.0%	54 100.0%

was observed that pre-peak was represented by MP3F and MP3FG in 96.3% of the samples, peak by MP3G in 64.3% of the samples and post peak by MP3H and MP3I in 74.9% of the samples collectively.

Table 5 gives correlation between MP3 stages and chronological age. The statistical analysis was done using ANOVA test. Correlation in both males and females were found to be of very high significance. The beginning of pre-peak in boys was at 12.18±1.25 years and in girls at 10.36±0.92 years. The active growth phase was essentially completed in boys at 17 years, and in girls at 14.60 ±0.55 years respectively.

Table5. Correlation between MP3 stages and chronological age

	SEX	
	MALE Mean	FEMALE Mean
MP3F	12.18±1.25	10.36±0.92
MP3FG	13.33±0.82	11.00±1.41
MP3G	13.50±0.71	12.13±0.35
MP3H	14.00±0.00	13.33±0.58
MP3I	17.00±0.00	14.60±0.55

DISCUSSION

ALARA[14] forms the important principle of diagnostic radiology, which states that the diagnostic radiation exposure for any patient has to be kept at a minimum, that is as low as reasonably achievable.

In 1972, Lamparski[10] proposed the use of cervical vertebrae as seen on lateral cephalogram for the assessment of skeletal maturity, which could avoid taking the hand-wrist radiograph.

In a pediatric patient, use of thyroid collar while taking the lateral cephalogram masks the cervical vertebrae. Hence in 1996, Kader[13] proposed the use of MP3 developmental stages as seen on IOPA film for assessing the skeletal maturity. In our present study, we found that the reliability of this method in comparison with a standard method like CVMA was of very high statistical significance.

Kucukkeles *et al.*[16] categorized CVMI stages into pre-peak represented by CVMI 1 and 2, peak by CVMI

3 and 4 and post-peak by CVMI 5 and 6 respectively. When MP3 stages were further classified into these stages, we found that, 96.3% of the samples under MP3F and MP3FG came under pre peak, 64.3% of the samples under MP3G came under peak stage and 74.9% of samples under MP3H and MP3I came under post-peak stages respectively. Thus, we can further categorize MP3 stages into pre- peak, peak and post-peak growth periods.

The pre-peak period coincides with MP3 F and MP3 FG and it is the ideal time to start a growth modification treatment.

The peak period of growth is represented by MP3 G stage. The prognosis may not be favorable if treatment is started at this stage.

At post-peak stage represented by MP3 H and MP3 I, the initiation of growth modification is contraindicated.

Another interesting observation was noted on comparing the corresponding chronological age in males and females according to MP3 stages. The initiation of pre-peak stage of growth was achieved at 12.18±1.25 years in boys and 10.36±0.92 years in girls, peak stage that is MP3G, at 13.50± 0.71 for boys and 12.13±0.35 for girls respectively.

The active growth phase was found essentially complete at 17 years for boys and 14.60±0.55 years for girls. A similar result was found by Fishman[7] when he compared SMI (Skeletal maturity indicator) with chronological age during the initiation and peak of pubertal growth spurt. However, the completion of the active growth phase was at 16.07±1.25 years in girls, which was 1.5years delayed than the results of the present study. Small sample size of girls at post peak stage in the present study could be the reason for this variation.

It was also observed during the study that the method of taking the MP3 radiographs was simple and accepted by the patient. The equipment required were also less expensive and simple as a standard dental radiograph instrument and an IOPA film, which is usually available in all private clinics and hospitals.

Thus, the method of skeletal maturity assessment using MP3 radiographs was found to be simple, highly reliable and less expensive and could be conveniently used as a simple diagnostic tool by all dental practitioners for an effective treatment planning.

CONCLUSIONS

1. The developmental stages of the middle phalanx of the third finger (MP3) could be used as a sole indicator in assessing the skeletal maturity.
2. The method proposed was highly reliable and its correlation with the known standard method like CVMA was found to be of high statistical significance.
3. The MP3 stages could be further classified into pre-peak (MP3 F, MP3 FG), peak (MP3 G) and post-peak (MP3 H, MP3 I) stages of pubertal growth spurt respectively.
4. This simple and reliable method could be used as an alternative to the hand-wrist and cervical vertebrae radiographs in assessing the skeletal maturity.

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