

# International Journal of Dental Science and Innovative Research (IJDSIR)

# IJDSIR : Dental Publication Service

Available Online at:www.ijdsir.com

Volume - 7, Issue - 4, July - 2024, Page No. : 52 - 59

A Longitudinal Study on the Time Lapse Assessment Across Stages of the Modified MP3 Skeletal Maturation Staging System in Indian Boys and Girls

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**Citation of this Article**: Veena R, Rajkumar S Alle, Raghavendra Shanbhog, "A Longitudinal Study on the Time Lapse Assessment Across Stages of the Modified MP3 Skeletal Maturation Staging System in Indian Boys and Girls", IJDSIR-July–2024, Volume –7, Issue - 4, P. No. 52–59.

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Type of Publication: Original Research Article

**Conflicts of Interest:** Nil

## Abstract

**Introduction**: This longitudinal study aimed to investigate the time intervals between MP3 skeletal stages, providing insights into the tempo of the staging system.

**Methodology:** X-rays of the left hand middle finger were taken every 6 months for 3 years from 26 boys and 26 girls. Using a modified MP3 system, stages were evaluated. Descriptive and inferential statistics were applied to the data.

**Results:** The results showed that the mean time for stage G ranged from 0.5 to 1.5 years, with an overall mean of  $0.83\pm0.360$  years. Females averaged  $0.87\pm0.368$  years, while males averaged  $0.77\pm0.352$  years for stage G.

**Conclusion**: Overall, each transition phase lasted from 6 months to 1.5 years in both genders, except for the FG stage in boys. Some individuals exhibited rapid transitions, less than 6 months, indicating accelerated growth rates.

**Keywords:** Modified MP3 Skeletal Maturation, Longitudinal Cohort Study, Time Interval Across Stages **Introduction** 

Growth spurts have distinct phases that are crucial for development, and the timing of these phases varies between individuals. Recognizing these phases is essential for effective treatment in fields like orthodontics. Growth rates peak during these phases, with females experiencing shorter spurts than males, highlighting the complexity of human growth.

Biological indicators, such as skeletal maturity markers, help determine the timing of adolescent growth. Handwrist radiographs, cervical vertebrae changes, and MP3 epiphyseal changes are key in orthodontic literature.

The MP3 indicator is gaining prominence due to its simplicity, reliability, and low radiation exposure. Hagg and Taranger's classification, modified by Kansal and Rajagopal, defines stages based on epiphyseal changes, reflecting advancements in skeletal maturity assessment. Each MP3 stage corresponds to a specific bone age, but the intervals between stages vary, affecting accuracy. This variability acknowledges individual progression rates, allowing for a nuanced assessment of growth and development. However, the time intervals between stages are not well documented in the literature. This longitudinal study aims to report the MP3 stages and the time lapses between them to understand the timing and tempo of this staging system using the modified MP3 staging system by Kansal and Rajagopal.

### Methodology

This study, part of a longitudinal cohort observational study, received approval from the Institutional Ethical Committee (Protocol no. 59/2019). Written informed consent was obtained from participants, ensuring they understood the study's purpose, design, and potential benefits.

The sample size was calculated with 90% power and a permissible error of 0.10, resulting in 20 subjects per group. To account for a 20% dropout rate, 6 samples per group were added, totaling 26 samples per group. The longitudinal estimation of MP3 staging was conducted every six months over three years.

## **Sampling Procedure**

A convenience sampling method was used to select 52 eligible children from government schools. Each child was assigned a unique 3-digit subject ID number, with the first digit indicating the school and the next two digits representing the individual study number.

### **Inclusion Criteria**

- Children willing to participate with parental consent
- Girls aged 10-11 years who have not reached menarche and boys aged 12-13 years

### **Exclusion Criteria**

- Children with systemic or metabolic disorders, or left hand injuries
- Girls who have reached menarche

### **Obtaining Radiographs**

Each child's left hand was placed on a flat table with the middle finger centered on a dental X-ray film (31 mm x 41 mm), parallel to the film's long axis. Dental X-ray equipment (70 kVp and 8 mA) was positioned perpendicular to the film, with minor contact with the middle phalanx, and an exposure time of 0.4 seconds. Radiographs of each child's left hand middle finger were taken every six months for three years, totaling 300 radiographs. These were processed uniformly and numbered for identification. Radiographic interpretation followed a skeletal and dental maturation assessment system, specifically a modified MP3 skeletal maturation system (Kansal and Rajagopal), categorizing MP3 phases.

# **Statistical Analysis**

Two expert investigators assessed MP3 stages twice within 15 days for all samples, with intra and inter observer reliability at 99% and 94% respectively. Data collected underwent descriptive and inferential statistical analysis using the Statistical Package for the Social Sciences (SPSS).

### Results

Of the 52 children initially involved (26 boys and 26 girls), 7 boys were lost to follow-up, resulting in a final sample of 26 girls and 19 boys.

At baseline, 57.9% of boys were in the F stage, while 46.2% of girls were in the G stage (Table 1). After the first 6 months, 31.6% of boys remained in the FG stage, with 26.3% progressing from F to FG. For girls, 38.5% remained in the G stage, while 23.1% progressed from FG to G. At the end of the second 6 months, 30.8% of boys remained in the G stage, with 34.6% progressing from G to H. Meanwhile, 26.7% of girls remained in the G stage, with 22.2% progressing from FG to G. At the end of the third 6 months, 7.7% of boys remained in the H stage, with 46.2% progressing from G to H. Additionally, 8.9% of girls remained in the G and FG stages, with 37.8% progressing from G to H. At the end of the fourth 6 months, 11.5% of boys remained in the H and HI stages, with 34.6% progressing from H to HI. Similarly, 13.3% of girls remained in the H stage, with 42.1% progressing from G to H. By the fifth 6-month interval, 34.6% of boys remained in the I stage, with 42.3% progressing from H to I. Conversely, 20% of girls remained in the I stage, with 26.7% progressing from HI to I (Table 2).

The mean duration for each stage varied between boys and girls. The mean duration of the F stage was  $0.71\pm0.257$  years for boys and 0.5 years for girls. Similarly, the FG stage lasted  $1.15\pm0.746$  years for boys and  $0.54\pm0.144$  years for girls (Table 3).

In terms of skipped stages, some participants showed accelerated growth, skipping stages within less than 6 months, as indicated by observations every 6 months. For instance, at the first 6 months, 7.7% of girls and 10.5% of boys seemed to skip a stage (Table 4).

### Discussion

Biological age, rather than chronological age, is essential for evaluating pubertal growth due to the significant variations in growth timing among individuals. Bone maturation studies, particularly those utilizing the MP3 staging system, provide a reliable means to assess biological age and physiological maturity, offering an accurate representation of an individual's growth status. Understanding maturation stages is crucial for orthodontic treatments, as it significantly influences diagnosis, planning, and outcomes. Aligning treatment strategies with a patient's biological age and growth stage enables orthodontists to make informed decisions, potentially improving treatment effectiveness and customization for optimal results.

Recognizing the timing of the pubertal growth spurt is particularly important in early orthodontics, as it marks a period of peak somatic growth that profoundly impacts skeletal development and overall growth. Each growth spurt follows distinct stages: onset, acceleration, peak, deceleration, and end. This growth spurt typically lasts around 3 to 4 years in females and 4 to 5 years in males, beginning earlier in girls. The accelerating growth phase lasts approximately 2 years, during which the growth rate significantly increases. Following the peak of the growth spurt, growth gradually slows down, and active growth typically ceases about 3 to 4 years later, indicating the completion of significant skeletal development. Understanding these timelines and gender differences is vital in early orthodontics for proper timing and planning of interventions to maximize the benefits of growth spurts for orthodontic treatment.

Assessing MP3 maturation through X-rays is valuable in orthodontic treatment planning. It helps determine the stage of the pubertal growth spurt, whether a patient has entered, is experiencing, or has completed it. Visualizing MP3 stages in X-rays provides insights into skeletal maturation and growth potential. Analyzing these stages enables orthodontists to make informed decisions about the timing and nature of orthodontic interventions.

Integrating MP3 maturation stage assessment through Xrays into treatment planning allows orthodontists to align strategies with the patient's growth stage, optimizing intervention effectiveness. Anticipation is crucial for an effective treatment strategy, especially in addressing dento-facial skeletal discrepancies. Understanding the duration of each growth stage is essential. For instance, in our study, the FG stage, representing the acceleration phase of the growth spurt, lasted 6 months to one year in girls and 6 months to 3 years in boys. This information provides guidance on when to initiate and how long to continue therapy for dento-facial discrepancies in girls and boys. Stage G, representing the maximum point of the growth spurt, is suggested as the ideal stage to start treatment for skeletal class II patients or at the end of the FG stage.

Understanding the duration of these stages helps clinicians determine when and for how long therapy should be administered and when to terminate it. Completing treatment until the stage ends fully helps prevent relapse. Knowledge about stage durations also guides clinicians on when further X-rays may be necessary.

Conducting a longitudinal study allows for a more clinically oriented approach rather than generalizing findings. Pubertal development and biological maturation are influenced by genetic and environmental factors, leading to variations. Therefore, some samples in our study appeared to skip stages due to these factors. The study's observation interval of every 6 months suggests a faster growth rate, with stages completed in less than 6 months observed as skipped stages. The time between telarche and menarche may be shorter in girls who start puberty late. Conducting a longitudinal study with 3-month intervals would enhance precision. Knowing the time lapses between stages would aid in correlating other parameters with MP3 more accurately. Having a thorough understanding of each stage's duration helps avoid missing the peak growth phase and prevents starting treatment prematurely.

## Conclusion

Transition phases lasted from a minimum of 6 months to a maximum of one and a half years for both boys and girls on average. Girls typically transitioned from the FG to G stage in 6 months to one year, while boys took the same time frame, with some taking up to 3 years, indicating later peak attainment in boys. Treatment initiation can occur in the FG stage for girls, while for boys, it may be delayed until the start of the G stage. The G stage lasted 1 to 1.5 years in both girls and boys, longer than other stages. The journey from the F stage to the I stage varies among individuals. Skipped stages suggest numerous factors influencing growth velocity.

# Limitation

Seven boys were lost to follow-up. Their retention would have made the study results more robust.

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# **Legend Tables**

Table 1: Distribution of study participants in various stages at baseline

Stages	Gi	rls	Boys			
	Ν	%	Ν	%		
F	5	19.2	11	57.9		
FG	8	30.8	8	42.1		
G	12	46.2	0	0		
Н	1	3.8	0	0		
Total	26	100.0	19	100.0		

Table 2: Distribution of study participants in various stages at the end of 1<sup>st</sup> to 5<sup>th</sup> 6 months' time intervals

Time	ime End of 1 <sup>st</sup> 6 months			5	End of 2 <sup>nd</sup> 6 months			End of $3^{rd}$ 6 months				End of $4^{th}$ 6 months				End of $5^{th}$ 6 months					
Stages	Girls		В	Boys		Girls		Boys		Girls		Boys		Girls		Boys		Girls		Boys	
	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%	
	No Change			No Change				No Change			No Change			No Change							
F	0	0	4	21.1	0	0	1	5.3	-	-	-	-	-	-	-	-	-	-	-	-	
FG	1	3.8	6	31.6	0	0	5	26.3	0	0	4	21.1	0	0	4	21.1	0	0	1	5.3	
G	10	38.5	0	0	8	30.8	4	21.1	0	0	4	21.1	0	0	1	5.3	0	0	1	5.3	
Н	1	3.8	0	0	4	15.4	0	0	2	7.7	0	0	3	11.5	3	15.8	0	0	6	31.6	
HI	-	-	-	-	-	-	-	-	-	-	-	-	3	11.5	0	0	1	3.8	1	5.3	
Ι	-	-	-	-	-	-	-	-	-	-	-	-	2	7.7	0	0	9	34.6	0	0	
	Progression			Progression				Progression			Progression			Progression							
F to FG	4	15.4	5	26.3	0	0	4	21.1	0	0	1	5.3	-	-	-	-	-	-	-	-	
F to G	1	3.8	2	10.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
FG to F	0	0	1	5.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
FG to G	6	23.1	1	5.3	5	19.2	5	26.3	0	0	5	26.3	0	0	1	5.3	0	0	3	15.8	
FG to H	1	3.8	0	0		-		-	-	-	-	-	-	-	-	-	-	-	-	-	
G to H	2	7.7	0	0	9	34.6	0	0	12	46.2	5	26.3	0	0	8	42.1	0	0	1	5.3	
G to HI	-	-	-	-	-	-	-	-	1	3.8	0	0	-	-	-	-	-	-	-	-	
H to HI	-	-	-	-	-	-	-	-	9	34.6	0	0	9	34.6	2	10.5	1	3.8	4	21.1	
H to I	-	-	-	-	-	-	-	-	2	7.7	0	0	2	7.7	0	0	2	7.7	1	5.3	
HI to I	-	-	-	-		-	-	-		-	-	-	7	26.9	0	0	13	50.0	1	5.3	
Total	26	100	19	100	26	100	19	100	26	100	19	100	26	100	19	100	26	100	19	100	

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# Table 3: Mean time taken (years) in each stage

Girls Stages Boys Stage F Ν 5 12  $0.50 \pm 0.000$ Mean± SD 0.71±0.257 0.50 Median 0.50 Min; Max 0.5; 0.5 0.5; 1.0 Stage FG 12 16 Ν Mean± SD  $0.54 \pm 0.144$ 1.15±0.746 Median 0.50 1.00 Min; Max 0.5; 1.0 0.5; 3.0 Stage G Ν 24 18 Mean± SD  $0.87 {\pm} 0.368$  $0.77 \pm 0.352$ Median 1.00 0.50 Min; Max 0.5; 1.5 0.5; 1.5 Stage H Ν 25 14 Mean± SD  $0.70 \pm 0.288$  $0.82 \pm 0.372$ 0.50 0.75 Median Min; Max 0.5; 1.5 0.5; 1.5 Stage HI Ν 21 6 Mean± SD  $0.62 \pm 0.218$  $0.58 \pm 0.204$ Median 0.50 0.50 Min; Max 0.5; 1.0 0.5; 1.0 Stage I Ν 24 1 Mean± SD 0.71±0.326  $0.50 \pm 0.00$ Median 0.50 0.50 0.5; 0.5 Min; Max 0.5; 1.5

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# Table 4: Skipped stages

Girls								
Stage Progression	1 <sup>st</sup> 6 months	2 <sup>nd</sup> 6 months	3 <sup>rd</sup> 6 months	4 <sup>th</sup> 6 months	5 <sup>th</sup> 6 months			
Stage F to G	1 (3.8)	-	-	-	-			
Stage FG to H	1 (3.8)	-	-	-	-			
Stage G to HI	-	-	1 (3.8)	-	-			
Stage H to I	-	-	2 (7.7)	2 (7.7)	1 (7.7)			
		Boys						
Stage Progression	1 <sup>st</sup> 6 months	2 <sup>nd</sup> 6 months	3 <sup>rd</sup> 6 months	4 <sup>th</sup> 6 months	5 <sup>th</sup> 6 months			
Stage F to G	2 (10.5)	-	-	-	-			
Stage H to I	-	-	-	-	10 (5.3)			

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