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SKELETAL AGE ASSESSMENT AND LATERAL COMPARISON USING MP3 AND HAND WRIST RADIOGRAPH

Sandhya Shyam Lohakare

Professor and HOD, Department of Orthodontics, Aditya Dental college, Maharashtra University of Health Sciences (MUHS), Nashik, Maharashtra, India

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ABSTRACT

MP3 stages were excellently correlated to Fishman's skeletal maturity indicators of hand wrist area. Developmental stages of middle phalanx of third finger (MP3) can be considered reliable for the assessment of the pubertal status with the methodology suggested by Hagg and Taranger and modified b y leito. The pre peak of puberty denoted by stage E ¾ and F are comparable to SMI 1 and 3, peak of puberty denoted by stage FG, G, H are comparable to SMI 4 and 7, post, peak of puberty denoted by stage 1 is comparable to SMI 11 which marks the end of pubertal growth spurt.

A significant correlation was found between ossification stages of SMI and MP3 on right and left hand wrist area indicates that the ossification stages of right and left hand are symmetrical. Thus either side of hand can be used for skeletal age assessment.

Chronological age was not significantly correlated to MP3 as well as SMI and there is wide variation in maturity level of each group, hence not a good indicator for maturational assess.

KEYWORDS: *Skeletal Age, Hand Wrist Radiograph, Middle Phalanx3*

INTRODUCTION

Growth and development should be recognized as one of the most important factor in orthodontics. Orthodontics include the study of growth and development of the detofacial complex particularly, and the growth and development of the body generally.

The pubertal growth spurt is considered to be an advantageous period for certain types of orthodontic treatment and should be taken into account in connection with orthodontic treatment planning. The early perception and interception of dentofacial deformities is dependent upon and accurate interpretation of the inherent facioskeletal pattern and the overall growth and development hereditary, functional, environmental, sexual, nutritional and metabolic factors influence normal growth and development greatly. The proportional effects of each of the factor are not easily determined, but nevertheless,

In Class II retrognathic mandible case or in Class III retrognathic maxilla or prognathic mandible case, growth modification is required to counteract the deformity and to guide the pubertal growth in correct direction. For the growth modification to be successful, it is absolutely essential that it should be initiate at the right time. The correct time of pubertal growth spurts can be identified by utilizing physical characteristics such as weight, height, chronological age, skeletal maturation and dental development in order to evaluate the growth and maturational status of patients.

Before of the wide individual variation in the timing of the pubertal growth spurt, chronolohic age cannot be used in the evaluation of pubertal growth. Many studies have shown a strong correlation between the peak of facial growth and peak height velocity. Longitudinal records of height can therefore be used for evaluation of the facial growth rate during puberty. In the clinical context, longitudinal growth records of height are seldom available. Even with adequate records, it may be difficult to locate the pubertal growth spurt before it is passed, since the increase in growth rate I often too small, especially in many girls, to be clinically discernible. Most of the time the clinician must base his judgment on a single examination and, therefore, determine the status of the individual by cross-sectional evaluation alone. Stature is not an indicator of maturity. Thus, additional information is necessary to estimate the maturation level of the individual. Such information can be obtained from the dental, skeletal, and pubertal development. By comparing with standards for age and sex, it is possible to assess whether the development of the individual is average, accelerated, or retarded. In orthodontics it is more relevant to evaluate the individual's maturation in relation to his or her own pubertal growth spurt. This presupposes knowledge of relationships in time between maturation indicators and pubertal growth events. Suitable maturation indicators for clinical orthodontics have been devised, and the associations between these indicators and the peak of growth have between reported.

Height and weight measurement are one of the powerful tools in growth assessment but become impractical in clinical orthodontics as it require longitudinal data which is seldom available and needs time and repeated observations. Thus the increase in growth velocity may only be recognized retrospectively, hence limiting the value of direct measurement in the recognition of onset of puberty.

Adolescence is the transitional period between the juvenile stage and adulthood, during which secondary sexual characteristic appear, the adolescent growth spurt takes place and profound physiologic changes occur. The stage of development of secondary sexual characteristics provides a physiologic calendar of adolescence that correlate with the individuals physical growth status. Growth prediction using appearance of secondary sexual characteristics require frequent physical examination and regular observational periods which are impractical in clinical orthodontic practices.

Among them the clinically relevant and reliable method is the assessment of skeletal maturity. The technique for assessing skeletal age consists of visual inspection of bones-their initial appearance and their subsequent ossification changes in shape and size. Various area of the skeleton have been used: the foot, the knee, the hand-wrist, and the cervical vertebrae.

Several methods have been developed for the assessment of the skeletal age. After Roentgen demonstrated his new radiographic discovery in 1895 Roland in 1896 introduced the idea of using the comparative size and shape of radiographic shadows of growing bones as indicators of rate of growth and maturity.

Fishman used skeletal maturity indicators (SMI) in hand wrist radiographs using four stages of bone maturation at six anatomic sites, which have been amongst the most commonly used methods to assess skeletal maturation.

Hassel and Farman utilized the cervical vertebrae and found them as reliable and valid as the hand wrist area for assessing skeletal age.

The ossificationm of the distal phalanx of the first digit have been used as an indicator of the skeletal maturity and for determination of late mandibular growth of the patient and of the potential for further growth. The method was helpful

in determining residual mandibular growth potential in Japanese female patients with Class III malocclusions and mild skeletal discrepancies.

Hagg and Tarranger introduced a method using the hand wrist radiograph to correlate certain maturity indicators to the pubertal spurt and noted that the stages of ossification of middle phalanx of third finger (MP3) of the hand follow the pubertal growth suurt from onset to the end. Leite et al later on stressed the use of first three fingers of the hand as a reliable maker and modified the five stages of ossification of MP3 by adding a new stage, $E^{3/4}$ where epiphysis reaches ¾ of the width of disphysis.

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

Watching a child grow has always been a source of interest to human beings. To each watcher, at some time, has come the question: “Is this child growing normally?” Gross defects, of course, are readily apparent, although their earliest onset may be far from obvious. It is the smaller deviations from normal growth patterns, however, that are by far the more usual and it is among thest that the problems of the orthodontist lie. It is a natural assumption that skeletal growth has an underlying symmetry and th skeletal development in one part of the body should bear some relationship to development in another part. We also know that this proportionality may be changed in some pathologic states, such as acromegaly, and even congenitally, as in anencephaly.

Bilateral asymmetry was observed in many studies. If bony changes occurring in both part of the body e.g. hands are not symmetrical even in healthy condition then examining radiograph of only one side would not provide a reliable estimate for skeletal maturation, so their symmetry should be evaluated.

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 ethod of skeletal maturity assessment usint the development stages of the middle phalanx of the third finger (MP3) as seen on an IOPA film taken using a standard dental x-ray Machine and correlating it with a known standard method like Fishman’s skeletal maturity indicators by using hand wrist radiograph and categorizing the MP3 stages into clinically relevant categories like prepeak, and post peak stages and Comparing the hand wrist radiograph of right and left hand to assess lateral differences between ossification events and stages of bone development by utilizing Fishman’s skeletal maturation indicators for hand wrist and Hagg U, Taranger J method for middle phalanx of third finger (MP3).

AIMS AND OBJECTIVES OF THE STUDY

Aims of the Study

To assess skeletal age using MP3 and hand wrist radiograph with lateral comparison and their correlation with chronological age.

Objectives of the Study

- To assess skeletal age using MP3 and hand wrist radiograph.
- To assess lateral difference between ossification events and stages of bone development in the hand and wrist by utilizing Fishman's method.
- To assess lateral differences between ossification events and stages of bone development in the middle phalanx of third finger according to Hagg and Taranger.
- To find correlation between MP3, hand wrist radiograph and chronological age.

MATERIALS & METHODS

The present study was conducted among OPD patients attending Department of Orthodontics andDentofacialOrthopaedic. A total sample of 250 radiographs were taken consisted of 125 male and female wit age group from 8 to 20 years. Written consent was obtained from the parents of the children prior to radiographic exposure.

Selection Criteria for the Study

- Age group selection from 7\8 to 20 years.
- The subject selected were physically and mentally healthy
- No histry of congenital and development disturbances due to syndrome or
- hormonal imbalance.
- No history of trauma or injury to face and hand wrist region.

  These subjects were divided into 13 groups.

Table 1

Group	Age	No of Study Subject	
		Male	Female
Group 1	8	7	7
Group 2	9	13	13
Group 3	10	24	25
Group 4	11	12	12
Group 5	12	21	25
Group 6	13	7	5
Group 7	14	11	7
Group 8	15	4	3
Group 9	16	--	--
Group 10	17	8	5
Group 11	18	3	6
Group 12	19	11	10
Group 13	20	6	4

Material

- Intra oral periapical radiograph for recording MP3 stage of right and left hand.
- Hand wrist radiograph of right and left hand.
- Birth certificates were obtained for confirming their chronological age.

For exposing intra oral radiograph

- Dental X ray machine with constant 70 kvp voltage peak 8 milli ampere 2mm total Al filtration round collimation.
- Electronic timer included in the circuit of X ray machine with time 0.3 seconds for MP3 respectively.
- Size (2) intra oral periapical Kodak E speed film.
- The patients were instructed to place the right hand firm followed by 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 ginger perpendicular to the IOPA film.

For exposing Hand wrist radiograph :

- Digital
- Commentional

For radiograph interpretation

- A well equipped light proof dark room.
- Radiographic view box.
- All intra oral periapical radiograph and Hand wrist radiograph selected for interpretation.

All radiographs were developed using conventional method. Any radiograph that showed motion dullness or had poor contrast was discarded. All the radiographs were carefully taken and developed by a single radiologist so that factor of error could be minimize.

METHODOLOGY

Exposure of IOPAR Firm for Recording MP3:

Intraoral periodical Kodak E speed films were used to record the MP3 stages. The subject were instructed to place their left hand with palm downward on a flat table. The middly finger was centered on 31x41 mm perpendicular to film.

Exposure of the Hand Wrist Radiograph:

Selected subject were made to wear lead apron and positioned carefully.

Interpretation of the Radiograph:

The Interpretation of the IOPA and respective Hand wrist radiographs was done using X ray radiograph view box.

Assessment of the skeletal maturation using MP3 as a indicator.

The MP3 radiographs were evaluated according to the five stages of assification described by Hagg and Taranger (1982) and later modified by adding E ¾ stage given by leite et al in (1987). Each subject was given a score from amongst E ¾, F, FG, G, H and I corresponding to the relation of epiphysis to metaphysic in the MP3 region as follows.

- Stage 1 (E3/4) The epiphyusis reaches ¾ of the width of the diaphysis.
- Stage 2 (MP3-F) epiphysis is as wide as metaphysic. In corresponds to the onset or start of the curve of pubertal growth spurt.
- State 3 (MP3-FG) epiphysis is as wide as metaphysic and there is a distinct medial and lateral border of the epiphysis forming a line of demarcation at right angle to the distal border. It Corresponds to the acceleration part of the curve of pubertal growth spurt.
- Stage 4 (MP3-G) the sides of epiphysis thicknen and cap its metaphysic forming a sharp edge distally at one or both the sides. It corresponds to the acceleration part of the curve of pubertal growth spurt.
- Stage 5 (MP3-H) fusion of epiphysis and metaphysic begins. It corresponds to deceleration part of the curve showing maximum point of pubertal growth spurt.
- Stage 6 (M3-I) fusion of epiphysis sna metaphysic is completed. It corresponds to end of pubertal growth spurt.

Assessment of skeletal maturation by using hand wrist radiograph

- Hand wrist radiograph were evaluated using fishman's skeletal maturity indicator.
- Skeletal maturity Indicator (SMI)
- Width of epiphysis as wide as diaphysis
- Third finger – proximal phalanx
- Third finger – middle phalanx.
- Fifth Finger – middle phalanx.

Ossification

- Adductor sesamoid of thumb

Capping of Epiphysis

- Third finger – distal phalanx.
- Third finger – middle finger.
- Fifth finger – middle finger.

Fusion of Epiphysis and Diaphysis

- Third finger – distal phalanx.
- Third finger – proximal phalanx.
- Third finger – middle phalanx

Radius

- Assessment of Bilateral symmetry:
- Bilateral symmetry was assessed by observing ossification stages of hand and wrist.

- Ossification stages of fishman's skeletal maturity index ad used for hand wrist.
- Ossification stages of hagg and Tarranger was used for middle phalanx of third finger.

Table 2: Score Allotted as per the Developmental Stages of MP3 and SMI for Male and Female of 8 Years

Sr. No.	Age	MP3-Stages	SMI-States	Male/ Female
1.	8	E ¾	1	M
2.	8	E ¾	1	M
3.	8	E ¾	1	M
4.	8	E ¾	1	M
5.	8	E ¾	1	M
6.	8	E ¾	1	M
7.	8	E ¾	1	M
8.	8	E ¾	1	F
9.	8	E ¾	1	F
10.	8	E ¾	1	F
11.	8	E ¾	1	F
12.	8	E ¾	1	F
13.	8	E ¾	1	F
14.	8	E ¾	1	F

RESULTS

Table 3: Distribution of Sample by Age and Sex

Groups	Age	No. of Study Subject	
		Male	Female
Group 1	8	7	7
Group 2	9	13	13
Group 3	10	24	25
Group 4	11	12	12
Group 5	12	21	25
Group 6	13	7	5
Group 7	14	11	7
Group 8	15	4	3
Group 9	16	--	--
Group 10	17	8	5
Group 11	18	3	6
Group 12	19	11	10
Group 13	20	6	

The Sample size selected for the study consisted of 250 subjects with distribution i.e. 125 males and 125 females. In each group the sample distribution between male and female was kept unequal to avoid selection bias.

Table 4: Dsicriptive Statistics for Age of Male and Female

Sex	Sample	Mean	S.d.	S.e.	Min	Max
Male	124	12.83	3.51	0.93	8.0	20.0
Female	126	12.44	3.48	0.91	8.0	20.0
Total	**300**	**12.63**	**3.495**	**0.92**	**8.0**	**20.0**

T = 0.861, p = 0.327(NS)

When the actual age of the sample was taken into consideration. Males were found to have mean age of 12.83 years, where as female were of 12.44 years. When independent sample 't' test was applied to there mean age a non significant difference was observed between mean age of boys and girla ('t' = 0.861; P = 0.327).

Table 5: Descriptive Statistics of Age of Both Sex for SMI

	Male			Female			Total		
SMI	No. of Subj.	Mean	S.d.	No.of Subj.	Mean	S.d.	No.of Subj.	Mean	S.d.
1	21	9.04	0.92	23	8.95	0.82	44	9.0	0.86
2	1	9.0	0.0	2	9.0	0.0	3	9.0	0.0
3	44	11.56	1.42	33	10.96	1.48	77	11.31	1.47
4	15	11.26	1.22	13	10.92	1.55	28	11.10	1.37
5	0	--	--	--	--	--	--	--	
6	2	12.0	0.0	6	11.66	0.81	8	11.75	0.7
7	9	12.88	1.36	15	12.33	0.97	24	12.54	1.14
8	0	--	--	--			--		
9	5	15.0	1.87	4	14.0	1.15	9	14.55	1.58
10	0	--	--	3	12.0	0.0	3	12.0	0.0
11	27	18.51	1.28	27	18.25	1.34	54	18.38	1.30

Table 6: Anova

Anova – SMI on Age (Males)					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1320.463	7	188.638	111.466	.000
Within Groups	196.311	116	1.692		
Total	**1516.774**	**123**			

Table 7: Anova – Age of SMI of Female

Anova – SMI on Age (Female)					
	Sum of Squares	Df	Mean Squares	F	Sig.
Between Groups	1332.410	8	166.551	106.658	.000
Within Groups	182.701	117	1.562		
Total	**1515.111**	**125**			

It is observe d that between SMI score a significant difference existed in the chronological age for both the sexes.

F value 111.466 of male and 106.658 of female is found to be significant at $P < 0.001$.

Table 8: Descriptive Statistics of SMI for Combined Male and Female

Smi	No. of Subj.	Male & Female (Age					95% Confidence Interval for Mean	
		Min	Max	Mean	S.d	S.e	Lower Bound	Upper Bound
1	44	8	11	9.0	0.86	0.13	8.73	9.26
2	3	8	9	9.0	0.0	0.0	9.0	9.0
3	82	9	14	11.31	1.47	0.16	10.97	11.64
4	28	9	14	11.10	1.37	0.25	10.57	11.63
5	--							
6	8	12	13	11.75	0.7	0.25	11.15	12.34
7	24	11	15	12.54	1.14	0.23	12.05	13.02
8	--							
9	9	13	17	14.55	1.58	0.52	13.33	15.77
10	3	12	13	12.0	0.0	0.0	12.0	12.0
11.	58	15	20	18.38	1.30	0.17	18.03	18.74
Total	**250**	**8**	**20.0**	**12.64**	**3.49**	**0.22**	**12.20**	**13.07**

Table 9: Anova – Age of SMI for Combined Male and Female

Anova SMI on Age (Overall)					
	Sum of Squares	**df**	**Mean Squares**	**F**	**Sig.**
Between Group	2640.888	8	331.236	203.792	.000
Within Groups	391.712	241	1.625		
Total	**3041.600**	**249**			

A significant association was observed between mean age of both males and female and SMI as it was seen that the mean age for both sexes increased with an increase in SMI grade. However there is no equality of mean age in all SMI grades (F-203, 792, P - < 0.001).

Table 10: Descriptive Statistics of Age in Both Sex of MP3

MP3	**Male**			**Female**			**Total**		
	No.of subj	**Mean**	**S.d**	**No.of Subj**	**Mean**	**S.d.**	**No.of Subj**	**Mean**	**S.d.**
F3/4	21	9.04*	0.92	25	8.95*	0.82	44	9.0	0.8
F	44	11.54*	1.45	38	10.85*	1.51	79	11.24	1.5
FG	16	11.18	1.22	11	11.0	1.59	28	11.10	1.3
G	11	12.72*	1.27	25	12.04*	0.976	36	12.25	1.1
H	5	15.0*	1.87	4	14.0*	1.15	9	14.55	1.5
I	27	18.51	1.28	27	18.25	1.34	54	18.38	1.3
Total	**124**	**12.83**	**3.51**	**126**	**12.44**	**3.48**	**250**	**12.64**	**3.4**

(* P < 0.04) (** P < 0.001)

Table 11: Anova MP3 on Age in Males

Anova (MP3 on Age in Males)					
	Sum of Squares	**df**	**Mean Squares**	**F**	**Sig.**
Between Group	1313.553	5	262.711	152.542	.000
Within Groups	203.222	118	1.722		
Total	**1516.774**	**123**			

Table 12: Anova MP3 on Age in Female

Anova (MP3 on Age in Females)					
	Sum of Squares	**df**	**Mean Squares**	**F**	**Sig.**
Between Group	1319.724	5	263.945	162.105	.000
Within Groups	195.387	120	1.628		
Total	**1515.111**	**125**			

It is observed from the present study that the mean age of both the sexes for MP3 is steadily increasing in relation to an increase in MP3 grades. F value 152.542 for male and 162.105 for female was observed at P < 0.001.

Mean age for initiation of skeletal maturation for male was 9.04 ±0.92 years and 8.95 ± 0.82 years for female. Mean age for completion of skeletal maturation for male was 18.51 ± 1.28 years and female was 18.25 ± 1.34 years. Female completed skeletal maturation earlier than males.

Difference in mean age between males and females when the MP3 stage is E3/4, F. G, H are found to be statistically significant at (P < 0.04) respectively, thus indicating the maturation development of female was earlier then tier male counterparts.

Table 13: Descriptive Statistics of Combined Male and Female for MP3

MP3	Age						95% Confidence Interview for Mean	
	No, of Subj	Min	Max	Mean	S.d	S.e.	Lower Bound	Upper Bound
E3/4	44	8	11	9.0	0.86	0.13	8.73	9.26
F	84	8	14	11.24	1.51	0.17	10/90	11.57
FG	27	9	14	11.10	1.37	0.25	10.57	11.63
G	36	10	15	12.25	1.10	0.18	11.87	12.62
H	9	13	17	14.55	1.58	0.52	13.33	15.77
I	55	15	20	18.38	1.30	0.17	18.03	18.74
Total	**250**	**8.0**	**20.0**	**12.64**	**3.49**	**0.22**	**12.20**	**13.07**

Table 14: Anova – MP3 on Age in Combined Male and Female

Anova (MP3 on Age in Overall)					
	Sum of Squares	df	Mean Squares	F	Sig.
Between Group	2626.685	5	525.337	308.937	.000
Within Groups	414.915	244	1.70		
Total	**3041.600**	**249**			

It is observed that the mean age for both male and female for MP3 steadily increased in relation to MP3 grades. However there is no equality in all the MP3 grades F- 308, 937, < 0.001).

Table 15: Bivariate Distribution of Age and SMI Grades in Males

Age	SMI											Total
	1	2	3	4	5	6	7	8	9	10	11	
8	7											7
9	7	1										8
10	6	13	6									25
11	1		11	1								13
12			9	7		2	6					24
13			4						1			5
14			7	1			1		2			11
15							2				1	3
16												
17									2		6	8
18											3	3
19											11	11
20											6	6
Total	**21**	**1**	**44**	**15**	**-**	**2**	**9**	**-**	**5**		**27**	**124**

(Chi-square = 2.755, p < 0.001**)(Spearman r =0.839, p < 0.001**)

This table shows that greater number of subjects shows less variation in percentage of growth completion in early and late adolescent as compared to mild adolescent as compared to mild adolescent.

The maximum variation was found in age of 10, 11 12 and 14 years indicating an increase in the growth velocity at this age. Whereas minimum variation was observed in age of 8.9, 13, 15, 17, 18, 19 and 20 years.Thus confirming the above statement. In addition, there is wide variation for SMI stages observed which suggests the chronological age is not a good indicator of maturity and hence it should not be relied upon completely.

A good correlation (r = 0.839) between the age of males and SMI grade is seen. Which is statistically highly significant (p < 0.001).

Table 16: Bivariate Distribution of Age and SMI Grades in Females

Age	SMI											Total
	1	2	3	4	5	6	7	8	9	10	11	
8	7											7
9	11	2	4	1								17
10	4		13	6		1						24
11	1		5	3			2					11
12			4	1		5	9			3		22
13			5				1		2			8
14				2			3					7
15									2		2	4
16												-
17											5	5
18											6	6
19											10	10
20											4	4
Total	**23**	**2**	**33**	**13**		**6**	**15**		**4**	**3**	**27**	**126**

(Chi-square = 3.08, p < 0.001**)(Spearman = 0.859, p < 0.001**)

The table shows that greater no of subjects shows less variation in percentage of growth completion in early and late adolescence as compared to mild adolescence.

The maximum variation was found in age group of 9, 10, 11, 12 and 13 indicating an increase in the growth velocity at these ages, whereas mediocre variation was observed in age of 8, 14-20 years.

Thus confirming the above statement. In addition, there is wide variation for SMI stages observed, which suggest that chronological age is not a good indicator for maturity.

Table 17: Bivariate Distribution of Age and MP3 in Males

Age	MP3						Total
	E3/4	F	FG	G	H	I	
8	7						7
9	7	1					8
10	6	12	7				25
11	1	11	1				13
12		9	7	8			24
13		4			1		5
14		7	1	1	2		3
15				2		1	3
16							-
17					2	6	8
18						3	3
19						11	11
20						6	6
Total	**21**	**44**	**16**	**11**	**5**	**27**	**124**

(Chi square = 2.55, p < 0.001**) (Spearman r = 0.001**)

The table shows that greater number of subject show less variation in percentage of growth completion in early and late adolescence as compared to mild adolescence.

The maximum variation was found in age of 10, 11, 12 and 14 minimum variation was found in age of 8, 9, 13, 17–20 years.

There I a good correlation (r = 0.827) between age of females and SMI grades which is statistically highly significant. Thus the results are very similar to age distribution of age and SMI grades in females.

Table 18: Bivariate Distribution of Age and MP3 Grades in Females

Age	MP3						Total
	E3/4	F	FG	G	H	I	
8	7						7
9	11	6	1				18
10	4	13	5	2			24
11	1	5	3	2			11
12		4	1	17			22
13		5		1	2		8
14		2	2	3			7
15					2	2	4
16							-
17						5	5
18						6	6
19						10	10
20						4	4
Total	**23**	**35**	**12**	**25**	**4**	**27**	**126**

(Chi square = 6.15, p < 0.001**) (Spearman r = 0.993, p < 0.001**)

All female subjects of age 8 years show E ¾ stage of MP3, 9 year female subjects show E ¾ and F stage maximum times. Subject from 10–14 year shows F, FG, G stages, From 17–20 year all subject show I stage.

Maximum variation was observed from 10 to 14 years. A good correlation (r = 0.993) was observed between age of female and MP3 grades which is increasingly significant (P < 0.001).

Association between SMI and stages of MP3

Table 19: Correlation between SMI and MP3 Stages in Combined Sample

SMI		MP3						Total
		E3/4	F	FG	G	H	I	
1	Frequency	44						44
	Percentage	100%	1					17.6%
2	Frequency		3					3
	Percentage		3.79%					1.2%
3	Frequency		76	1				77
	Percentage		96.2%	3.5%				30.82%
4	Frequency			27	1			28
	Percentage			96.4%	2.7%			11.2%
5	Frequency							0
	Percentage							
6	Frequency				8			8
	Percentage				22.2%			3.2%
7	Frequency				24			24
	Percentage				66.6%			9.6%
8	Frequency							0
	Percentage							
9	Frequency					9		9

Table 19 (contd..)

	Percentage					100%		3.6%
10	Frequency				3			3
	Percentage				8.33%			1.2%
11	Frequency						54	54
	Percentage						100%	21.6%
	Total	**44**	**79**	**28**	**36**	**9**	**54**	**250**
		17.6%	**31.6%**	**11.2%**	**14.4%**	**3.6%**	**21.6%**	**100%**

(Chi square Value = 122.3, p < 0.001**)

Graph 6: Distribution of Subject under different SMI stage by MP3.

A significant association was observed between middle phalanx of third finger (MP3) stages and stages of skeletal maturity indicators (SMI). The correlation was statistically analyzed using Chi square test and highly significant correlation (P < 0.001) was found. From the table it is clear that more frequencies was associated with lesser MP3 stages to lesser SMI STAGES. Again higher the MP3 stage, higher was the SMI stage. There was a significant association between MP3 and SMI stages, where a clear tyrend could be seen in the above table and graph.

Table 20: Distribution of the Sample by SMI Stage and MP3 Stages (Peaks)

Age	**MP3**				**Total**
		Pre-Peak	**Peak**	**Post Peak**	
1	Frequency	44	0	0	44
	Percentage	35.8%	0%	0%	17.6%
2	Frequency	3	0	0	3
	Percentage	2.4%	0%	0%	1.2%
3	Frequency	76	1	0	77
	Percentage	61.8%	1.4%	0%	30.8%
4	Frequency	0	28	0	28
	Percentage	0%	38.4%	0%	11.2%
5	Frequency	0	0	0	0
	Percentage	0%	0%	0%	0%
6	Frequency	0	8	0	8
	Percentage	0%	100%	0%	3.2%
7	Frequency	0	24	0	24
	Percentage	0%	32.9%	0%	9.6%
8	Frequency	0	0	0	0
	Percentage	0%	0%	0%	0%
9	Frequency	0	9	0	9
	Percentage	0%	12.3%	0%	3.6%
10	Frequency	0	3	0	3
	Percentage	0%	4.1%	0%	1.2%
11	Frequency	0	0	54	54
	Percentage	0%	0%	100%	100%
Total		**100%**	**100%**	**100%**	**250 (100%)**

Chi – square test = 7.812, p < 0.001** (HS)

The MP3 stages when further reduced to only 3 classes, namely pre-peak (E ¾, F), peak (FG, G, H), post peak (I) and subjected to association with SMI stages, a significant association was observed between them when statistically analyzed with Chi square test (P < 0.001). Most of the pre-peak frequencies (97.6 %) were with SMI 1 and 3, most of the

peak frequencies (71.3%) were with SMI 4 and 7 and most of the post-peak frequencies (54%) were with SMI 11. All these trends are graphically shown in graph.

Table 21: Distribution of Sample According to Age, SMI and Sex

Age	SMI		Sex		Total	Chi- Square Test	P Value
			Male	Female			
8	1	Frequency	7	7	14	C = 0.0	P = 1.00
		Percentage	50%	50%	5.6%		
9	1	Frequency	7	11	18	C = 16.42	P = 0.001**
		Percentage	38.8%	61.1%	7.2%		
	2	Frequency	2	1	3		
		Percentage	66.6%	33.3%	1.2%		
	3	Frequency	0	4	4		
		Percentage	0	100%	1.6%		
	4	Frequency	0	1	1		
		Percentage	0	100%	0.4%		
10	1	Frequency	6	4	10	C = 2.31	P = 0.092
		Percentage	60%	40%	4%		
	3	Frequency	14	13	27		
		Percentage	51%	48%	10.8%		
	4	Frequency	6	5	11		
		Percentage	54.5%	45.4%	4.4%		
	6	Frequency	0	1	1		
		Percentage	0	100%	0.4%		
11	1	Frequency	1	1	2	C = 14.72	P < 0.001 **
		Percentage	50%	50%	0.8%		
	3	Frequency	11	5	16		
		Percentage	68.7%	31.2%	6.4%		
	4	Frequency	1	3	4		
		Percentage	25%	75%	1.6%		
	7	Frequency	0	2	2		
		Percentage	0	100 %	0.8%		
12	3	Frequency	9	4	13	C = 34.81	P < 0.001**
		Percentage	69.2%	30.7%	5.2		
	4	Frequency	7	1	8		
		Percentage	87.5%	12.5%	3.2%		
	6	Frequency	2	5	7		
		Percentage	28.5%	71.4%	2.8%		
	7	Frequency	6	9	15		
		Percentage	40%	60%	6%		
	10	Frequency	0	3	3		
		Percentage	0	100%	1.2%		
13	3	Frequency	7	7	14	C=11.53	P = 0.021**
		Percentage	509%^	50%	5.6%		
	7	Frequency	0	1	1		
		Percentage	0	100%	0.4%		
	9	Frequency	1	2	3		
		Percentage	33.3%	66.3%	1.2%		
14	3	Frequency	2	9	11	C = 41.82	P = 0.003 **
		Percentage	18.1%	81.8%	4.4%		
	4	Frequency	1	2	3		
		Percentage	33.3%	66.6%	1.2%		

	Table 21 (Contd..)						
	7	Frequency	1	3	4		
		Percentage	25%	75%	1.6%		
	9	Frequency	2	0	2		
		Percentage	100%	0%	0.8%		
15	7	Frequency	2	0	2	C = 71.29	P <0.001 **
		Percentage	100%	0%	0.8%		
	9	Frequency	0	2	2		
		Percentage	0%	100%	0.8%		
	11	Frequency	1	4	5		
		Percentage	20%	80%	2%		
16	7	Frequency	7	5	13	C = 9.82	P = 0.045 *
		Percentage	53.8%	38.4%	5.2%		
17	11	Frequency	5	8	13	C =12.84	P = 0.017 *
		Percentage	38.4$	61.5 %	5.2%		
18	11	Frequency	3	6	9	C = 19.03	P = 0.001 *
		Percentage	33.3%	66.6%	3.6%		
19	11	Frequency	11	10	21	C = 1.271	P = 0.281
		Percentage	52.3%	47.6%	8.4%		
20	11	Frequency	6	4	10	C = 4.982	P =0.39*
		Percentage	60%	40%	4%		

p < 0.05* - significant p < 0.001** - highly significant

From this table it is evident that in all age group except 8 and 10 years, females were ahead of males in maturation scale as statistically analyzed by Chi square test. Analysis revealed that sample of age 13, 14, 16, 17, 18, 19, 20 years showed significant correlation and samples from age 9, 11, 12, 15 years were highly significant.

Table 22: Distribution of Sample According to MP3, Age, and Sex

Age	**MP3**		**Sex**		**Total**	**Chi- Square Test**	**P Value**
			Male	**Female**			
8	E3/4	Frequency	7	7	14	C = 0.0	P = 1.00
		Percentage	50%	50%	100%		
9	E3/4	Frequency	7	11	18	C = 13.81	P < 0.001**
		Percentage	38.9%	61.1%	69.2%		
	F	Frequency	1	6	7		
		Percentage	14.3%	85.7%	26.9%		
	FG	Frequency	0	1	1		
		Percentage	0%	100%	3.8%		
10	E3/3	Frequency	6	4	10	C = 6.19	P = 0.061
		Percentage	60%	40%	20.4%		
	F	Frequency	12	13	25		
		Percentage	48%	52%	515		
	FG	Frequency	7	5	12		
		Percentage	58.3%	41.7%	24.5%		
	G	Frequency	0	2	2		
		Percentage	0%	100%	4.1%		
11	E ¾	Frequency	1	1	2	C = 9.02	P = 0.028*
		Percentage	50%	50%	8.3%		
	F	Frequency	11	5	16		
		Percentage	68.7%	31.2%	66.7%		

	Table 22 (Contd..)						
	FG	Frequency	1	3	4		
		Percentage	25%	75%	16.7%		
	G	Frequency	0	2	2		
		Percentage	0%	18.2%	8.3%		
12	F	Frequency	9	4	13	C = 18.02	P = 0.005*
		Percentage	69.2%	30.8%	28.3%		
	FG	Frequency	7	1	8		
		Percentage	87.5%	12.5%	17.4%		
	G	Frequency	8	17	25		
		Percentage	33.3%	77.3%	54.3%		
13	F	Frequency	4	5	9	C = 17.39	P = 0.013*
		Percentage	44%	55%	69.2%		
	G	Frequency	0	1	1		
		Percentage	0%	100%	7.7%		
	H	Frequency	1	2	3		
		Percentage	33.3%	66.7%	23.1%		
14	F	Frequency	7	2	9	C =27.01	P < 0.001**
		Percentage	77.7%	22.2%	50%		
	FG	Frequency	1	2	3		
		Percentage	33.3%	66.6%	16.7%		
	G	Frequency	1	3	4		
		Percentage	25%	75%	22.2%		
	H	Frequency	2	9	2		
		Percentage	100%	0%	11.1%		
15	G	Frequency	2	0	2	C = 42.82	P < 0.001**
		Percentage	100%	0%	28.6%		
	H	Frequency	0	2	2		
		Percentage	0%	100%	28.6%		
	I	Frequency	1	2	3		
		Percentage	33.3%	66.7%	42.9%		
17	H	Frequency	2	0	2	C = 11.06	P = 0.037*
		Percentage	100%	0%	15.4%		
	I	Frequency	6	5	11		
		Percentage	54.5%	45.4%	84.6%		
18	I	Frequency	34	6	9	C = 24.81	P < 0.001**
		Percentage	33.3%	66.6%	100%		
19	I	Frequency	11	10	21	C = 1.82	P = 0.251
		Percentage	52.3%	47.6%	100%		
20	I	Frequency	6	4	10	C = 13.91	P = 0.22 *
		Percentage	60%	40%	100%		

P < 0.05* - significant P < 0.001 ** - highly significant

From the above table it is evident that in all sample, girls were ahead of boys in maturation scale sample from age 9, 14, 15, 18 years showed highly significant correlation and from age 11, 12, 13, 17 and 20 years showed significant correlation.

Table 23: Bilateral Comparison of SMI Score and MP3 Score of Right and Left Hand Wrist

	Symmetrical	Asymmetrical	Chi-Square Test	P Value, Significance
SMI Score	245 (98%)	5 (2%)	Chi = 125.91	P < 0.001**
MP3 Score	250 (100%)	0 (0%)	Chi=286.43	P < 0.001**

From this table it is evident that when SMI scores were used for bilateral comparison. 98% of SMI score showed symmetrical ossification in right and left hand where as 2% SMI scores were asymmetrical. Chi square test was used for comparing the ossification stages and it was found to be highl significant (P < 0.001).

Similarly when MP3 stages were used to assess symmetry in middle phalanx of third finger area 100 % symmetry between right and left middle phalanx of third finger was assessed and they were highly significant (P < 0.001).

Table 24: Correlation Coefficient of SMI and MP3 Grades at Different Age Group of Both Males and Females

Age (yrs.)	Correlation Coefficient of SMI & MP3	P-va;ie
8	r = 0.983	P < 0.001**
9	r = 0.995	P < 0.001**
10	r = 0.992	P < 0.001**
11	r = 0.995	P < 0.001**
12	r = 0.997	P < 001**
13	r = 0.998	P < 0.001**
14	r =0.991	P < 0.001**
15	r =0.999	P < 0.001**
16	r =0.987	P < 0.001**
17	r =0.995	P < 0.001**
18	r =0.998	P < 0.001**
19	r =0.996	P < 0.001**
20	r =0.998	P < 0.001**
Over All	**r =0.994**	**P < 0.001****

In the above table, correlation was statistically analysed for significance which showed that coorelation coefficient (r = 0.994) of hand wrist to middly phalanx of third finger (MP3) is highly significant at P < 0.0001.

The study revealed that there is a highly degree of positive correlation between SMI and MP3 stages from 8 to 20 years as well as te overall age group that are statistically highly significant.

Table 25: Correlation Coefficient of SMI and MP3 between Males and Females

Sex	Correlation Coefficient of SMI & MP3	P-va;ie
Male	r = 0.995	P < 0.001**
Female	r = 0.993	P < 0.001**
Combined	r = 0.994	P < 0.001**

This study shows that there is a high degree of positive correlation between SMI and MP3 stages between the two sexes as well as in the combined that are statistically significant (P < 0.001).

This indicate that the eleven discrete stages of SMI can be confidently correlated to corresponding 6 stages of MP3 in both male and female subjects.

In order to counter check the highly correlation significance a siple bar diagram was drawn.

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