

SKELETAL MATURITY INDICATORS – SIMPLIFIED METHOD FOR CLINICAL REFERENCE

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ABSTRACT: The stage of Skeletal Maturation of an individual is essential for assessing the growth potential of an individual. This helps in formulating Diagnosis and Treatment Planning which may affect the final prognosis of the orthodontic treatment. The course of orthodontic treatment often depends upon the intensity of facial growth. Thus the knowledge of the timing of these growth velocity variations in craniofacial complex is important in clinical orthodontics. There are different methods of assessing skeletal maturity for orthodontic treatment purpose. The main source is Hand Wrist X-rays, Cephalograms and Radiographs for assessing the status of dental development. Review of Literature reveals a wide data on this aspect related to methods and the correlation between different methods. Most of them are academically oriented. The purpose of this article is to present a simplified method for clinical reference during treatment.

KEYWORDS: Skeletal Maturity Indicators, Hand wrist Radiographs, Timing, Orthodontic Treatment.

INTRODUCTION

Time is an important characteristic or parameter of growth. All individuals grow and mature but not at the same time. Another characteristic feature called as variability. It means that growth maturation occurs at different times in different individuals. Biologic age, skeletal age, bone age, and skeletal maturation are synonymous terms used to describe the stages of maturation of a person. This biological maturation is set at different clocks for different individuals due to individual variations in timing, duration and velocity of growth.

Growth modulation procedures which bring about changes in the skeletal base such as use of extra oral orthopedic forces or functional appliances are based on active growth periods. These active growth periods have to be objectively assessed for both the timing and the amount of active growth vector or direction of growth. Thus the Skeletal maturity indicators provide an objective diagnostic evaluation of stage of maturity in an individual.

Importance of Pubertal / Adolescent growth spurt ^{1,2,3}

The timing of recognition of the last and important growth spurt i.e., the Pubertal Growth spurt is important in percept of Orthodontics. It is during this growth phase the somatic growth rate is at its maximum. Every growth spurt has definite onset, accelerating phase, Peak of the growth

spurt, decelerating phase, end of growth spurt. The duration of this growth spurt is short in Females around 3-4 years compared to Boys which extends 4-5 years. The Girls have an earlier onset and the Boys have late onset. The accelerating phase may last for 2 years on average. After 3-4 years of the end of this growth spurt, the active growth ceases. Orthodontist has the advantage of taking the growth of maxilla and mandible to his best in treatment planning. The treatment for patients who require orthopedic force should be initiated before the onset of pubertal growth. The removable myofunctional appliances for correction of class II skeletal conditions should be given treatment when the patient is in accelerating phase. The patients seeking orthodontic care for skeletal problems in decelerating phase should be given fixed functional appliances. The patients treated for the class III conditions with mandibular prognathism should continue the treatment till the active growth is completed. The time lag between different phases of this growth spurt is short and the orthodontist cannot take a chance to miss this phases in order to provide the best treatment possibility to his growing patients. (Fig.2).

Assessment of Timing of Adolescent Growth spurt

The timing of growth spurt can be assessed by chronological age, skeletal age and Dental development.

The chronological age is not reliable as variability is the rule of Growth pattern. In most of the conditions skeletal age is assessed to pin point identify the different phases of growth spurt. A number of methods are available to assess the skeletal maturity of an individual in orthodontic practice. Practically the following methods are followed:

- A. Use of hand-wrist radiographs:- This is the most common method and widely accepted method.⁴⁻⁷
- B. Evaluation of skeletal maturation using cervical vertebrae on an lateral cephalogram.^{8,9}
- C. Evaluation of Assessment of maturity by clinical and radiographic examination of different stages of tooth development.¹⁰⁻¹⁴
- D. Evaluation of Frontal sinus using lateral cephalogram¹⁵

The review of literature shows a vast ore on this topic¹⁶⁻²². These studies or reviews are either related to methods of assessment, correlation between different methods, correlation between skeletal age and dental age and chronological etc. This article reviews and presents a simple clinical method of reference for skeletal assessment.

I. HAND-WRIST RADIOGRAPHS

The hand-wrist region is made up of numerous small bones. These bones show a order or sequence and predictable scheduled pattern of appearance, ossification and union from birth to maturity. Thus by comparing a patient’s hand – wrist radiograph with standard radiographs that represent different skeletal ages, one can determine the skeletal maturation status of that individual. Usually the left hand wrist radiograph is taken with palm facing the film screen. The hand-wrist region is made up of the following four groups of bones.

- 1. Distal ends of long bones of forearm – Radius and Ulna—2 bones
- 2. Carpals – Eight small bones arranged in two rows in wrist
- 3. Metacarpals- . These are bones of palm. Five in number corresponding to each finger
- 4. Phalanges: Bones of the fingers. They are three in number in each finger, except the thumb which has only two phalanges. Thus there are 14 phalanges in total
- 5. Sessamoid bone: The sessamoid bone is a small nodular bone more often present embedded in tendons in the region of the thumb.

. Methods of skeletal maturity estimation bases on Hand Wrist Radiographs

The hand wrist radiograph is considered to be the most standardized method of skeletal assessment. Assessment of skeletal maturation using hand wrist radiograph as an index based upon time and sequence of appearance of carpal bones and certain ossification events has been reported by many investigators. A number of methods have been described to assess the skeletal maturity using handwrist radiographs. The following are the most commonly used methods:

- A. Atlas Method by Greulich and Pyle
- B. Bjork, Grave and Brown Method modified by Schopf in 1978
- C. Singers method of assessment
- D. Fishman’s Skeletal Maturity Indicators
- E. Hagg and Taranger Method

Amongst them, Atlas Method by Greulich and Pyle is a comparative method where as all the other methods are individualized methods. All of these methods rely on the stage of the development of epiphysis over the diaphysis.

Usually all the methods depend on the assessment of the following stages Stages in Ossification of Phalanges; (Fig.1)

- STAGE 1:** The epiphysis and diaphysis are equal (Sign convention ‘=’)
- STAGE 2:** The epiphysis caps the diaphysis by surrounding it like a cap. (cap)
- STAGE 3:** Fusion occurs between the epiphysis and diaphysis. .(U-Union)

These stages occur at different times in different miniature skeletal bones of the Hand wrist.

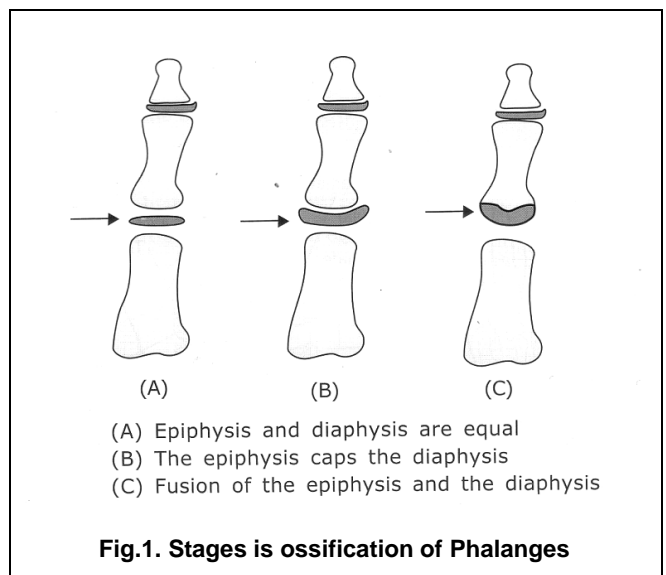


Fig.1. Stages is ossification of Phalanges

These stages occur at different times in different miniature skeletal bones of the Hand wrist.

Anatomical sites

The different sites used by all these methods are

Pp3 (Proximal phalanx of third finger)
Mp3 (Middle phalanx of third finger)
Dp3 (Distal phalanx of third finger)
Mp5 (Middle phalanx of fifth finger)
R-Radius and
S- Sesamoid (thumb)
H- Hook of hamate

Amongst them MP3, R and S are the found to be most reliable and can be correlated with the development of cervical vertebrae or dental development.

II. SKELETAL MATURATION EVALUATION USING CERVICAL VERTEBRAE

Hassel and Farman⁸ using the cervical vertebrae, developed a system of skeletal maturation determination. Later this was modified by Baccetti and Franchi⁹. The shapes of the cervical vertebrae were seen to differ at each level of skeletal development. This provided a means to determine the skeletal maturity of a person and thereby determine whether the possibility of potential growth existed. The shapes of the vertebral bodies of C3 and C4 changes from wedge shape to rectangle followed by square shape. In addition they became taller as skeletal maturity progressed. The inferior vertebral borders were flat when immature and becomes concavity with maturity. The curvatures of the inferior vertebral borders seems to appear sequentially from C2 to C3 to C4 as the skeleton matures. The concavities becomes more distinct as the person matures.

TOOTH MINERALIZATION AS AN INDICATOR OF SKELETAL MATURITY¹⁰⁻¹⁴

Dental maturity can be determined by the stage of tooth eruption or by the stage of tooth formation. Tooth formation is proposed as a more reliable criterion for determining dental maturation. The ease of recognition of dental development stages, together with the availability of periapical or panoramic radiographs in most orthodontic or pediatric dental practices are practical reasons for attempting to assess the physiologic maturity without resorting to handwrist radiographs. Various researchers has carried out extensive work to correlate the dental age and skeletal age. It is believed that stages of root formation and mineralization have a close relationship with the skeletal maturation of an individual. Relationships between the stages of tooth mineralization of the mandibular canine appear to correlate better with

ossification stages than do the other teeth. Some of the dental indicators for skeletal maturity were put forward by Seymour Chertkow based on the mineralization of the lower canine. Nolla's stage of calcification was utilized by some workers to correlate with skeletal maturity. Goldstein and Tanner have described a similar method based on third molar. If a strong association exists between skeletal maturity and dental calcification stages, the stages of dental calcification might be used as a first-level diagnostic tool to estimate the timing of the pubertal growth spurt. Relationships between the stages of tooth mineralization of the mandibular canine appear to correlate better with ossification stages than do the other teeth. According to method given by Demirjian, stage of calcification of mandibular canine is assessed by the radiological appearances of the tooth. Each tooth has been rated according to developmental criteria (amount of dentinal deposit, shape change of pulp chamber, etc.)

rather than changes in size. Eight stages, A to H, have been defined from the first appearance of calcified points to the closure of the apex.

APPLICATION TO DENTOFACIAL ORTHOPEDICS AND FUNCTIONAL APPLIANCE THERAPY²³⁻²⁸ (Fig.2)

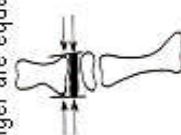

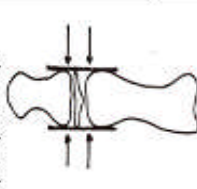


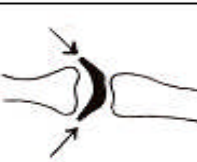


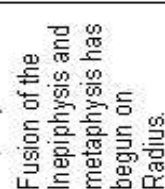

This revised clinical reference gives an idea maturational index to detect the optimal time to start treatment of mandibular deficiencies by means of functional jaw orthopedics. The effectiveness of functional treatment of Class II skeletal disharmony depends strongly on the biological responsiveness of the condylar cartilage, which in turn is related to the growth rate of the mandible. The treatment for such conditions can be treated in early onset or accelerating phase.






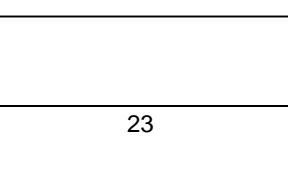
Cephalometric and morphometric investigations using Class III untreated controls have demonstrated that treatment of Class III malocclusion by means of efficient protocols (eg, maxillary expansion and protraction) is more effective in the early than in the late mixed dentition. Treatments requiring mandibular restrictions should be started as early as onset of growth spurt and continued till the end of skeletal maturation. The treatments requiring maxillary expansion should be done even before the onset of pubertal growth spurt as interdigitation of Midpalatal sutures increases at circum pubertal growth. while pubertal or postpubertal use of the rapid maxillary expander entails more dentoalveolar effects.



CONCLUSION

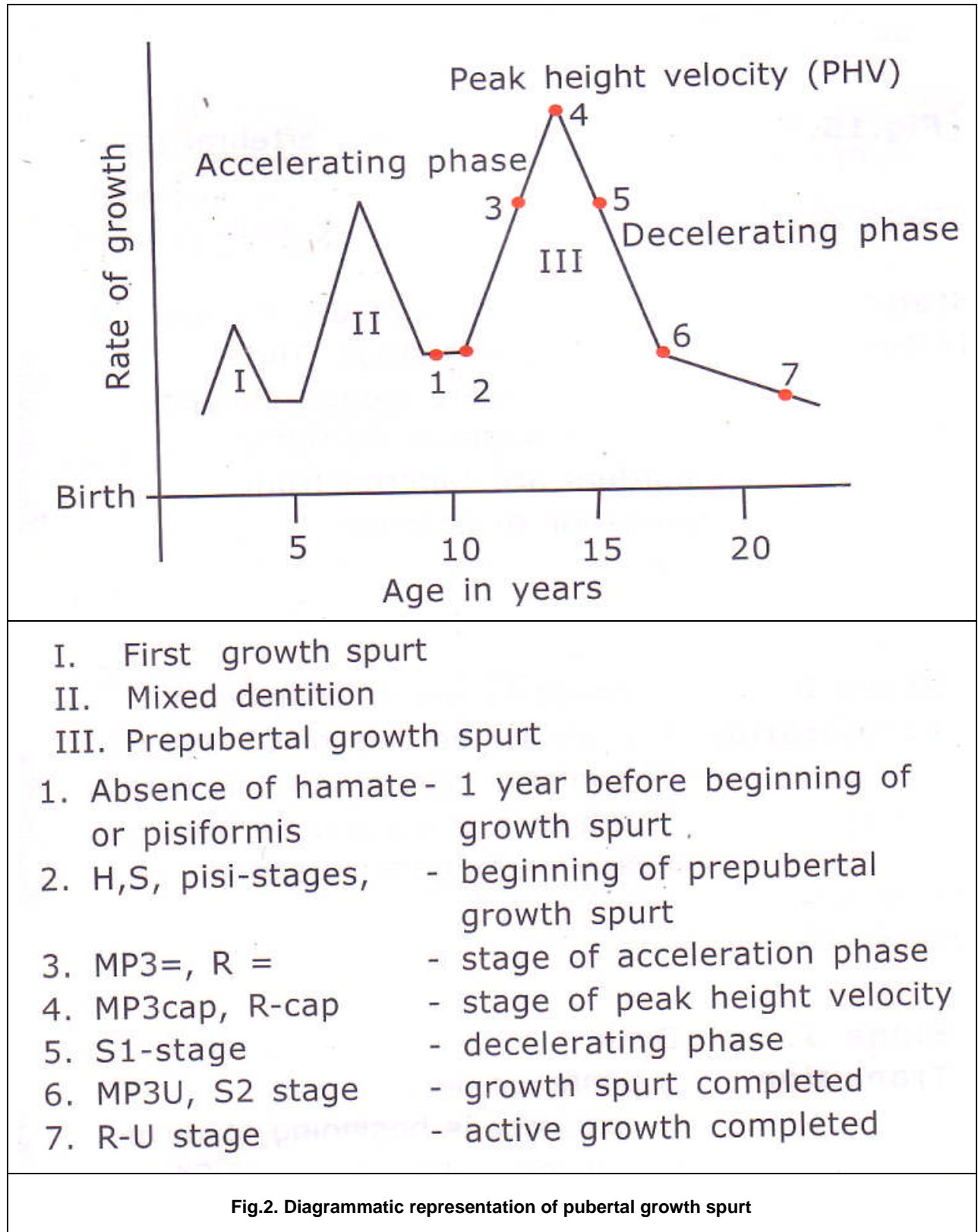
A simplified clinical reference is presented in a illustrative tabulated form. This saves time for clinician in taking decision during treatment plan.

CLINICAL REFERENCE OF SKELETAL MATURITY INDICATORS

Features	Pre initiation/ Pre onset	Initiation/ onset	Accelerating phase	Peak of growth spurt	Decelerating phase	End of Growth spurt	End of Active growth Completion.
Chronological age in Males	10.6	12.6	13	14	14.6	15.0	18.5
Chronological age -F-emales	8.1	9.6	10.6	11	11.5	13.0	16.0
Findings on Hand wrist radiographs	<ul style="list-style-type: none"> Absence of Hook of hamate (H^{ve}) Absence of Sessamoid(S^{ve}) The epiphysis and diaphysis of the proximal phalanx of index finger are equal 	<ul style="list-style-type: none"> The hamular process(hook) of the hamate exhibits initial ossification(H^o) The Sessamoid initial ossification(S^o) 	<p>The epiphysis and diaphysis of the middle phalanx of the middle finger are equal(MP3=)</p>  <p>Increase calcification of hook of hamate(H^o)</p>  <p>Increased ossification of sessamoid</p> 	<p>Capping of the epiphysis over the diaphysis is seen in the middle phalanx of third finger. (MP3_{cap})</p> 	<p>Initiation of fusion on MP3 begins</p> <p>fully calcified ulnar sesamoid (S^u)</p> 	<p>Complete Fusion of epiphysis and diaphysis in the Middle phalanx of third finger(MP3U)</p>  <p>Fusion of the In epiphysis and metaphysis has begun on Radius.</p> 	<p>End of fusion of epiphysis and diaphysis of the radius.(R-U)</p> 

Features	Pre initiation/ Pre onset	Initiation/ onset	Accelerating phase	Peak of growth spurt	Decelerating phase	End of Growth spurt	End of Active growth Completion.	
Findings in Lateral cephalogram—cervical vertebrae	Inferior borders of C2, C3 and C4 are flat. The vertebrae were wedge shaped	Concavities were developing in the inferior borders of C2 and C3. The inferior border of C4 was flat.	Distinct concavities were seen in the inferior borders of C2 and C3.	More accentuated concavities were seen in the inferior borders of C2, C3 and C4.	Deep concavities were seen in the inferior borders of C2, C3, and C4.	 <p>Initiation</p>  <p>Acceleration</p>  <p>Transition</p>	 <p>Deceleration</p>  <p>Maturation</p>  <p>Completion</p>	<p>The superior vertebral borders were tapered from posterior to anterior.</p> <p>The bodies of C3 and C4 were nearly rectangular in shape.</p> <p>A concavity was beginning to develop in the inferior border of C4.</p> <p>The bodies of C3 and C4 were rectangular in shape.</p> <p>The vertebral bodies of C3 and C4 were becoming more square in shape.</p> <p>The bodies of C3 and C4 were nearly square to square in shape.</p> <p>The bodies of C3 and C4 were square or were greater in vertical dimension than in horizontal dimension.</p>

Features	Pre initiation/ Pre onset	Initiation/ onset	Accelerating phase	Peak of growth spurt	Deceleratin g phase	End of Growth s purt	End of Active growth Completion.
Dental development on Iopa x-ray/Orthopantomograph	The root length is relatively less than the length of the cervico occlusal length of the crown	Coincides with the 'F' stage of Demirjian The root length is relatively equal or greater than than the length of the cervico occlusal length of the crown. 	Intermediate stage between 'F' and 'G' of Demirjian	Coincides with the 'F' stage of Demirjian  The walls of the root canal are still parallel and apex is still open.			
Features of adolescent Growth	1 year before beginning of peak pubertal growth	corresponds to beginning of adolescent growth with 80 % to 100 % of adolescent growth expected . Will reach peak growth spurt within two years.	Growth on Accelerating slope-- acceleration begins at this stage, with 65 % to 85 % of adolescent growth expected. This stage is attained at or 1 year after onset of growth spurt and will reach peak after 1 year.	Acceleration of growth towards peak height velocity with 25 % to 65 % of adolescent growth expected. Will reach peak growth spurt within one year.	This stage called corresponds to deceleration phase of adolescent growth spurt with 10 % to 25 % of adolescent growth expected. Has crossed the peak of the spurt one year before.	End of Growth spurt with 5 % to 10 % of adolescent growth expected Has crossed the peak of the spurt more than two years before.	This is the last stage and end of active growth. Has crossed the peak of the spurt more than two years before.



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