

## SKELETAL MATURITY INDICATORS

- **Biological age, skeletal age, bone age and skeletal maturation** are synonymously used to describe the stages of maturation of a person
- **Maturity indicators** provide an *objective diagnostic evaluation* of stage of maturity in an individual
- **Basis:** Different ossification centres appear and mature at different times and in a predictable sequence

### COMMONLY USED METHODS FOR SKELETAL MATURITY ASSESSMENT

1. Hand wrist radiographs
2. Evaluation of skeletal maturation using cervical vertebrae
3. Assessment of maturity by clinical and radiographic examination of different stages of tooth development

### HAND-WRIST RADIOGRAPHS

- Most widely accepted method
- Hand wrist region is made up of numerous small bones which show a predictable and scheduled pattern of appearance, ossification and union from birth to maturity
- Methods used to assess skeletal maturity via hand-wrist radiographs are
  1. Atlas Method by Greulich and Pyle
  2. Bjork, Grave and Brown Method
  3. Fishman's Skeletal Maturity Indicators
  4. Hagg and Taranger Method

### ANATOMY OF HAND-WRIST REGION

- The hand-wrist region is made up of the following four groups of bones
  1. Distal ends of long bones of fore arm-radius and ulna
  2. Carpals
  3. Metacarpals
  4. Phalanges

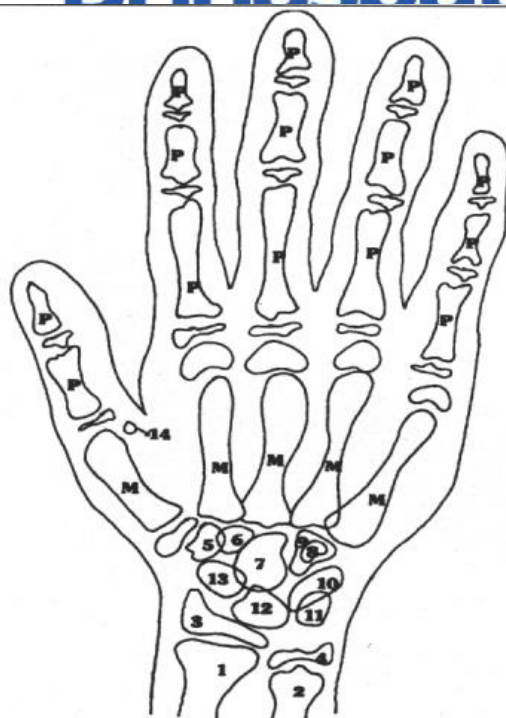


Fig 1 Anatomy of hand and wrist

- |                               |                |
|-------------------------------|----------------|
| 1. Radius                     | 9. Hamate      |
| 2. Ulna                       | 10. Triquetral |
| 3. Distal Epiphysis of Radius | 11. Pisiform   |
| 4. Distal Epiphysis of Ulna   | 12. Lunate     |
| 5. Trapezium                  | 13. Scaphoid   |
| 6. Trapezoid                  | 14. Sesamoid   |
| 7. Capitate                   | M = Metacarpal |
| 8. Hamular process of Hamate  | P = Phalanx    |

### Distal ends of Radius and Ulna

- Ulna is on the medial aspect
- Radius is on the distal aspect
- The distal projections of these bones are called **ulna styloid** and **radial styloid**

### The Carpals

- 8 small, irregularly shaped bones arranged in two rows- a proximal row and a distal row
- The bones of the proximal row - **scaphoid, lunate, triquetral** and **pisiform**
- The distal row of bones - **trapezium, trapezoid, capitate** and **hamate**
- Each of these bones ossifies from one primary center, which appears in a predictable pattern

### The Metacarpals

- 5 miniature long bones forming the skeletal framework of the palm of the hand.
- Each metacarpal ossifies from one primary center (in its shaft) and a secondary center on the distal end (except for the first metacarpal where it appears at the proximal end)

### The Phalanges

- The fingers are formed by these small bones
- They are 3 in number in each finger, except the thumb which has only 2 phalanges
- The 3 bones are referred to as the proximal, middle (absent in thumb) and the distal phalanges
- The 3 phalanges ossify in 3 stages
  1. Stage 1- The epiphysis and diaphysis are equal
  2. Stage 2- The epiphysis caps the diaphysis by surrounding it like a cap
  3. Stage 3- The epiphysis and diaphysis fuse.

### The Sesamoid

- The sesamoid bone is a small nodular bone most often present embedded in tendons in the region of the thumb

## INDICATIONS FOR HAND-WRIST RADIOGRAPHS

1. In patients who exhibit major discrepancy between dental and chronologic age
2. Determination of skeletal maturity status prior to treatment of skeletal malocclusion such as a skeletal Class II or Class III malocclusion
3. To assess the skeletal age in a patient whose growth is affected by infections, neoplastic or traumatic conditions.
4. To predict the pubertal growth spurt
5. Predict future skeletal maturation rate and status
6. Helps in studying the role of heredity, environment, nutrition etc., on the skeletal maturation pattern.
7. It is indicated in patients with skeletal malocclusion needing orthognathic surgery, if undertaken between 16-20 years to assess growth status

## GREULICH AND PYLE METHOD

- Uses an atlas containing ideal skeletal age pictures of the hand-wrist for different chronological ages and for each sex

- Each photograph in the atlas is representative of a skeletal age
- The patient's radiograph is matched on an overall basis with one of the photographs in the atlas

### BJORK, GRAVE AND BROWN

- They have divided skeletal development into 9 stages
- Appropriate chronological age for each of the stages was given by **Schopf in 1978**
- **Stage One (males 10.6 y, females 8.1 y):** The epiphysis and diaphysis of the proximal phalanx of index finger are equal. It occurs approximately 3 yrs before peak of pubertal growth spurt
- **Stage two (males 12.0 y, females 8.1y):** The epiphysis and diaphysis of the middle phalanx of the middle finger are equal
- **Stage three (males 12.6y, females 9.6 y):** This stage is characterized by presence of 3 areas of ossification
  - The hamular process of the hamate exhibits ossification
  - Ossification of pisiform
  - The epiphysis and diaphysis of radius are equal
- **Stage four (males 13.0 y, females 10.6 y):** This stage marks the beginning of the pubertal growth spurt. It is characterized by
  - Initial mineralization of the ulnar sesamoid of the thumb
  - Increased ossification of the hamular process of the hamate bone
- **Stage five (males 14.0 y, females 11.0 y):** This stage heralds the peak of the pubertal growth spurt. Capping of diaphysis by the epiphysis is seen in
  - Middle phalanx of the third finger
  - Proximal phalanx of the thumb
  - Radius
- **Stage six (males 15.0 y, females 13.0):** This stage signifies the end of the pubertal growth spurt. It is characterized by union between epiphysis and diaphysis of the distal phalanx of the middle finger
- **Stage seven (males 15.9 y, females 13.3 y):** Union of epiphysis and diaphysis of the proximal phalanx of the little finger occurs
- **Stage eight (males 15.9 y, females 13.9 y):** This stage shows fusion between the epiphysis and diaphysis of the middle phalanx of the middle finger
- **Stage nine (males 18.5 y, females 16.0 y):** This is the last stage and it signifies the end of skeletal growth. It is characterized by fusion of epiphysis and diaphysis of the radius

### SINGER'S METHOD OF ASSESSMENT

- Enables the clinician to rapidly and with some degree of reliability help determine the maturational status of the patient.
- Six stages of hand-wrist development are described.

#### Stage one (Early)

- Absence of the pisiform,
- Absence of the hook of the hamate
- Epiphysis of proximal phalanx of second finger being narrower than its diaphysis

#### Stage two (Prepubertal)

- Initial ossification of hook of the hamate
- Initial ossification of the pisiform
- Proximal phalanx of second finger being equal to its epiphysis
- Represents **that period prior to the adolescent growth spurt during which significant amounts of mandibular growth are possible**

#### Stage three (Pubertal onset)

- Beginning of calcification of ulnar sesamoid

- Increased width of epiphysis of proximal phalanx of the second finger
- Increased calcification of hook of hamate and pisiform

**Stage four (Pubertal)**

- Calcified ulnar sesamoid
- Capping of the diaphysis of the middle finger by its epiphysis

**Stage five (Pubertal deceleration)**

- Fully calcified ulnar sesamoid
- Fusion of epiphysis of distal phalanx of third finger with its shaft
- Epiphyses of radius and ulna not fully fused with respective shafts
- Represents **that period of growth when orthodontic treatment might be completed, and the patient is in retention therapy**

**Stage six (Growth completion)**

- No remaining growth sites seen

**FISHMAN'S SKELTAL MATURITY INDICATORS - Leonard S. Fishman in 1982**

- Makes use of anatomical sites located on the **thumb, third finger, fifth finger and radius**
- 11 discrete adolescent skeletal maturity indicators (S.M.I.s) have been described
- The Fishman's system of interpretation uses **four stages** of bone maturation
- They are
  1. Epiphysis
  2. Appearan
  3. Capping c
  4. Fusion of

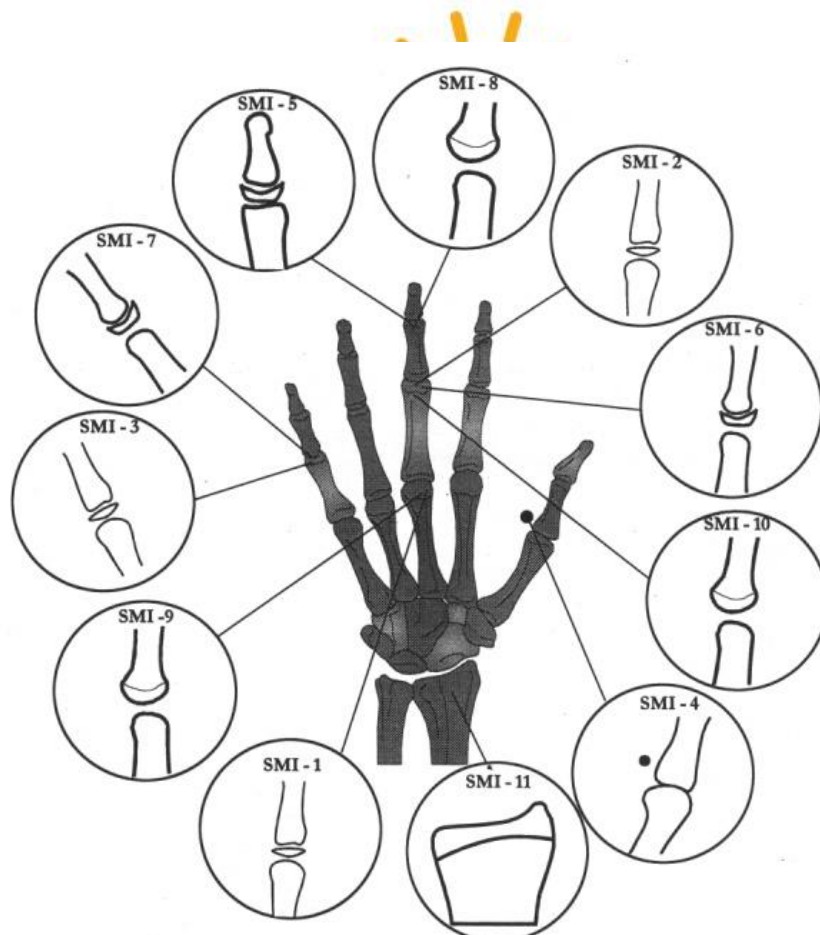


Fig 5. Fishman's skeletal maturity indicators

The 11 S.M.I.s are as follows:

- S.M.I. 1: the third finger proximal phalanx shows equal width of epiphysis and diaphysis.
- S.M.I. 2: width of epiphysis and diaphysis is equal in the middle phalanx of third finger.
- S.M.I. 3: width of epiphysis and diaphysis is equal in the middle phalanx of fifth finger.
- S.M.I. 4: appearance of adductor sesamoid of the thumb.
- S.M.I. 5: capping of epiphysis seen in distal phalanx of third finger.
- S.M.I. 6: capping of epiphysis seen in middle phalanx of third finger.
- S.M.I. 7: capping of epiphysis seen in middle phalanx of fifth finger.
- S.M.I. 8: fusion of epiphysis and diaphysis in the distal phalanx of third finger.
- S.M.I. 9: fusion of epiphysis and diaphysis in proximal phalanx of third finger.
- S.M.I. 10: fusion of epiphysis and diaphysis in middle phalanx of third finger.
- S.M.I. 11: fusion of epiphysis and diaphysis seen in the radius.

#### MATURATION ASSESSMENT BY HAGG AND TARANGER

- Analyzed from *annual radiographs*, taken between the ages of 6 and 18 years, by assessment of the ossification of the ulnar sesamoid of the metacarpophalangeal joint of the first finger(S) and certain specified stages of 3 epiphyseal bones: the middle and distal phalanges of the third finger (MP3 and DP3) and the distal epiphysis of the radius (R).

#### Sesamoid

- Sesamoid is usually attained during the acceleration period of the pubertal growth spurt

#### Third finger middle phalanx

- **MP3-F:** The epiphysis is as wide as the metaphysis. This stage is attained before onset of pubertal growth spurt by about 40% of the subjects and at pubertal growth spurt by many others.
- **MP3-FG:** The epiphysis is as wide as the metaphysis and there is distinct medial and/or lateral border of the epiphysis forming a line of demarcation at right angles to the distal border. This stage is attained 1 year before or at pubertal growth spurt
- **MP3-G:** The sides of the epiphysis have thickened and also cap its metaphysis, forming a sharp edge distally at one or both sides. This stage is attained at pubertal growth spurt.
- **MP3-H:** Fusion of the epiphysis and metaphysis has begun and is attained after pubertal growth spurt but before end of growth spurt by practically all boys and about 90% of the girls.
- **MP3-I:** Is attained before or at end of growth spurt in all subjects except a few girls.

#### Third finger distal phalanx

- **DP3-I:** Fusion of the epiphysis and metaphysis is completed. This stage signifies the fusion of the epiphysis and metaphysis and is attained during the deceleration period of the pubertal growth spurt by all subjects.
- **Radius**
- **R-I:** Fusion of the epiphysis and metaphysis has begun. This stage is attained 1 year before or at the end of growth spurt by about 80% of the girls and 90% of the boys.
- **R-IJ:** Fusion is almost completed but there is still a small gap at one or both margins.
- **R-J:** Is characterized by fusion of the epiphysis and metaphysis.
- These stages were not attained before end of growth spurt by any subject

#### SKELTAL MATURATION EVALUATION USING CERVICAL VERTEBRAE

- **Hassel** and **Farman** developed a system of skeletal maturation determination using cervical vertebrae.
- The shapes of the cervical vertebrae were seen to differ at each level of skeletal development.
- Following 6 stages in vertebral development.



**Stage 1 - initiation**

- Corresponds to beginning of adolescent growth with 80% to 100% of adolescent growth expected.
- Inferior borders of C2, C3 and C4 were flat at this stage.
- The vertebrae were wedge shaped and the superior vertebral borders were tapered from posterior to anterior

**Stage 2 - Acceleration**

- 65% to 85% of adolescent growth expected.
- Concavities were developing in the inferior borders of C2 and C3.
- The inferior border of C4 was flat.
- The bodies of C3 and C4 were nearly rectangular

**Stage 3- Transition**

- Corresponded to acceleration of growth towards peak height velocity with 25% to 65% of adolescent growth expected.
- Distinct concavities were seen in the inferior borders of C2 and C3.
- A concavity was beginning to develop in the inferior border of C4.
- The bodies of C3 and C4 are rectangular.

**Stage 4 - Deceleration**

- 10% to 25% of adolescent growth expected.
- Distinct concavities were seen in the inferior borders of C2, C3 and C4.
- The vertebral bodies of C3 and C4 become squarer in shape.

**Stage 5- Maturation**

- 5% to 10% of adolescent growth expected.
- More accentuated concavities were seen in the inferior borders of C2, C3 and C4.
- The bodies of C3 and C4 were nearly square in shape.

**Stage 6 - completion**

- Corresponds to completion of growth.
- Little or no adolescent growth could be expected.
- Deep concavities were seen in the inferior borders of C2, C3 and C4.
- The bodies of C3 and C4 were square or were greater in vertical dimension than in horizontal dimension.



**TOOTH MINERALIZATION AS A S.M.I**

- The calcification patterns and stage of mineralization of the teeth is believed to have a close relationship with the skeletal maturation of an individual.
- **Seymour Chertkow, Demirjain, Goldstein and Tanner-** described method of determining the skeletal maturity based on the mineralization of the lower canine.

