SKELETAL MATURITY INDICATORS AND HAND WRIST RADIOGRAPH

CONTENTS

INTRODUCTION

- An understanding of growth events is of primary importance in the practice of clinical orthodontics.

- Due to individual variations in timing, duration and velocity of growth, skeletal age assessment is essential in formulating viable orthodontic treatment plan.

A number of methods are available to assess the skeletal maturity of an individual. These include:

- Use of **hand wrist radiographs.**
- Evaluation of skeletal maturation using **cervical vertebrae**
- Assessment of maturity by clinical and radiographic examination of **different stages of tooth development.**

HISTORY

After Roengten described his new radiographic discovery in 1895 Ronaldo, in 1896, introduced the idea of using the comparative size and shape of the radiographic shadows of growing bones as indicators of rate of growth and maturity.

In early 1900s PRYOR, ROTCH, & CRAMPTON began tabulating indicators of maturity on sequential radiographs of the growing hand and wrists.

HELLMAN published his observations on the ossification of epiphyseal cartilage of the hand in 1928.

TODD compiled hand wrist data that was further elaborated on by Greulich and Pyle in atlas form.

In 1936 FLORY indicated that beginning of calcification of the carpal sesamoid was a good guide to determine the period immediately before puberty.

FISHMAN developed a system of hand wrist skeletal maturation using four stages of bone maturation at six anatomic sites on the hand and wrist.

HAGG and TARANGER created a method using the hand wrist radiograph to correlate certain maturity indicators to the pubertal growth spurts.

HAND WRIST RADIOGRAPHS

ANATOMY OF HAND WRIST

There are numerous small bones which show a predictable sequence of ossification from birth to maturity.

Ossification of the bones of the hand and wrist is standard for skeletal development.

Helps in the calculation of skeletal age.

The hand wrist region is made up of the following four bones:

1. Distal end of long bones of forearm
2. Carpals
3. Metacarpals
4. Phalanges

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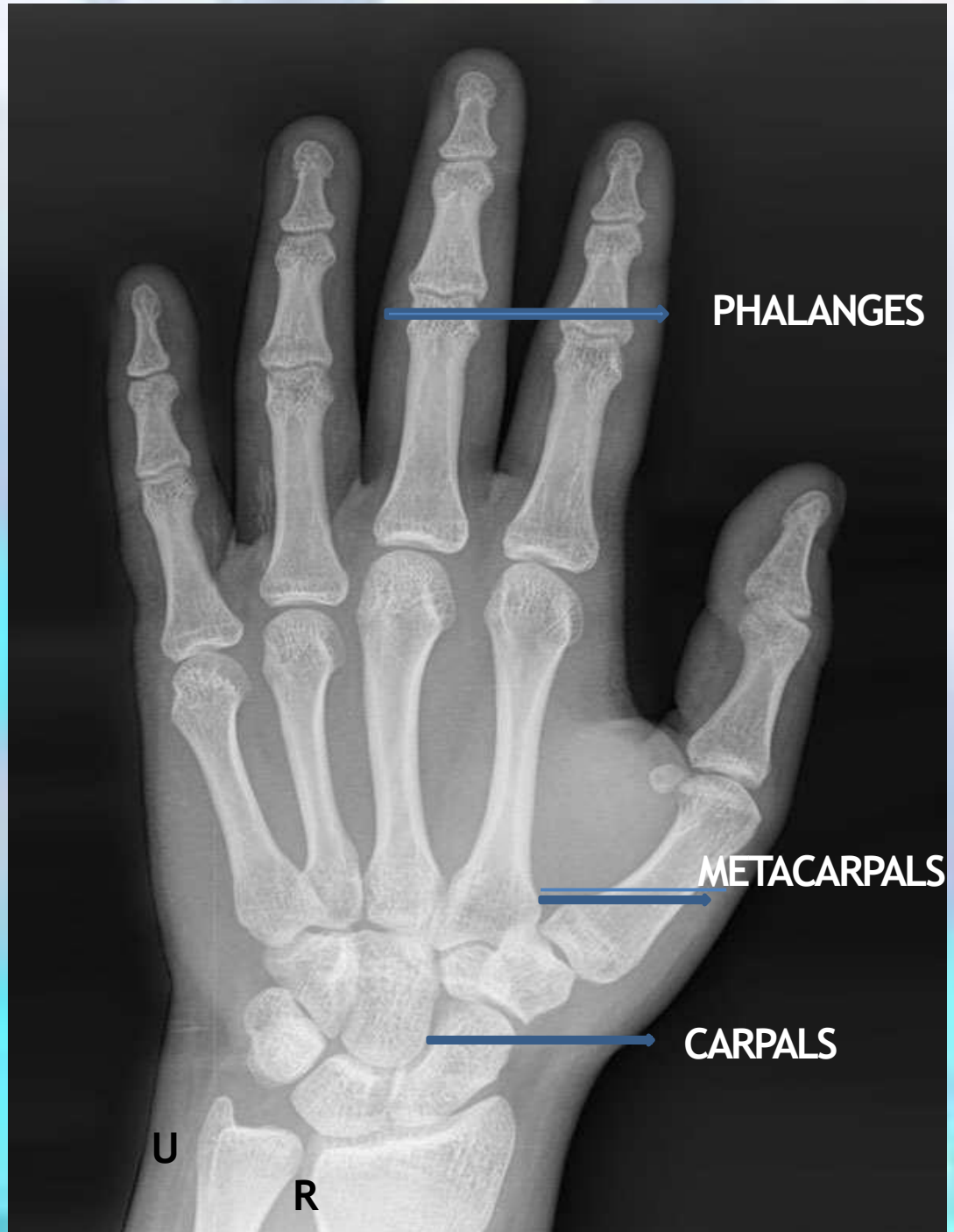
R


PHALANGES
METACARPALS
CARPALS
U
R

Distal end of long bones of forearm

The distal ends of radius and ulna, which are long bones of the forearm form the first group of bones.

The metacarpals

They are 5 miniature long bones forming the skeletal framework of the palm of hand.

The carpals

They consist of eight small, irregularly shaped arranged in two rows, a proximal row and a distal row. The bones of the proximal row are

- scaphoid,
- lunate,
- triquertal and
- pisiform.

The distal row of bones include

- trapezium,
- trapezoid,
- capitate, and
- hamate.

Each of these eight carpal bones ossifies from one primary centre, which appears in a predictable form.


3rd metacarpal
2nd metacarpal
4th metacarpal
1st metacarpal
5th metacarpal
trapezoid
hamate
trapezium
capitate
triquetrum
pisiform
scaphoid (navicular)
lunate
ulna
radius

The phalanges

They are small bones forming the fingers.

They are three in number in each finger, except the thumb, which has only two phalanges.

the three bones are referred to as the proximal, middle(absent in thumb) and the distal phalanges. They ossify in three stages.

STAGE 1: the epiphysis and diaphysis are equal

STAGE 2: the epiphysis caps the diaphysis by surrounding like a cap.

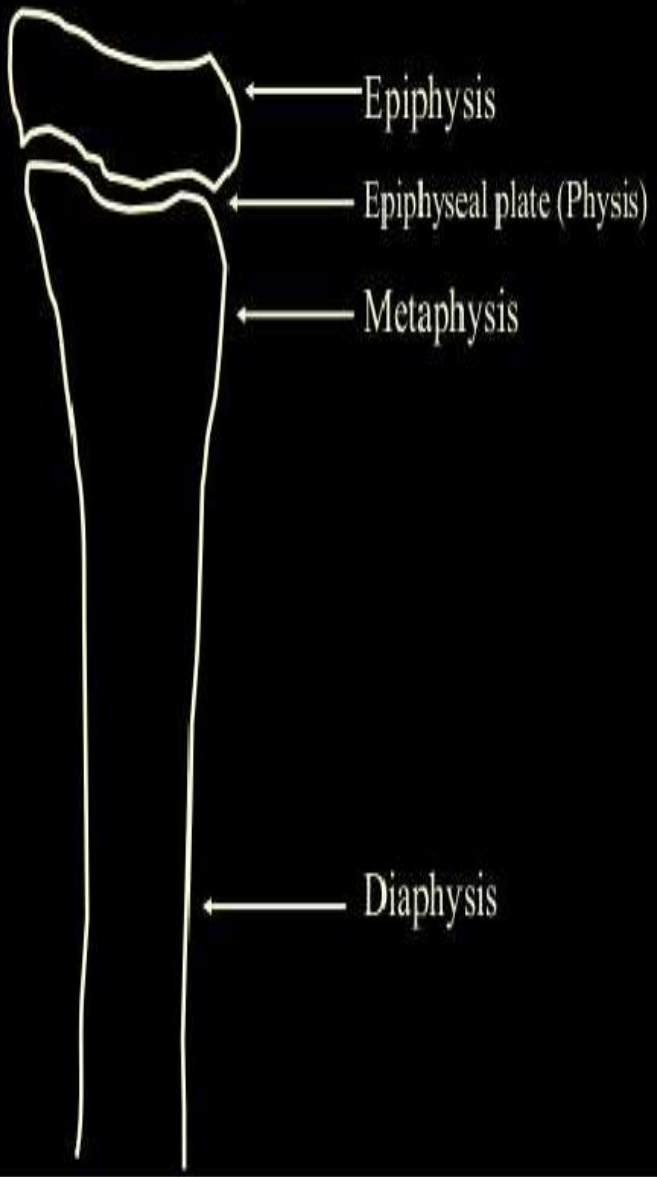
STAGE3: fusion occurs between the epiphysis and diaphysis.

The sesamoid bone

It is a small nodular bone most often present embedded in tendons in the region of the thumb.

Parts of a Long Bone

You will need to know these for describing fractures in children.



Parts of a Growing Bone

FIGURE 7 - Epiphyseal stages of the proximal phalanx of the thumb identified on hand-wrist radiograph: **A**) Pre-capping (Stage D); **B**) Capping (Stage E); **C**) Fusion onset (Stage F); **D**) Fusion in progress (Stage G); **E**) fusion complete (Stage H).


distal phalanges (DP)
middle phalanges (MP)
proximal phalanges (PP)
metacarpals (MC)
carpals
carpals
ulna
radius
2 DP
3 DP
4 DP
5 DP
2 MP
3 MP
4 MP
5 MP
2nd PP
3rd PP
4th PP
5th PP
1st DP
1st PP
1st MC
2nd MC
3rd MC
4th MC
5th MC

INDICATIONS

- In patients who exhibit major discrepancy between dental and chronological age.
- Determination of skeletal maturity status prior to treatment of skeletal class II and class III malocclusion.
- To assess the skeletal age in a patient whose growth is affected by infections, neoplastic or traumatic conditions.
- To predict the pubertal growth spurts

A number of methods have been described to assess the skeletal maturity using hand wrist radiographs. The following are the most commonly used methods:

1. Atlas method by Greulich and Pyle
2. Bjork, Grave and Brown method
3. Fishmans skeletal maturity indicators
4. Hagg and Taranger method.

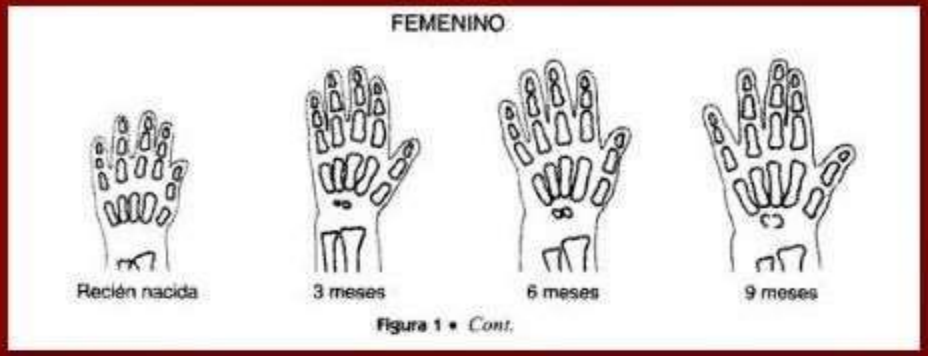
GREULICH AND PYLE METHOD

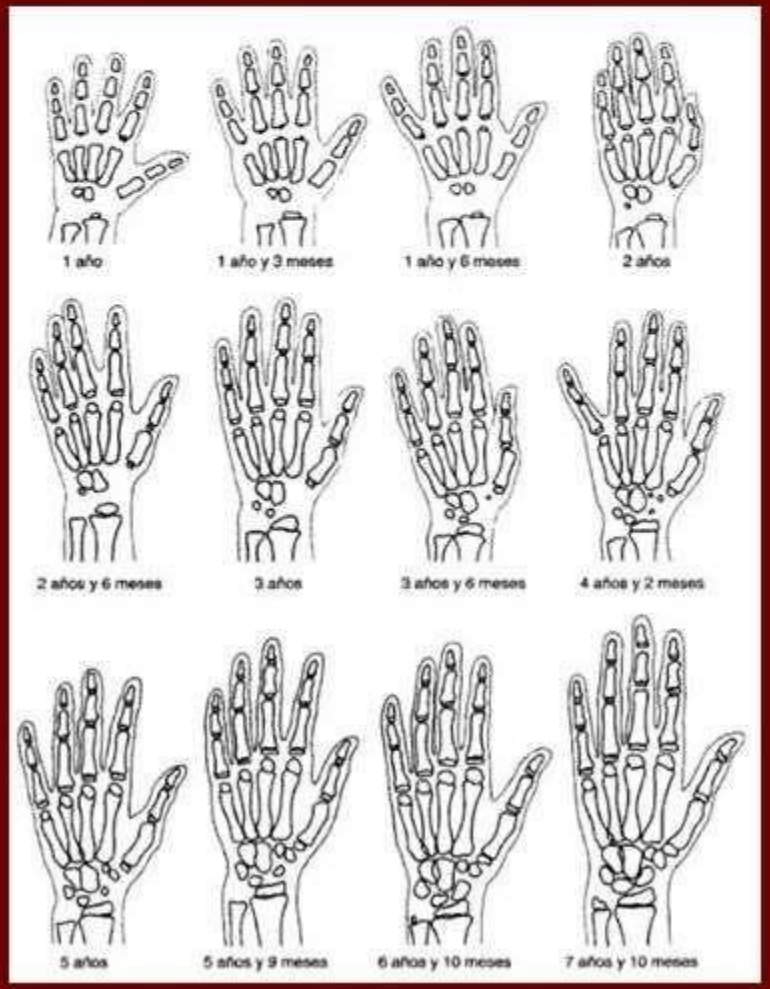
Greulich and Pyle published an atlas containing ideal skeletal age pictures of the hand wrist for different chronological ages and for each sex.

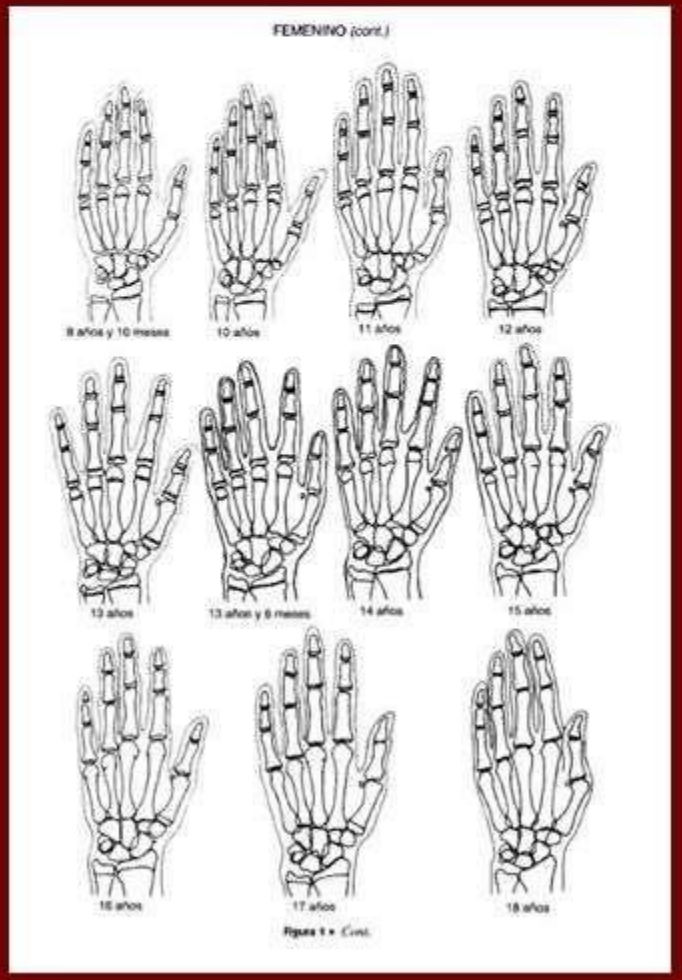
Each photograph in the atlas is representative of a particular skeletal age.

The patients radiograph is matched on an overall basis with one of the photographs in the atlas.

Greulich & Pyle Atlas

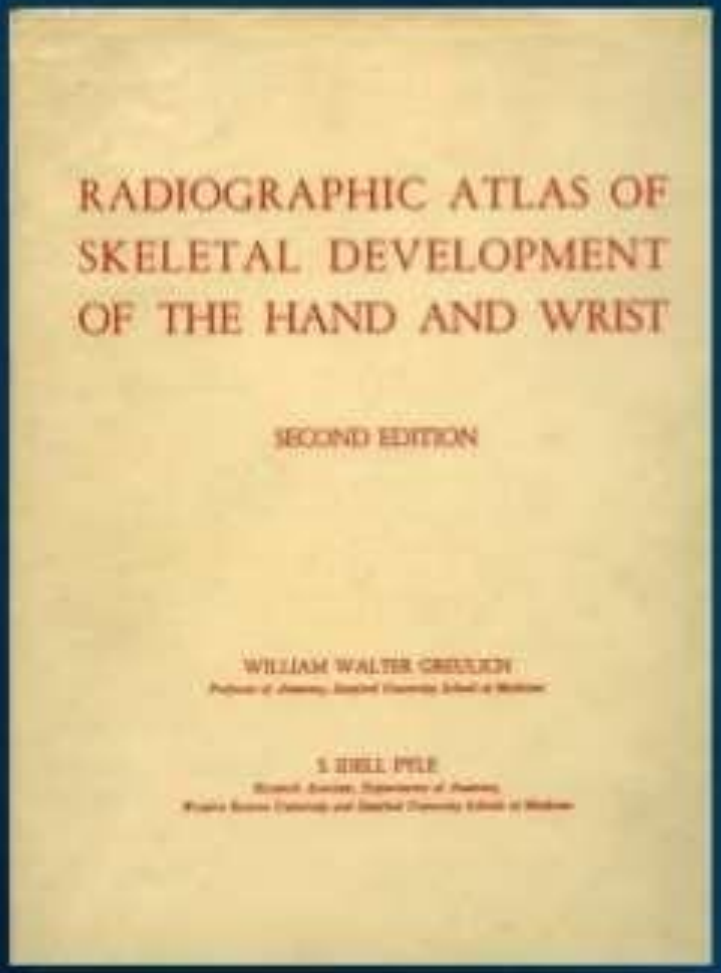






Hand wrist Radiograph

Atlas of Greulich and Pyle (1959)



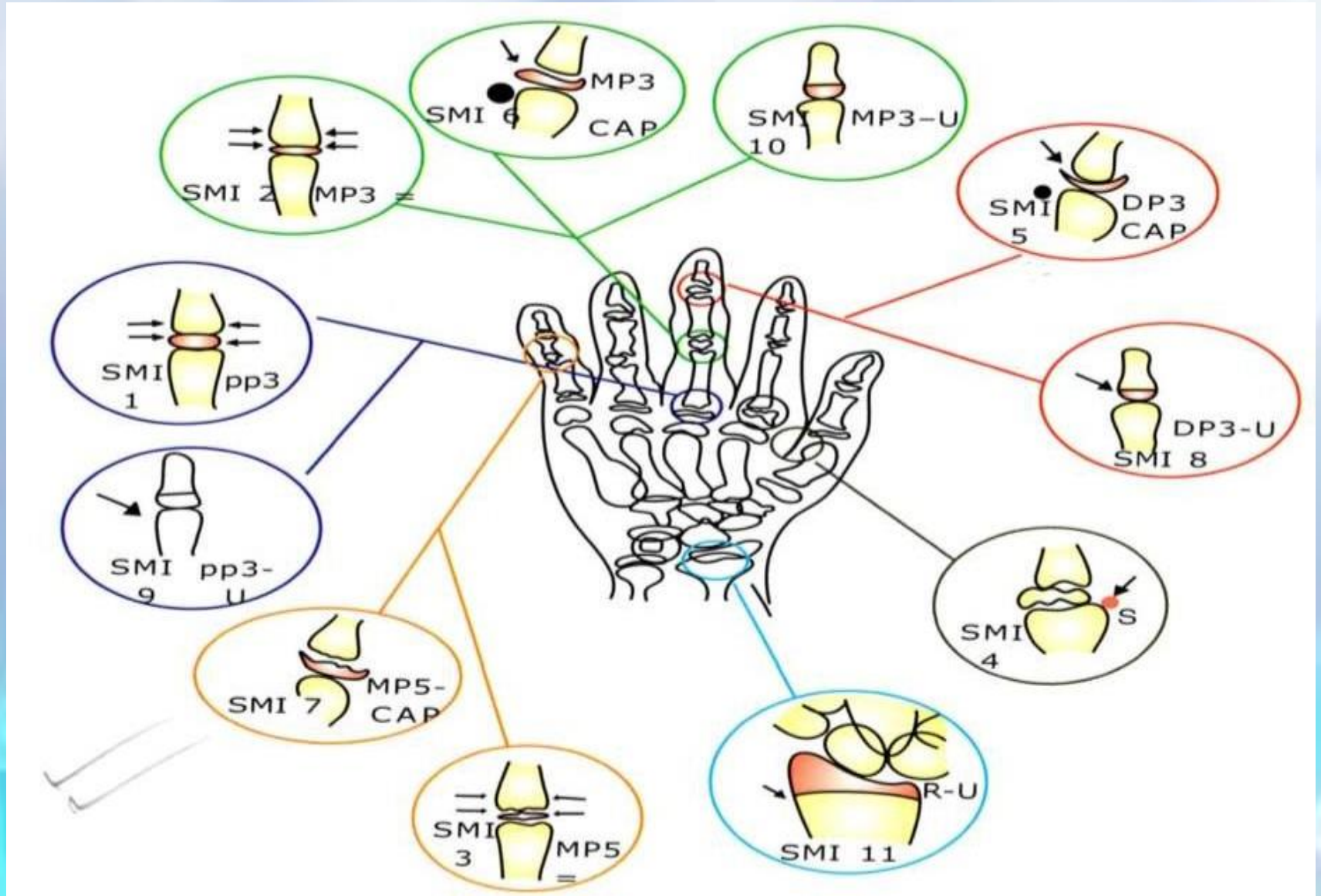
FISHMAN'S SKELETAL MATURITY INDICATORS

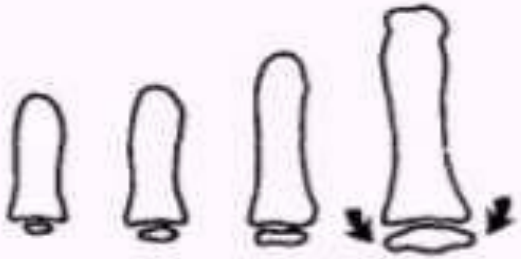
- A system for evaluation of skeletal maturation was proposed by Leonord S Fishman in 1982.
- Fishman made use of four anatomical sites located on the thumb (adductor sesamoid), third finger, fifth finger and radius.

4 stages utilised are :

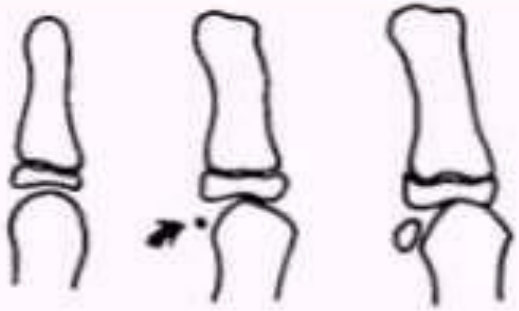
1. **Epiphysis equal to diaphysis**
2. **Appearance of adductor sesamoid of thumb**
3. **Capping of epiphysis**
4. **Fusion of epiphysis**

Fishman's index utilises four anatomic sites and 11 skeletal maturity indicators

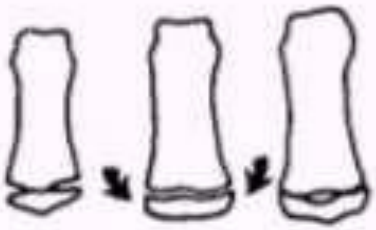




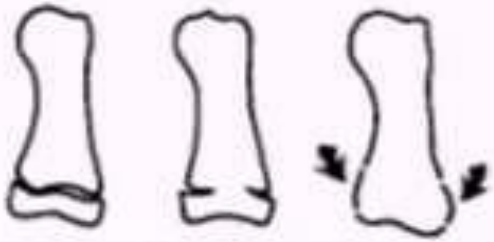
WIDTH OF EPIPHYSIS



OSSIFICATION



CAPPING OF EPIPHYSIS



FUSION

Fig. 2 Radiographic identification of skeletal maturity indicators.
A. Epiphysis equal in width to diaphysis.
B. Appearance of adductor sesamoid of the thumb.
C. Capping of epiphysis.
D. Fusion of epiphysis.

EPIPHYSIS EQUAL TO DIAPHYSIS

1) Proximal phalanx of third finger(PP3)
2) Middle phalanx of third finger(MP3)
3) Middle phalanx of fifth finger(MP5)

It indicates the onset of the prepubertal growth velocity

4) APPEARANCE OF ADDUCTOR SESAMOID OF THE THUMB

it indicates a period of very rapid growth velocity

CAPPING OF THE EPIPHYSIS OVER DIAPHYSIS

5) Distal phalanx of third finger (DP3)
6) Middle phalanx of third finger (MP3)
7) Middle phalanx of fifth finger (MP5)

It indicates peak height velocity

FUSION OF THE EPIPHYSIS OVER DIAPHYSIS IN

8) Distal phalanx of third finger (DP3)
9) Proximal phalanx of third finger (PP3)
10) Middle phalanx of third finger (MP3)
11) Radius

It indicates decelerating growth rate and growth completion

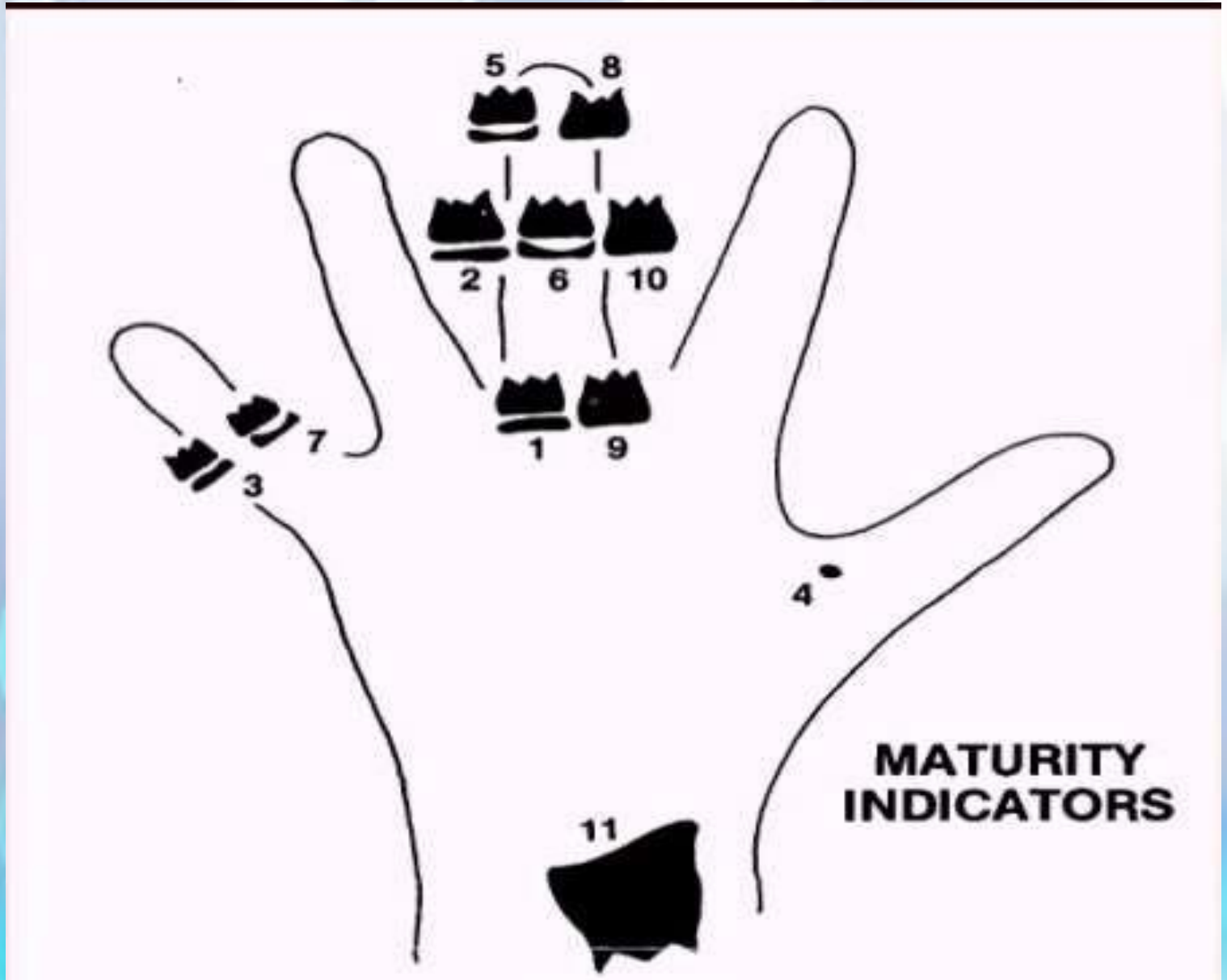
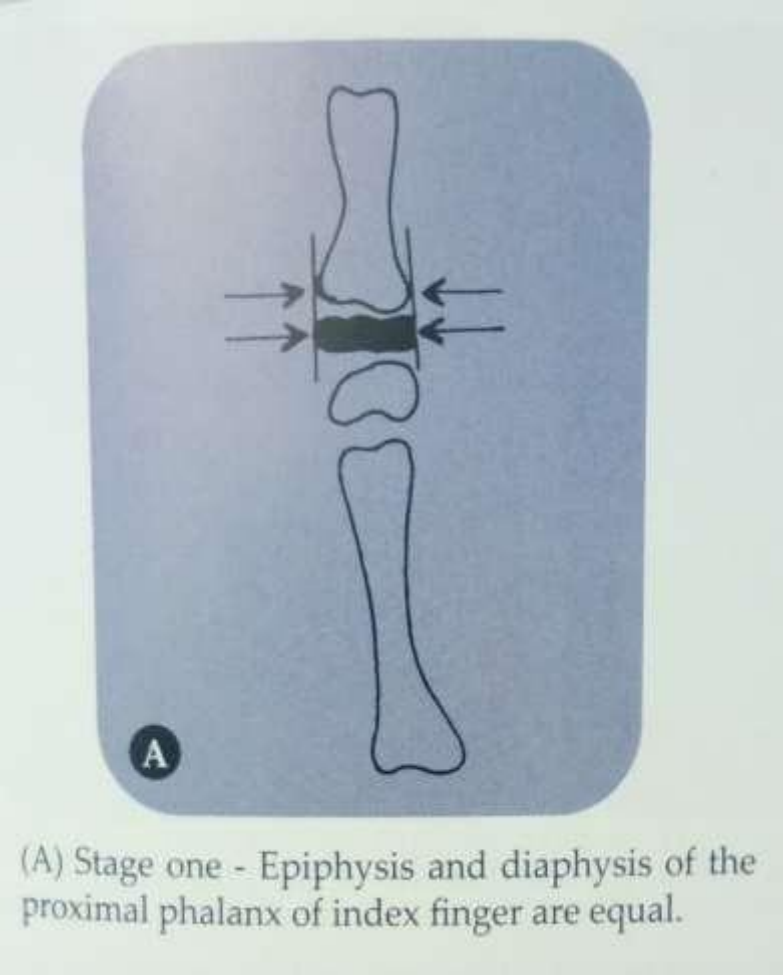


Fig. 3 Eleven skeletal maturity indicators (SMIs).

BJORK, GRAVE & BROWN METHOD

- They have divided skeletal development into 9 stages. Each of these stages represents a level of skeletal maturity. Appropriate chronological age for each of the stages was given by Schopf in 1978.

Stage 1 (males 10.6y, females 8.1y)

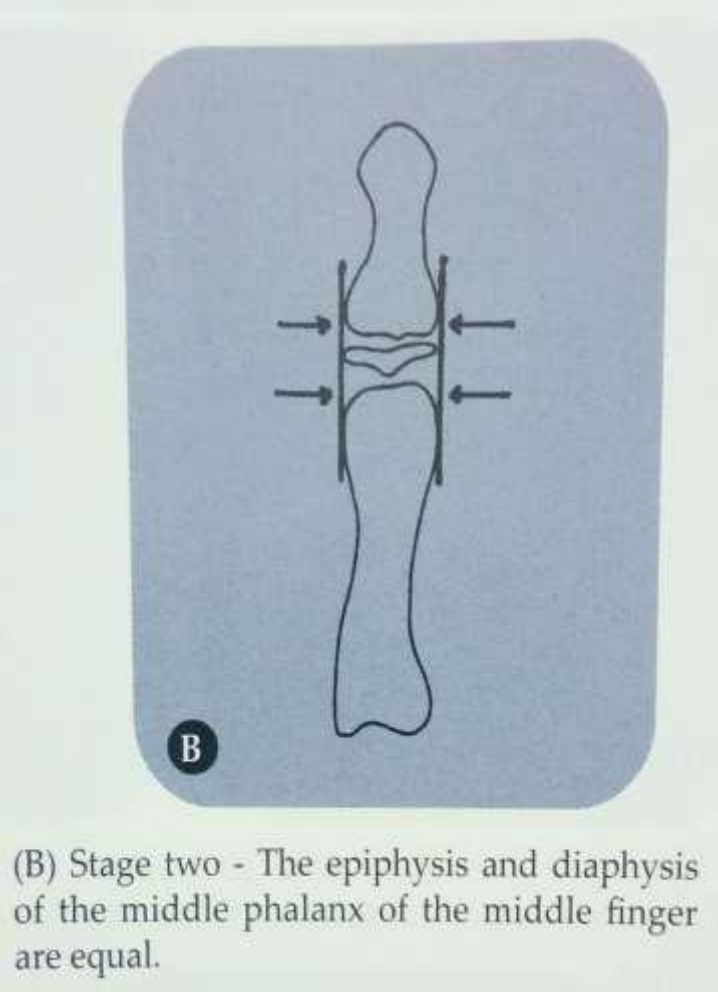


(A) Stage one - Epiphysis and diaphysis of the proximal phalanx of index finger are equal.

EPIPHYSIS AND DIAPHYSIS OF THE PROXIMAL PHALANX OF INDEX FINGER ARE EQUAL.

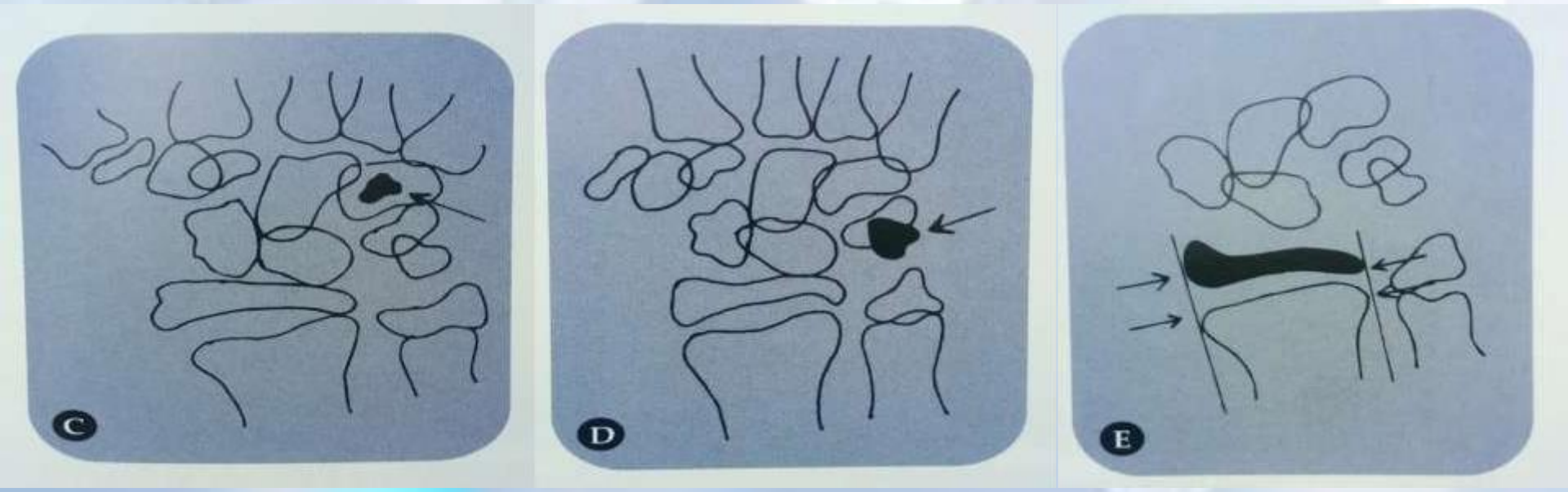
Stage 2 (males 12.0y. females 8.1y)

THE EPIPHYSIS AND DIAPHYSIS OF THE MIDDLE FINGER ARE EQUAL.



(B) Stage two - The epiphysis and diaphysis of the middle phalanx of the middle finger are equal.

Stage 3(males 12.6y, females 9.6y)



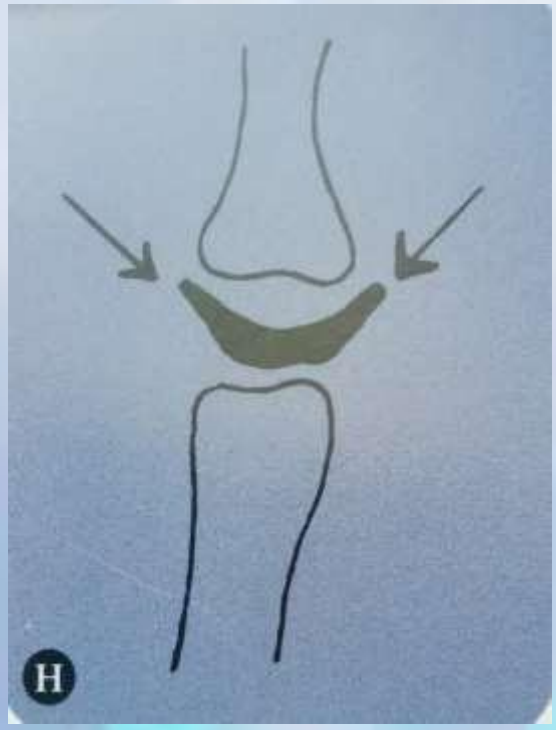
1. **THE HAMALAR PROCESS OF THE HAMATE EXHIBITS OSSIFIICATION**
2. **OSSIFICATION OF THE PISIFORM**
3. **THE EPIPHYSIS AND THE DIAPHYSIS OF RADIUS ARE EQUAL.**

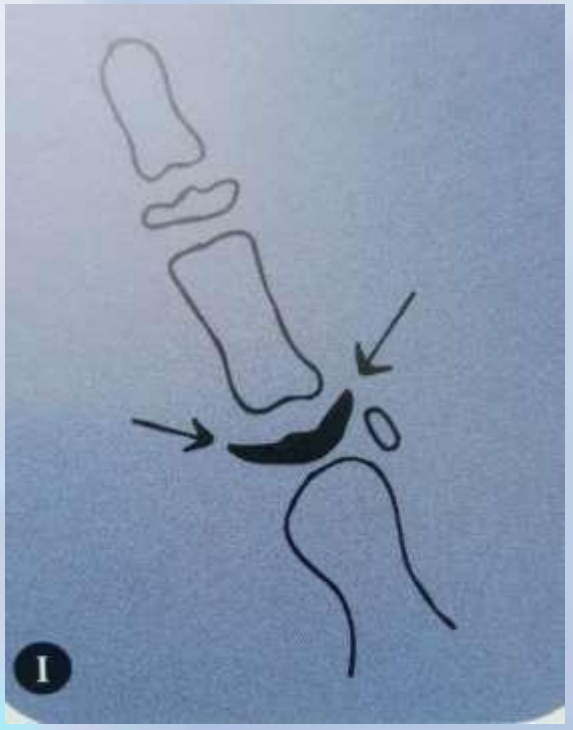
Stage 4 (males 13.0y, females 10.6y)

1. **INITIAL MINERALISATION OF THE ULNAR SESAMOID OF THE THUMB**

2.INCREASED OSSIFICATION OF THE HAMULAR PROCESS OF THE HAMATE BONE

Stage 5 (males 15.0y, females)





CAPPING OF THE

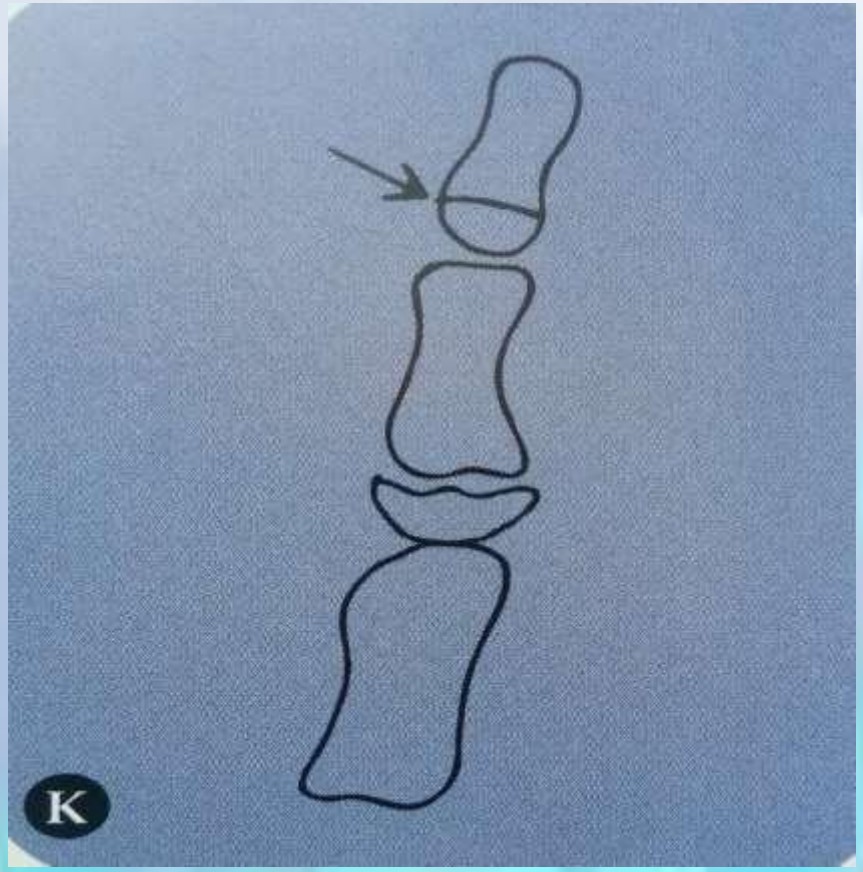
•DIAPHYSIS BY THE EPIPHYSIS IS SEEN IN THE MIDDLE PHALANX OF THE THIRD FINGER

• PROXIMAL PHALANX OF THE THUMB

•RADIUS

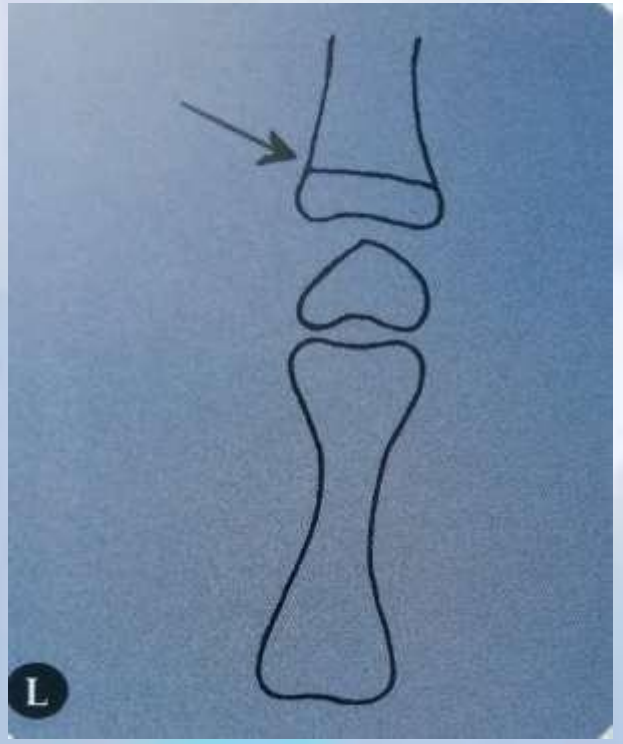
Stage 6 (males 15.0y, females 13.0y)

- **UNION BETWEEN EPIPHYSIS AND DIAPHYSIS OF THE DISTAL PHALANX OF THE MIDDLDE FINGER**



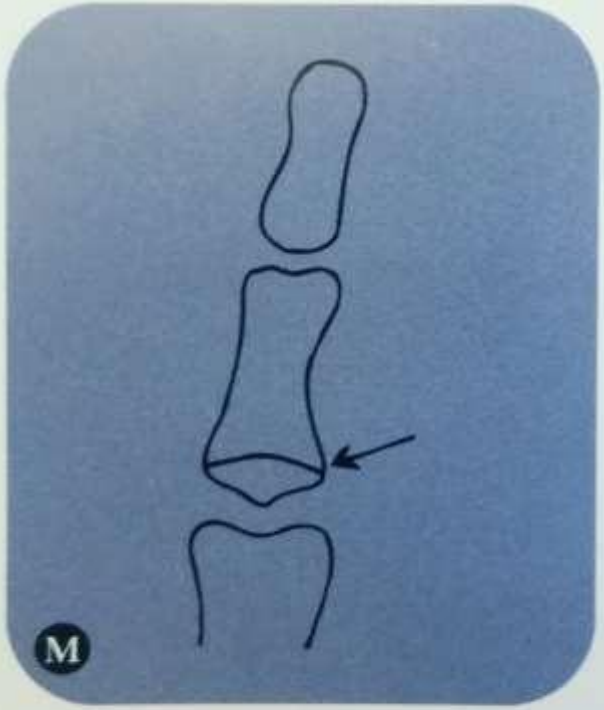
Stage 7 (males 15.9y, females 13.3y)

UNION OF EPIPHYSIS AND DIAPHYSIS OF THE PROXIMAL PAHALANX OF THE LITTLE FINGER



Stage 8 (males 15.9y, females 13.3y)

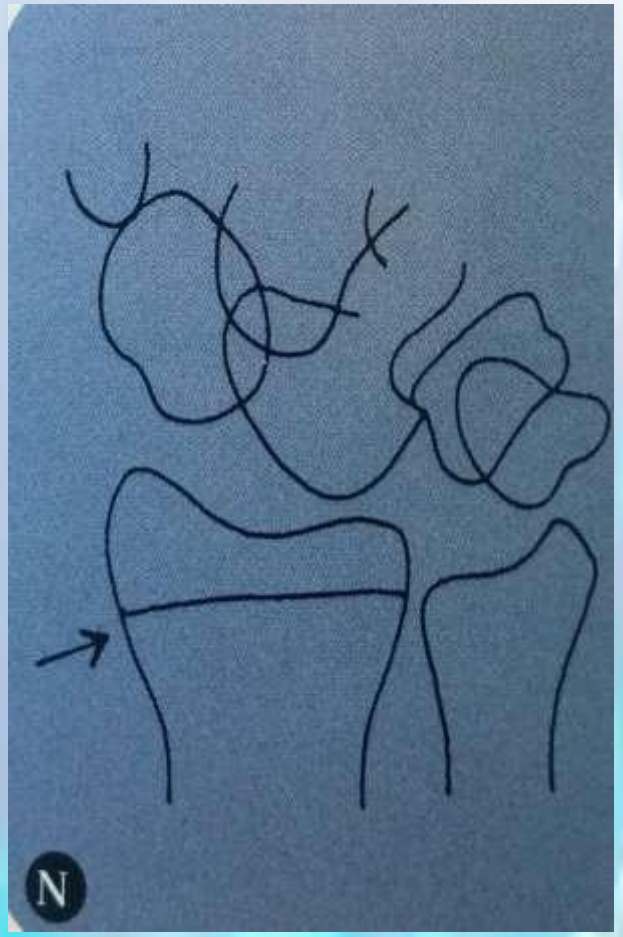
FUSION BETWEEN TH EEPIPHYSIS AND DIAPHYSIS OF THE MIDDLE PHALANX OF THE MIDDLE INGER

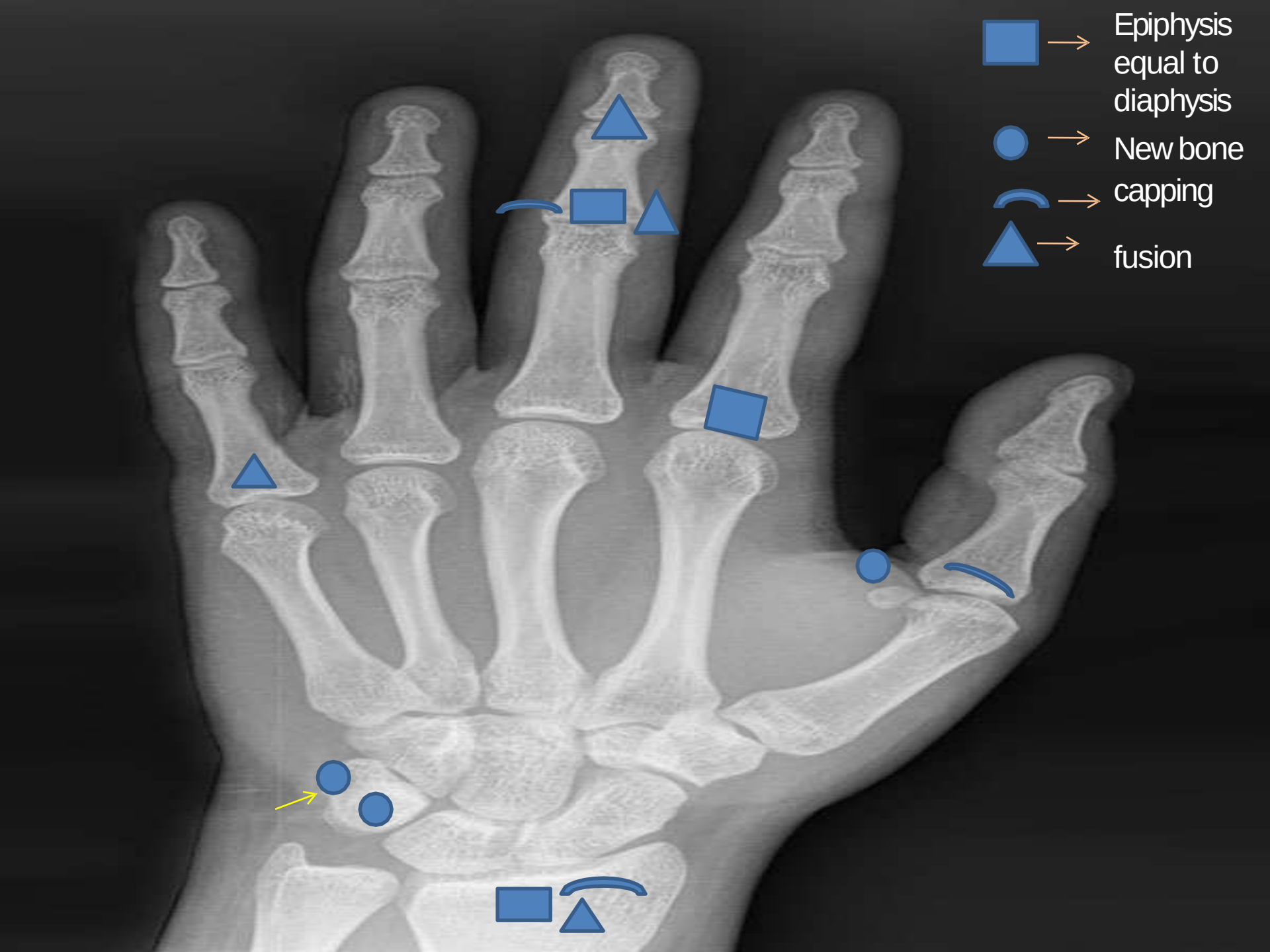


(M) Stage Eight - Fusion between the epiphysis and diaphysis of the middle phalanx of the middle finger.

Stage nine (males 18.5y females 16.0)

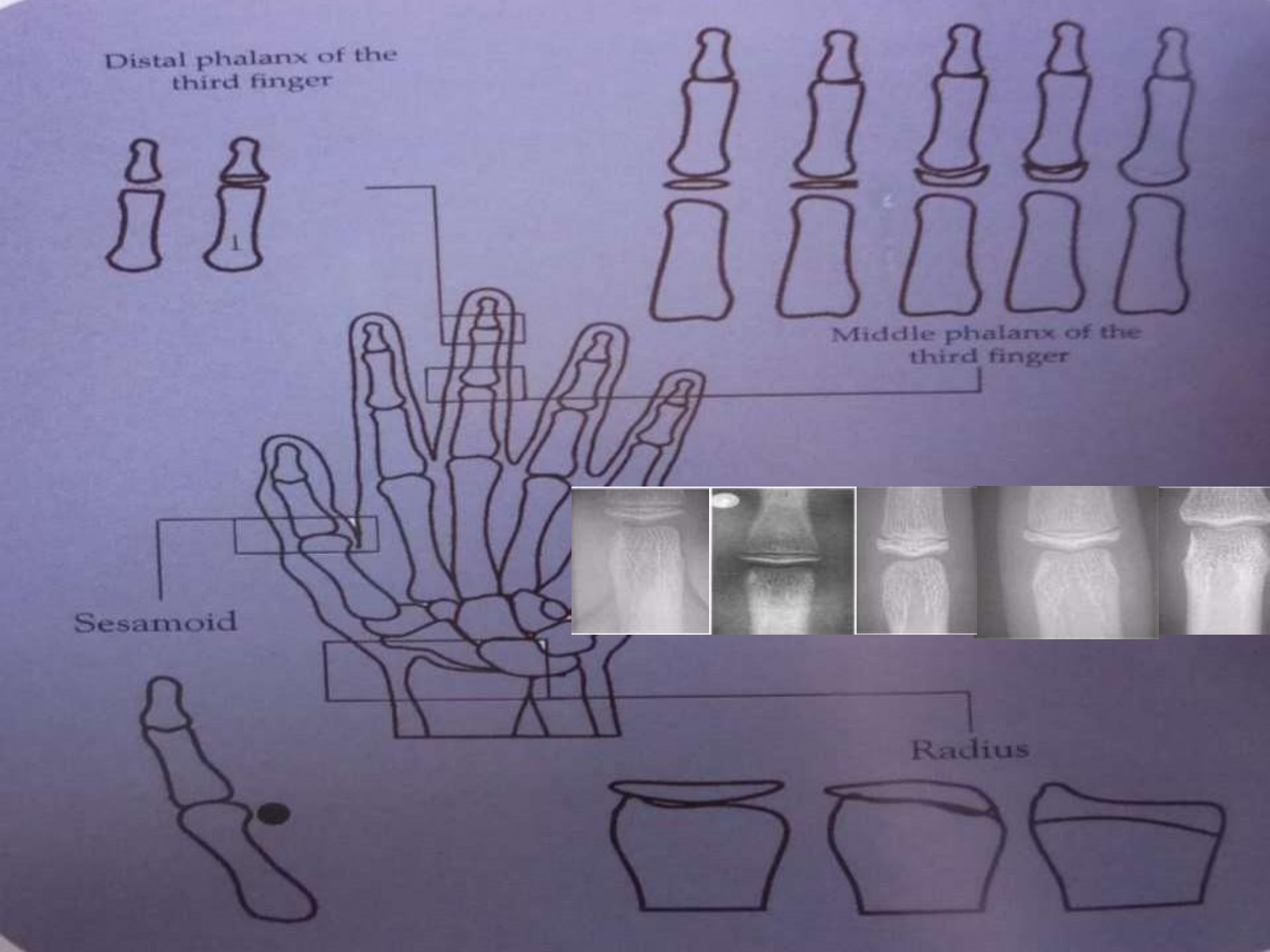
- **FUSION OF EPIPHYSISANAD IAPHYSIS OF THE RADIUS**




Epiphysis equal to diaphysis
New bone capping
fusion

HAGG & TARANGER METHOD

They described a in which skeletal development is assessed by ossification of the ulnar sesamoid of the meta carpo pharyngeal joint of the first finger and certain specified stages of three epiphyseal bones; the middle and distal phalanges of the third finger(MP3 & DP3) and the distal epiphysis of the radius

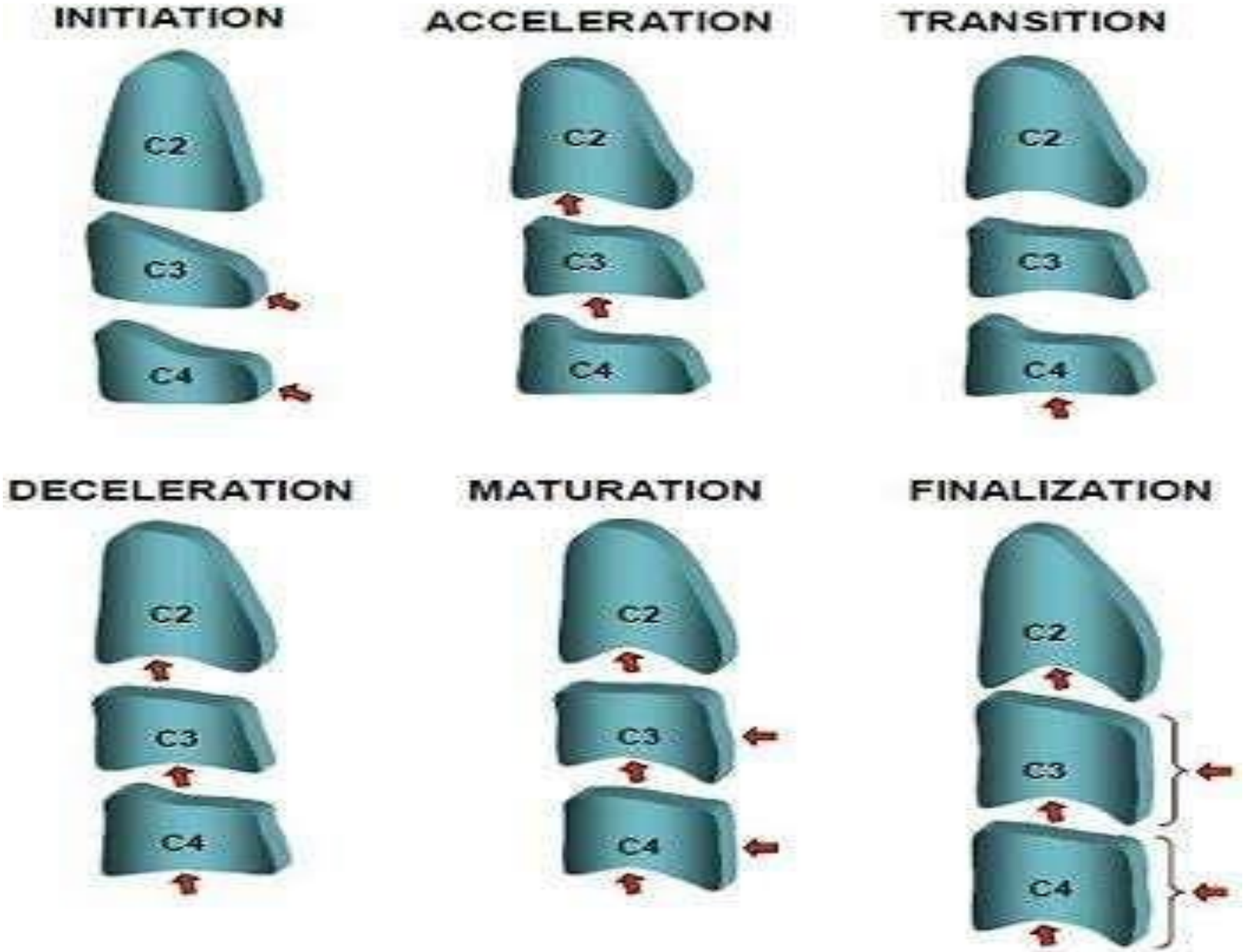

Distal phalanx of the third finger
Middle phalanx of the third finger
Sesamoid
Radius

CERVICAL VERTEBRAE MATURATION INDICATORS

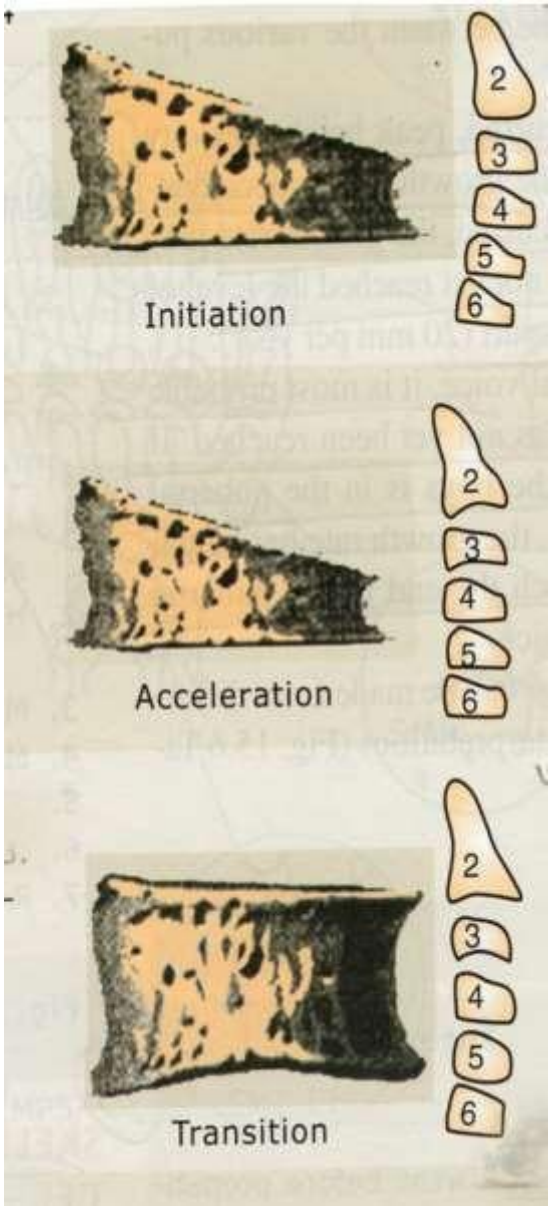
- The use of cervical vertebrae to determine skeletal maturity was suggested by Lamparski in 1972.
- The first seven vertebrae in the spinal column constitutes the cervical spine.
- The first two, the atlas and the axis are quite unique, the third through the seventh have great similarity.
- Vertebral growth takes place from the cartilaginous layer on the superior and inferior surface of each vertebrae.

Lamparski concluded that the cervical vertebrae as seen on routine cephalogram, were as statistically and clinically reliable in assessing skeletal age as the hand wrist technique.

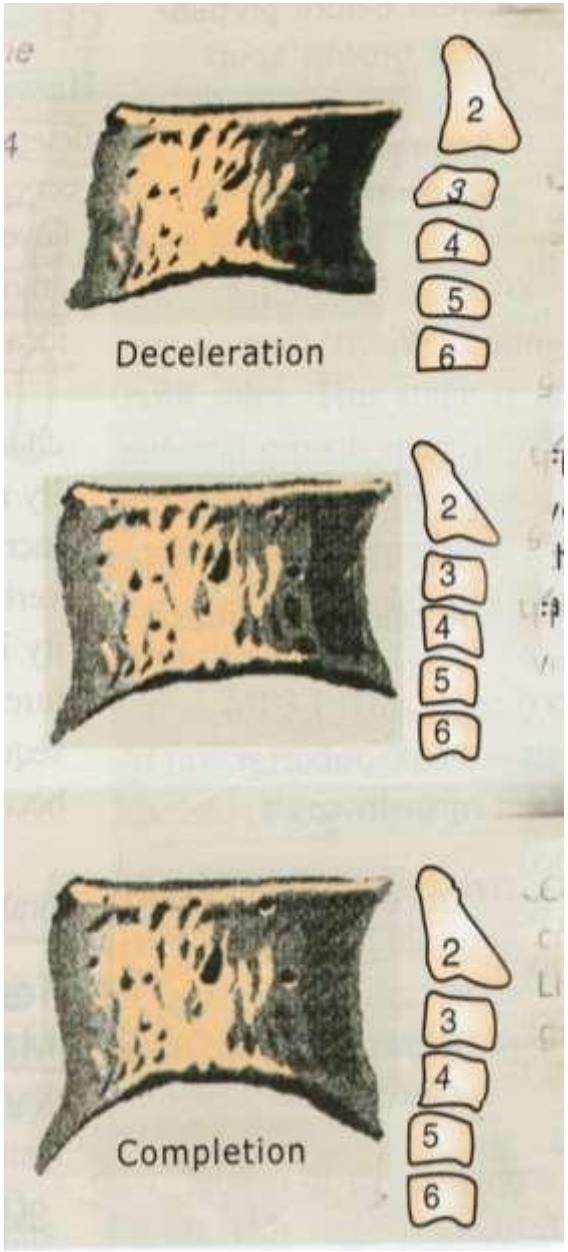
He found out that the cervical vertebral indicators were the same for the females and males, but that females developed the changes earlier.


INITIATION
C2
C3
C4
ACCELERATION
C2
C3
C4
TRANSITION
C2
C3
C4
DECELERATION
C2
C3
C4
MATURATION
C2
C3
C4
FINALIZATION
C2
C3
C4

Stage	Characteristic features	Inference
Initiation	Inferior borders of C2, C3 and C4 are flat at this stage. The vertebrae were wedge shaped, and the superior vertebral borders are tapered from posterior to anterior.	Corresponds to beginning of adolescent growth with 80% to 100% of adolescent growth expected
Acceleration	Concavities are developing in the inferior borders of C2 and C3. The inferior border of C4 is flat. The Bodies of C3 and C4 are nearly rectangular in shape.	Growth acceleration begins at this stage, with 65% to 85% of adolescent growth expected
Transition	Distinct concavities are seen in the inferior borders of C2 and C3. A concavity is beginning to develop in the inferior border of C4. The bodies of C3 and C4 are rectangular in shape.	The third stage corresponds to acceleration of growth towards peak height velocity with 25% to 65% of adolescent growth expected.



Deceleration	Distinct concavities are seen in the inferior borders of C2, C3 and C4. The vertebral bodies of C3 and C4 are becoming more square in shape.	This stage corresponds to deceleration of adolescent growth spurt with 10% to 25% of adolescent growth expected
Maturation	More accentuated concavities are seen in the inferior borders of C2, C3 and C4. The bodies of C3 and C4 are nearly square to square in shape.	Final maturation of the vertebrea took place during this stage, with 5% to 10% of adolescent growth expected.
Completion	Deep concavities are seen in the inferior borders of C2, C3, and C4. The bodies of C3 and C4 are square or are greater in vertical dimension than in horizontal dimension .	Corresponds to completion of growth. Little or no adolescent growth could be expected



TOOTH MINERALIZATION AS AN INDICATOR F SKLETAL MATURITY

The calcification patterns and stage of mineralization of the teeth is believed to have a close relationship with the skeletal maturation of an individual.

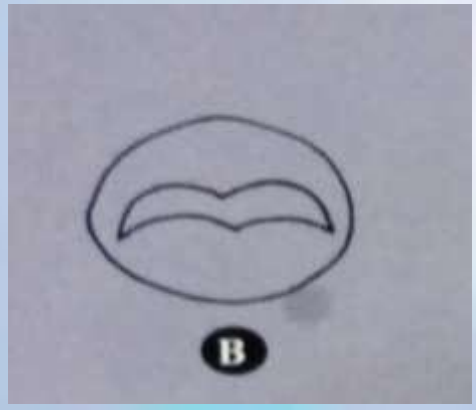
Dental development have been widely investigated as the potential skeletal maturity level.

Generally the dental development can either be assessed by the phase of tooth eruption or the stage of tooth calcification, with the latter being more reliable.

DENTAL CALCIICATION SATGES USING DEMIRJAN INDEX (DI)

STAGE A

Calcification of single occlusal points without fusion of different calcifications.

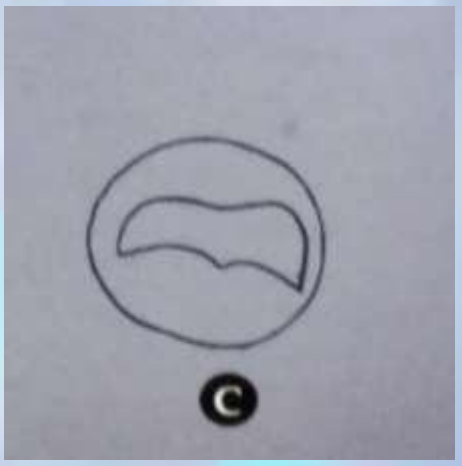


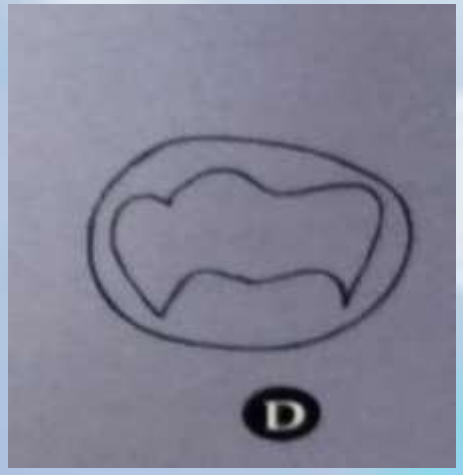
STAGE B

Fusion of mineralization points, the contour of the occlusal surface is recognizable

STAGE C

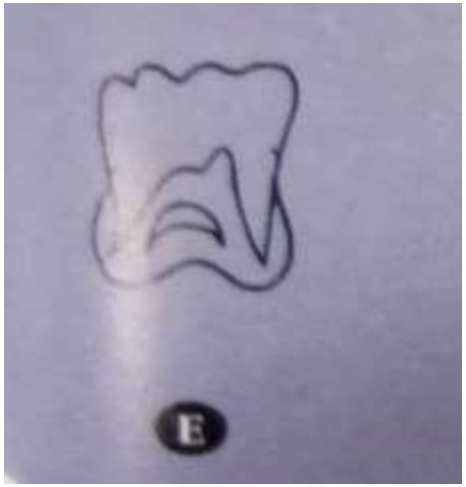
Enamel formation has been completed at the occlusal surface, dentin formation has commenced. The pulp chamber is curved, and no pulp horns are visible.





STAGE D

Crown formation has been completed to the level of the cemento – enamel junction. Root formation has commenced. Pulp horns are beginning to differentiate, but the walls of the pulp chamber remain curved.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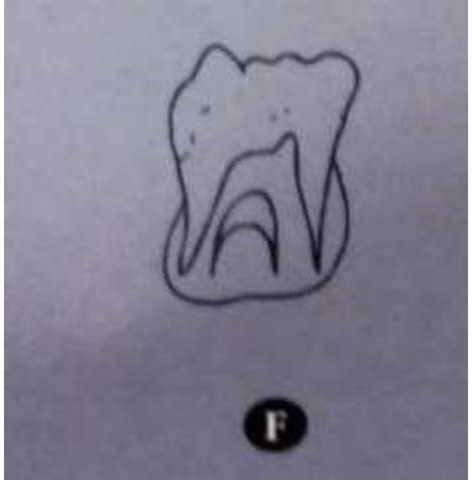

F


G


H

STAGE E

The root length remains shorter than the crown height. The walls of the pulp chamber are straight, and the pulp horns have become more differentiated than in the previous stages. In molars the radicular bifurcation has commenced to calcify.

STAGE F

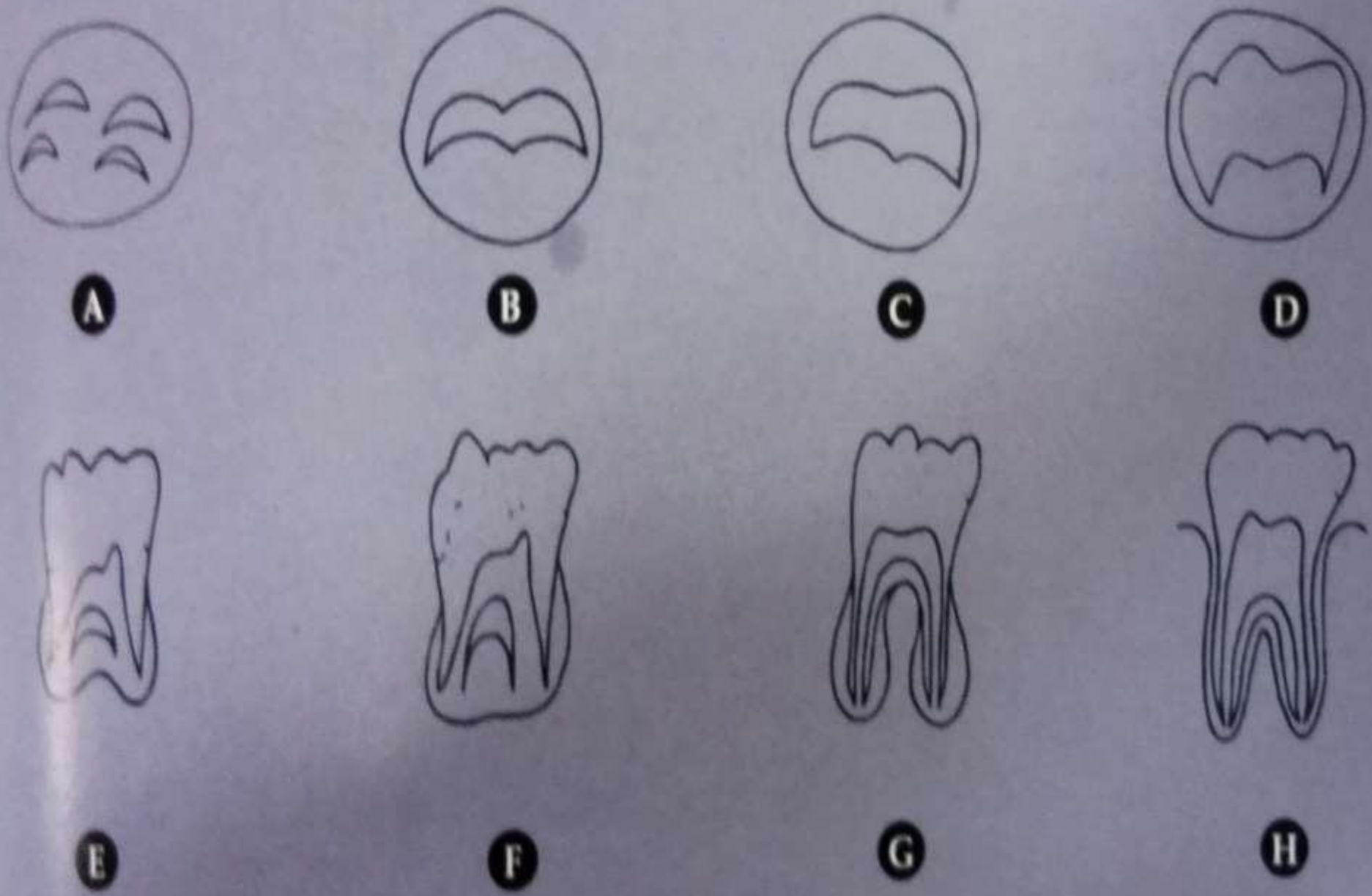
The walls of the pulp chamber now form an isoleces triangle and the root length is greater than the crown height.

STAGE G

The walls of the root canal are now parallel but the apical end is partially open.

STAGE H

The root apex is completely closed.


A
B
C
D
E
F
G
H

CONCLUSION

Clinical decisions regarding use of extraoral traction forces, functional appliances, extraction versus non extraction treatment or orthognathic surgery are atleast partially, based on growth consideration

Prediction of both the time and the amount of active growth, especially in the craniofacial complex, would be useful to the orthodontist.

REFERENCES

- Salzmann
- American Journal of Orthodontics
- Rakozi
- Contemporary Orthodontics – William Proffit
- Orthodontics, The art & science – SIBalajhi

thank you!