Growth changes of the musculoskeletal system

Children fracture healing and remodeling

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PWH

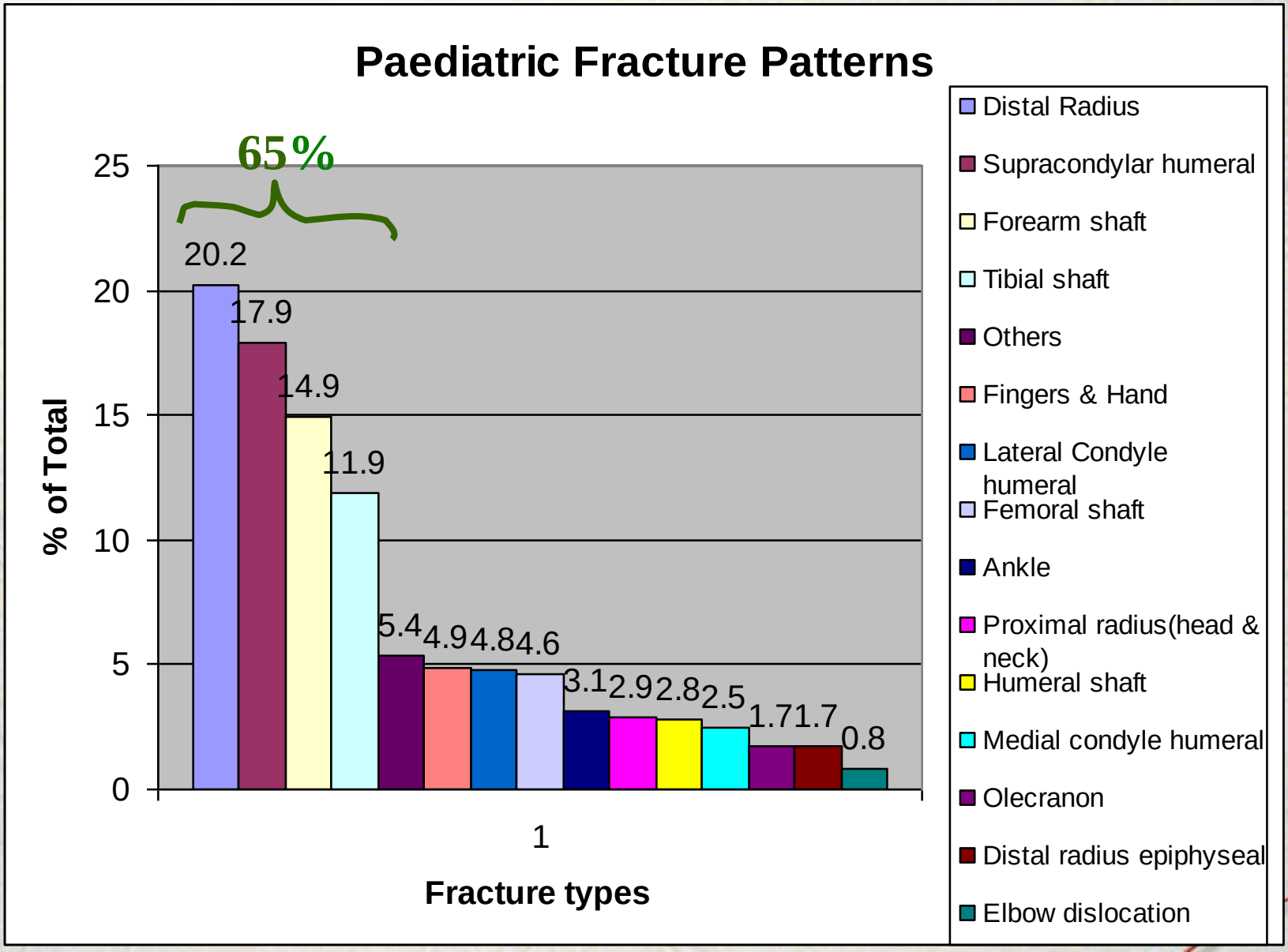
Agenda

- Basic Principles in Fracture Healing and Remodeling
- Non Accidental Injury
- Principles of Treatment Options

Epidemiology of children fracture

- 1 Distal radius fracture 20.2%
- 2 Supracondylar humeral 17.9%
- 3 Forearm shaft 14.9%
- 4 Tibial Shaft 11.9%
- 5 Fingers & hand 4.9%
- 6 Lateral condyle 4.8%
- 7 Femoral shaft 4.6%
- 8 Ankle 3.1%
- 9 Proximal radius (head & neck) 2.9%
- 10 Humeral shaft 2.8%
- 11 Medial Condyle humeral 2.5%
- 12 Olecranon 1.7%
- 13 Distal radius epiphyseal 1.7%
- 14 Elbow dislocation 0.8%
- 15 Rarities 5.4%

Review of 6493 fractures JCY Cheng et al JPO 19:344-350 1999


Paediatric Fracture Patterns
65%
% of Total
25
20
15
10
5
0
20.2
17.9
14.9
11.9
5.4
4.9
4.8
4.6
3.1
2.9
2.8
2.5
1.7
1.7
0.8
1
Fracture types
Distal Radius
Supracondylar humeral
Forearm shaft
Tibial shaft
Others
Fingers & Hand
Lateral Condyle humeral
Femoral shaft
Ankle
Proximal radius(head & neck)
Humeral shaft
Medial condyle humeral
Olecranon
Distal radius epiphyseal
Elbow dislocation

Chilren ≠
Small adult

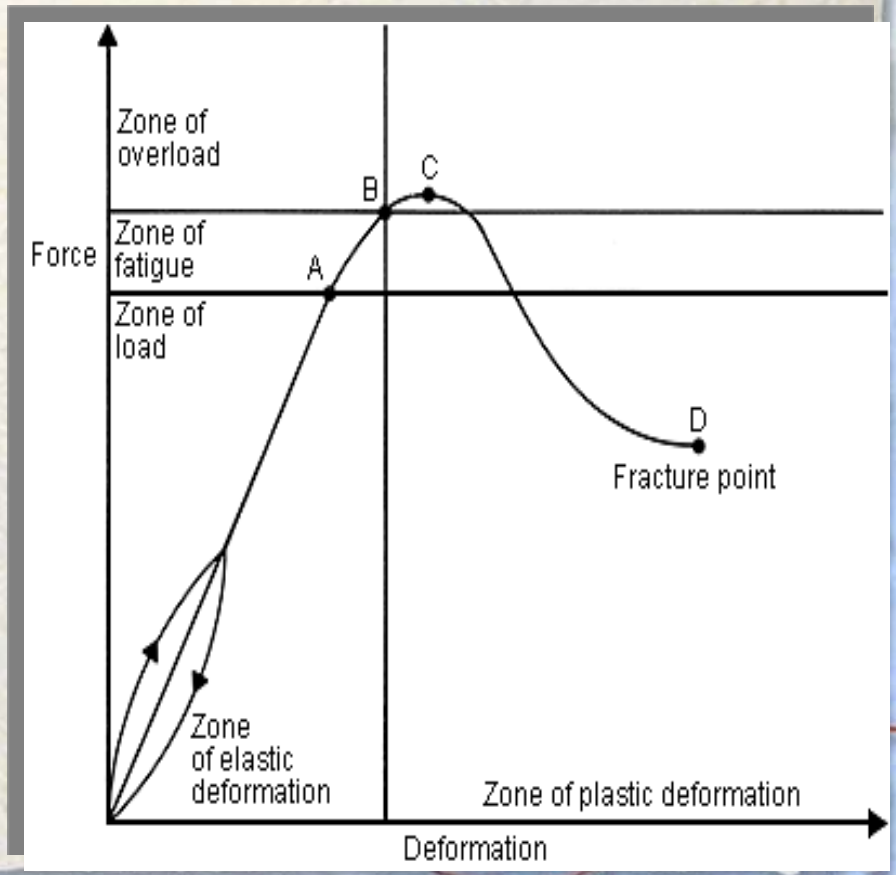
Chilren ≠ Small adult

- Bone quality
- Periosteum
- Ligament
- Growth plate

Bone

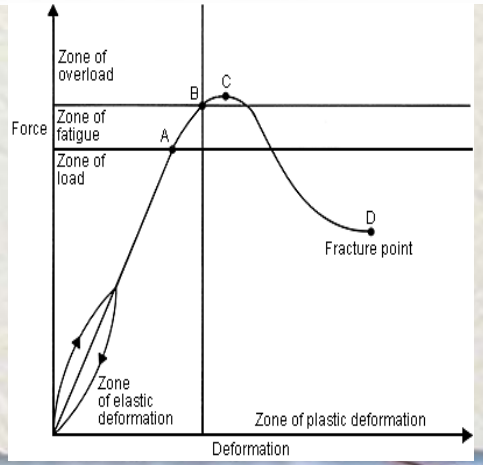
Higher collagen to bone ratio in paediatric bone

- Lower modulus of elasticity (less brittle) and higher ultimate strain to failure ratio than adult



Plastic Deformation

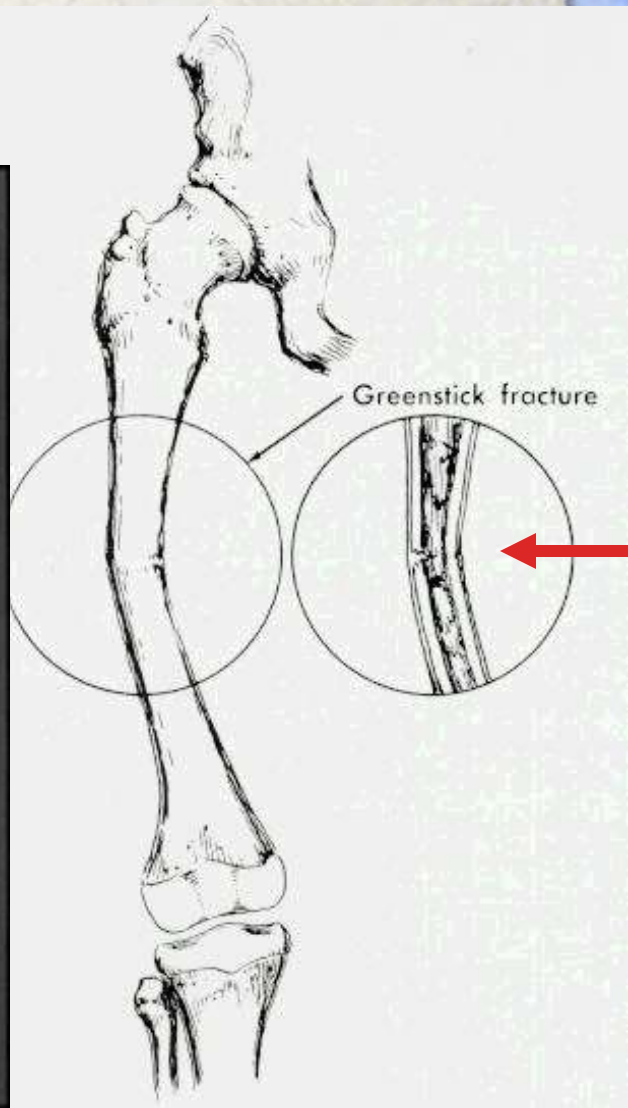
- Fixed bending remains when bone deformed past elastic limit
- Most commonly in forearm, fibula
- Periosteum intact and thus usually no periosteal callus
- Permanent deformity can result



greenstick fracture

(A) direct impact perpendicular to the axis of the long bone:

-periosteal stripping on convex side of the fracture:



Plastic Deformation

(B) longitudinal compression – impact parallel to the axis of the long bone results in incomplete fractures

(1) bowing (plastic deformity)

Plastic Deformation

- Remodeling not as reliable
- Significant curvature should be corrected
- General anesthesia
- Considerable force
- Slowly applied over a padded fulcrum

Comminuted fracture uncommon

- Higher cellular and porous
  - Reduce tensile strength
  - Reduce the tendency of fractures to propagates

Bone

- Bone fails in both tension and compression
  - Mechanism of buckle fracture in children

Bone

- Bone transitions
  - Between the metaphysis and diaphysis cause a mechanical discontinuity leading to certain fracture types

Buckle or Torus Fracture

- Compression failure
- Stable
- Usually at metaphyseal / diaphyseal junction

Bone-Blood Supply

- The blood supply is different
  - a rich metaphyseal circulation with fine capillary loops ending at the physis
  - In neonate, small vessels may transverse the physis and end in epiphysis

Periosteum

- Periosteum in children is thicker and stronger
  - Offer additional resistance to shear force
  - Little displacement, help in reduction

Greenstick Fractures

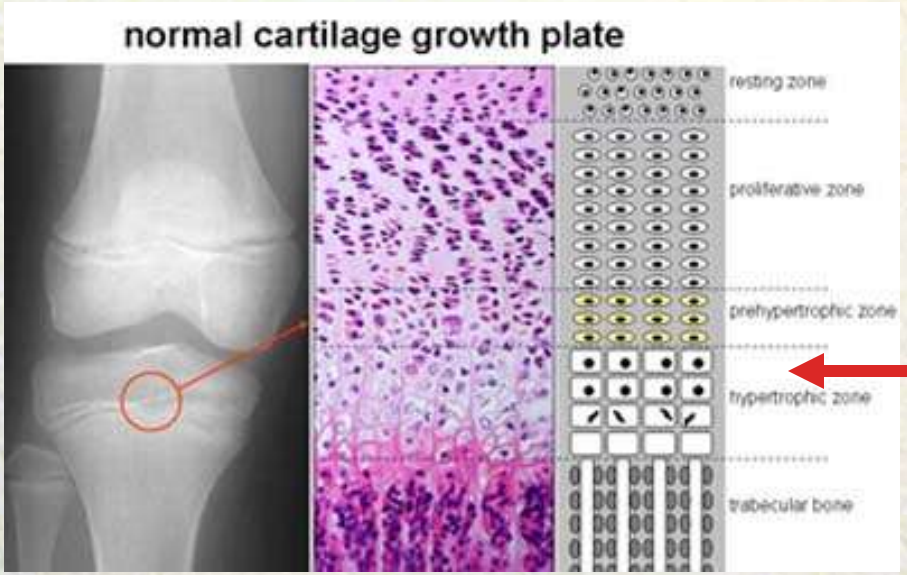
- Bending mechanism
- Failure on tension side
- Incomplete fracture, plastic deformation on compression side

- May need to complete fracture to realign

Ligaments

- Ligaments in children are functionally stronger than bone
  - –Force that procedure sprains in adults result in fracture in children

Physeal Fractures



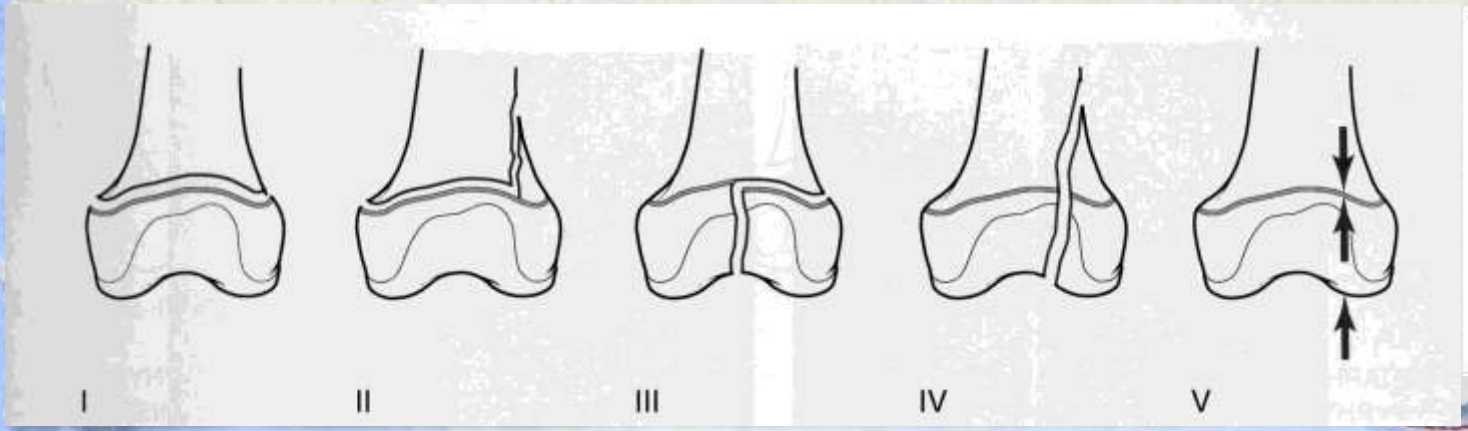
- Traditionally believed to occur primarily through zone of hypertrophy
- Some fractures may traverse more than one zone

Growth plate

- The physis is weaker than bone in torsion, shear and bending
- Potential for remodeling
- Growth plate injury causes deformity

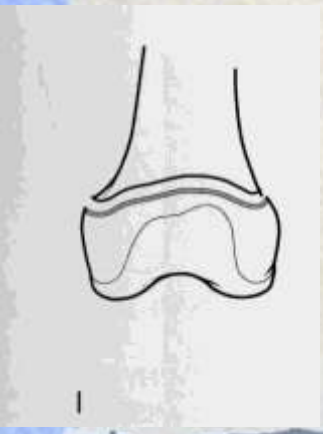
Physeal fractures

- Salter-Harris classification
  - I - # across physis
  - II - # across physis and metaphysis
  - III - # across part of physis & epiphysis
  - IV - # across metaphysis, physis & epiphysis
  - V - crush injury of physis without fracture
  - VI - Perichondral ring injury



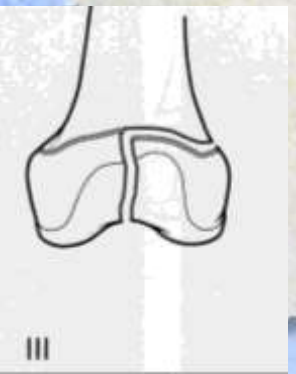
Physeal fracture

- Type I
  - Transphyseal fracture involving the hypertrophic and calcified zones
  - Prognosis is excellent, although complete or partial growth arrest may occur in displaced fracture

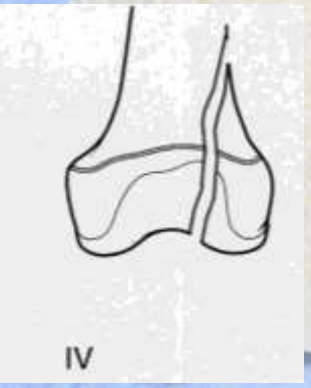


- Type II
  - Transphyseal fracture that exits the metaphysis
  - The metaphyseal fragment is call Thurston Holland fragment
  - The periosteal hinge is intact on the side with metaphyseal fragment
  - Prognosis is excellent, although complete or partial growth arrest may occur in displaced fracture

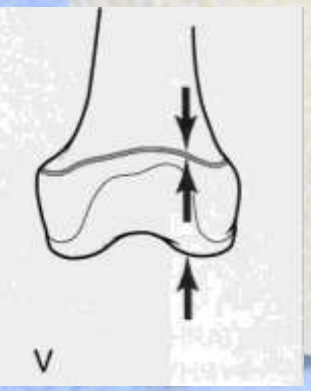
- Type III
  - Exits the epiphysis, causing intra-articular disruption
  - anatomic reduction and fixation without violating the physis are essential
  - Prognosis is guarded, partial growth arrest and angular deformity are common



- Type IV
  - Transverse epiphysis, physis and metaphysis
  - anatomic reduction and fixation without violating the physis are essential
  - Prognosis is guarded, partial growth arrest and angular deformity are common



- Type V
  - Diagnosis is generally made retrospectively
  - Prognosis is poor
  - growth arrest and partial physeal closure common



Growth Arrest Secondary to Physeal Injury

- Complete cessation → limb length discrepancy

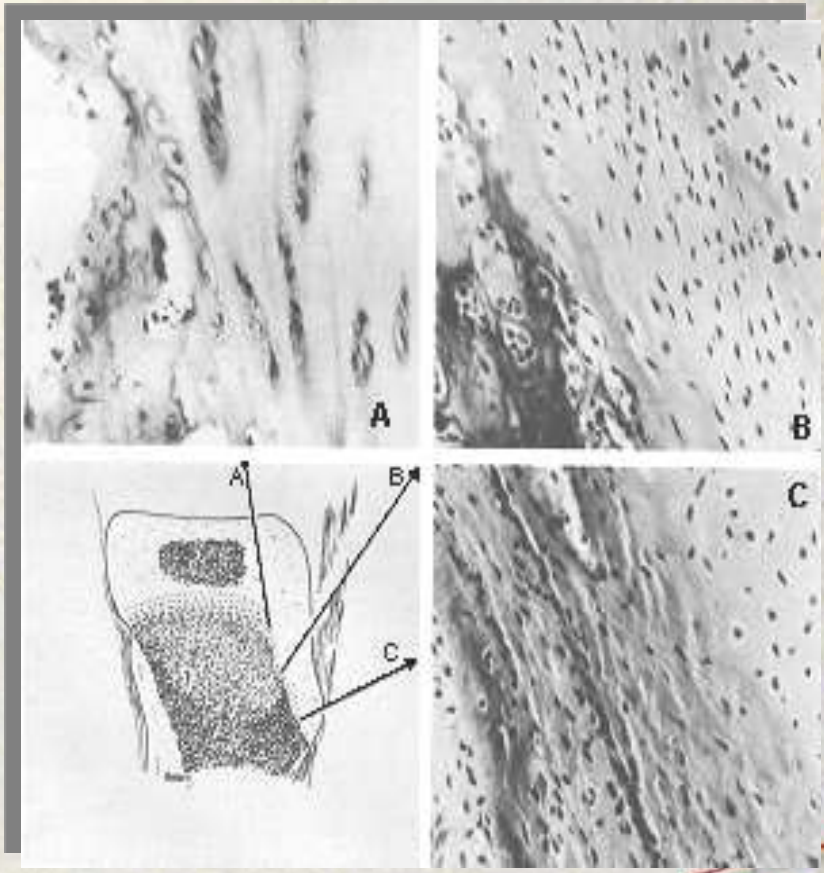
- Partial cessation

→angular deformity if peripheral

→progressive shortening if central

Epiphysis or Apophysis?

- Epiphysis - forces are compressive on physeal plate
- Apophysis - forces are tensile
- Histologically distinct

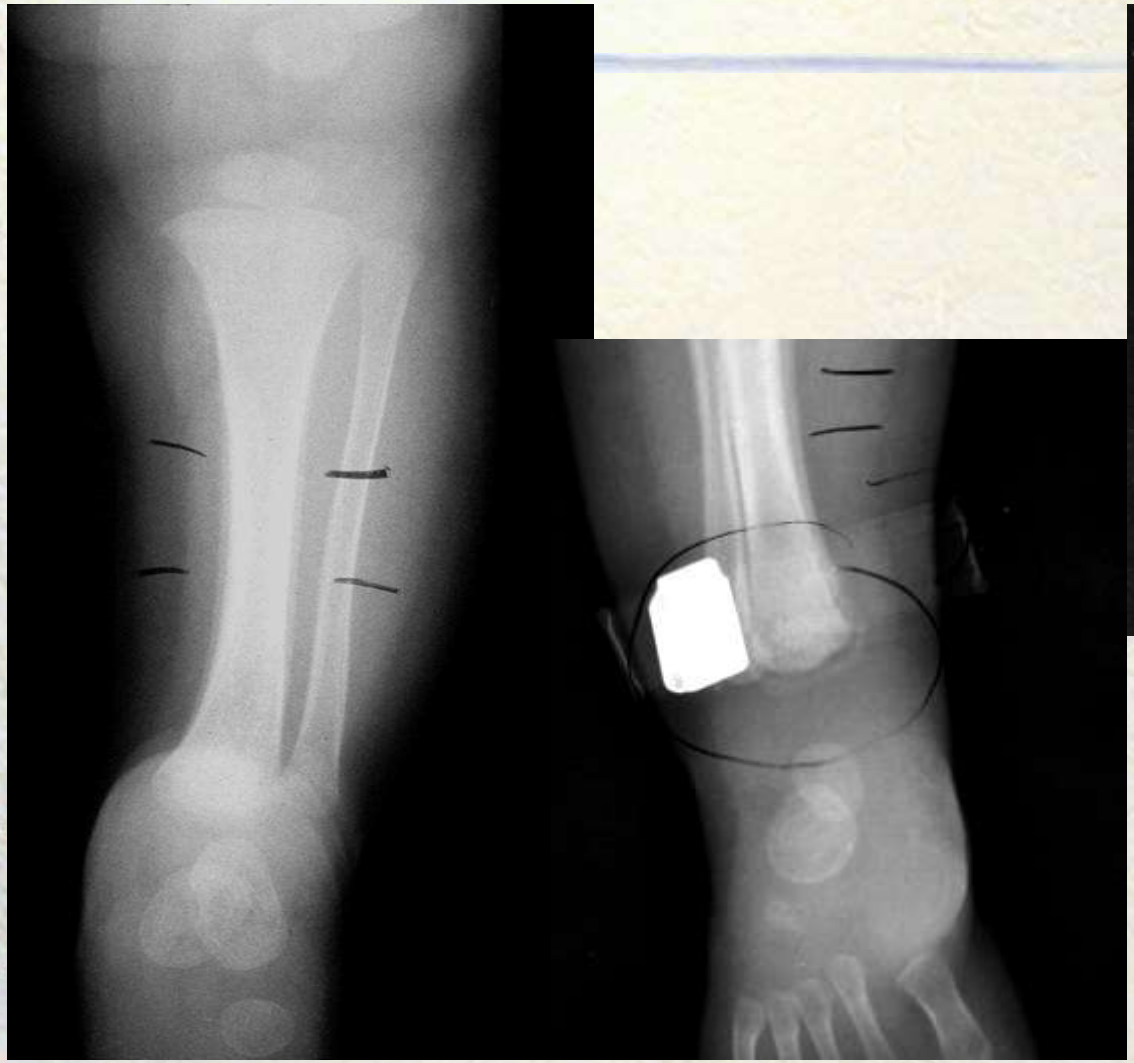


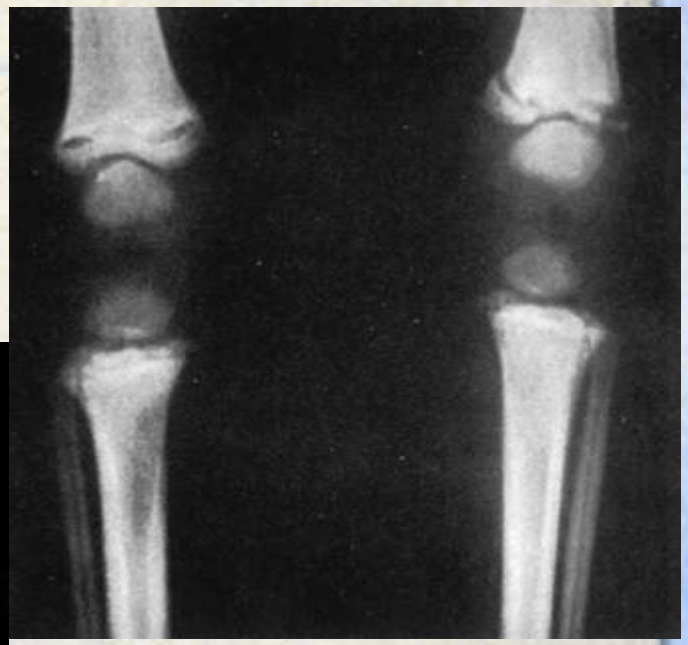
Apophyseal Injuries

- Tibial tubercle
- Medial Epicondyle
- May be preceded by chronic injury/repetitive processes

Non-accidental injury

Radiographic Findings in NAI





Radiographic Findings in NAI

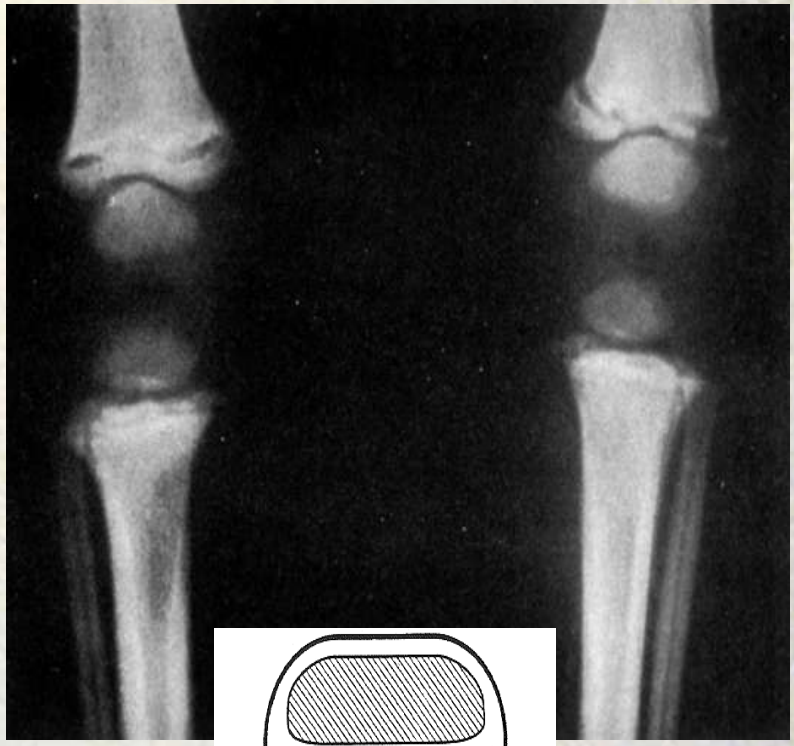
- Fracture pattern not specific (spiral, transverse, etc.)
- Metaphyseal Corner # or Bucket Handle #
- Multiple fractures at different stages of healing highly specific

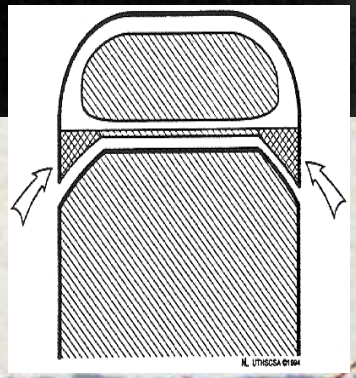
- Humerus diaphyseal # < 3 yo are almost always associated with NAI
- Femur # < 1 yo are usually due to NAI
- Risk or re-abuse is 35% and risk of death 5-10%

Metaphyseal Corner # or Bucket Handle

- Pathognomonic of NAI
- Traction/rotation mechanism of injury

- Planar fracture through primary spongiosa





DDX: NAI

- Accidental trauma/Birth trauma
- Osteogenesis Imperfecta
- Metabolic Bone Disease (rickets, etc.)
- Physiologic periostitis

Management

General Principles

- Acute Fracture Care
  - immobilization of joints above and below
    - provides comfort, reduces deformity, reduces risk of additional injury
    - cast or splint depending on anticipated swelling & compartment syndrome

Post-fracture care

- Post-fracture Care
  - F/U to ensure union & restoration of alignment and length

Special Considerations

- Open fracture
- Compartment Syndrome
- Pathologic Fracture
  - tumors e.g. osteosarcoma
  - hereditary diseases e.g. osteogenesis imperfecta
  - metabolic diseases e.g. rickets
  - neuromuscular diseases e.g. Muscular Dystrophy
  - infectious diseases e.g. osteomyelitis

Treatment options

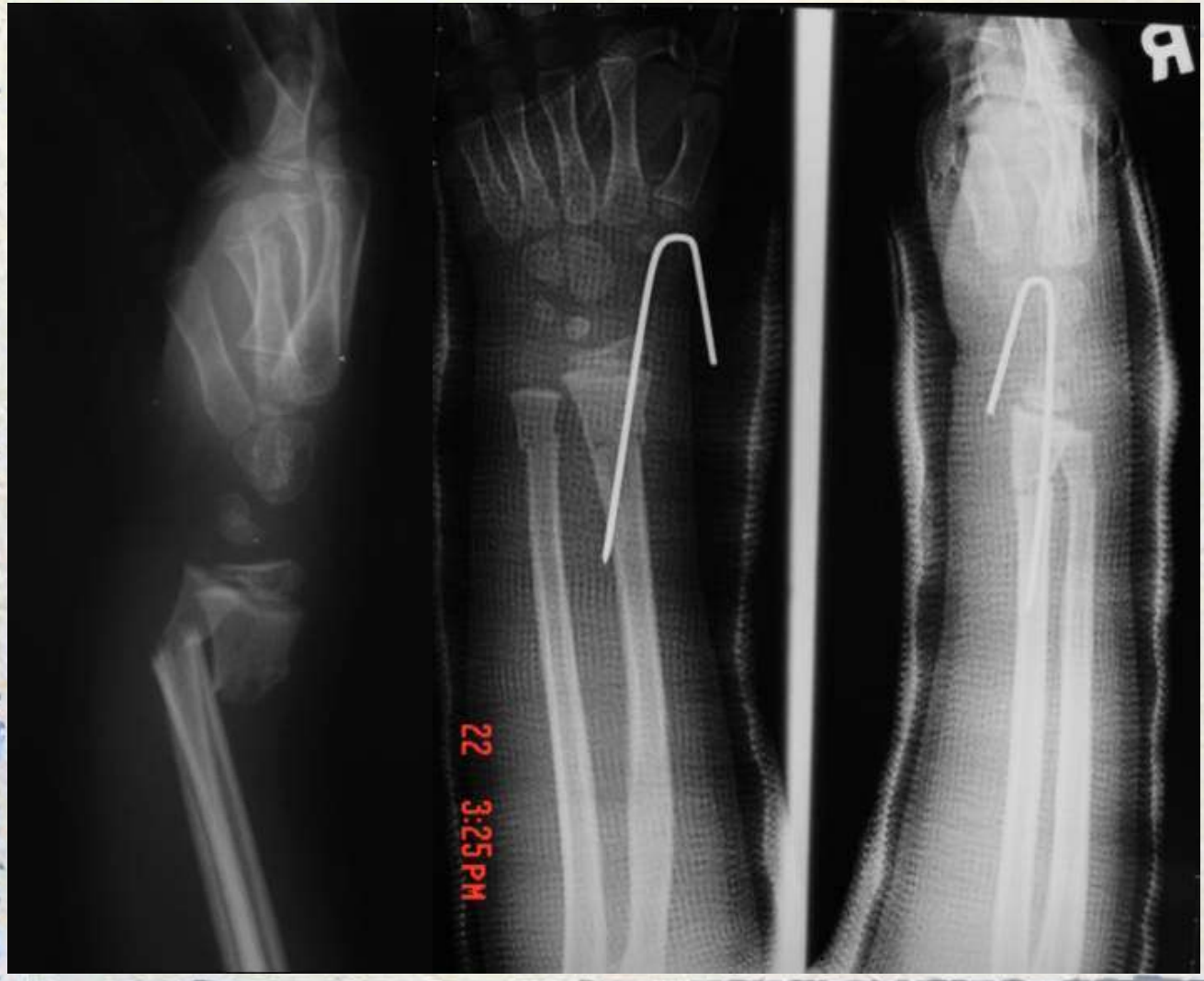
Most upper limb #- 90/90 elevation

Most Lower limb # Back slab

Treatment of minimal / Un-displaced


8°


Completely Displaced Fractures



Closed/
Open
Reduction
+ K-wire
Fiation
+ Casting

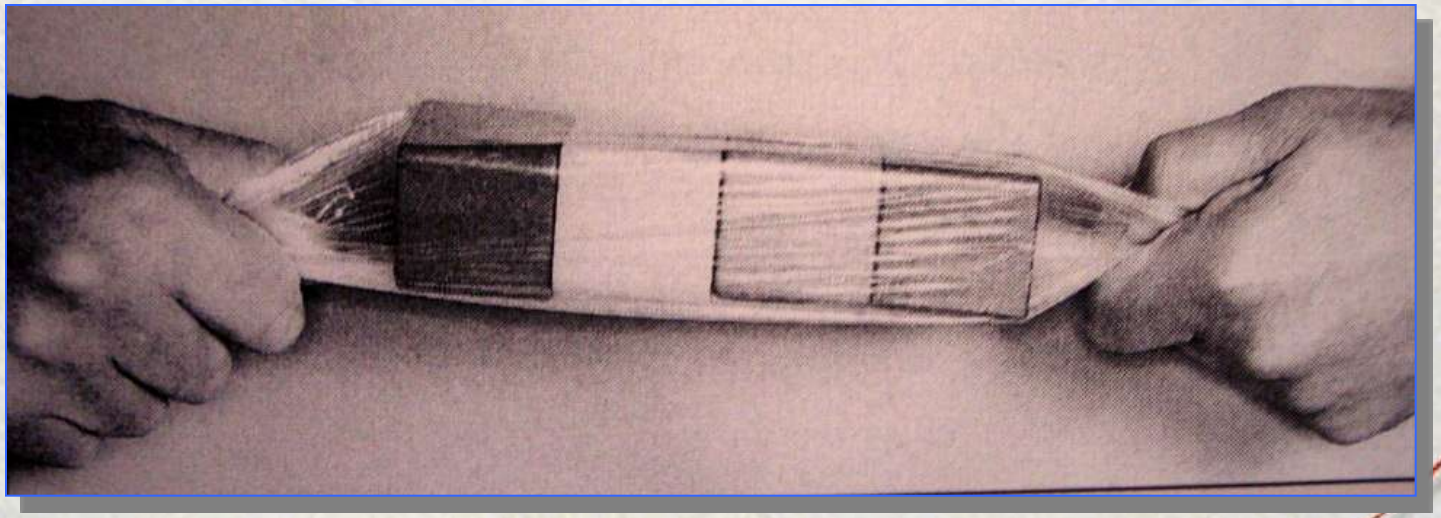
Excellent remodelling power

Forearm shaft

Tibial Shaft , Wedging Works Beautifully !

Traction Principle

- Traction produces a reduction through the surrounding soft parts which align the fragments by their tension.



Purpose

*Regain normal length and alignment of involved bone

*Reduce and immobilize a fractured bone

*Lessen or eliminate muscle spasms

*Relieve pressure on nerves, especially spinal

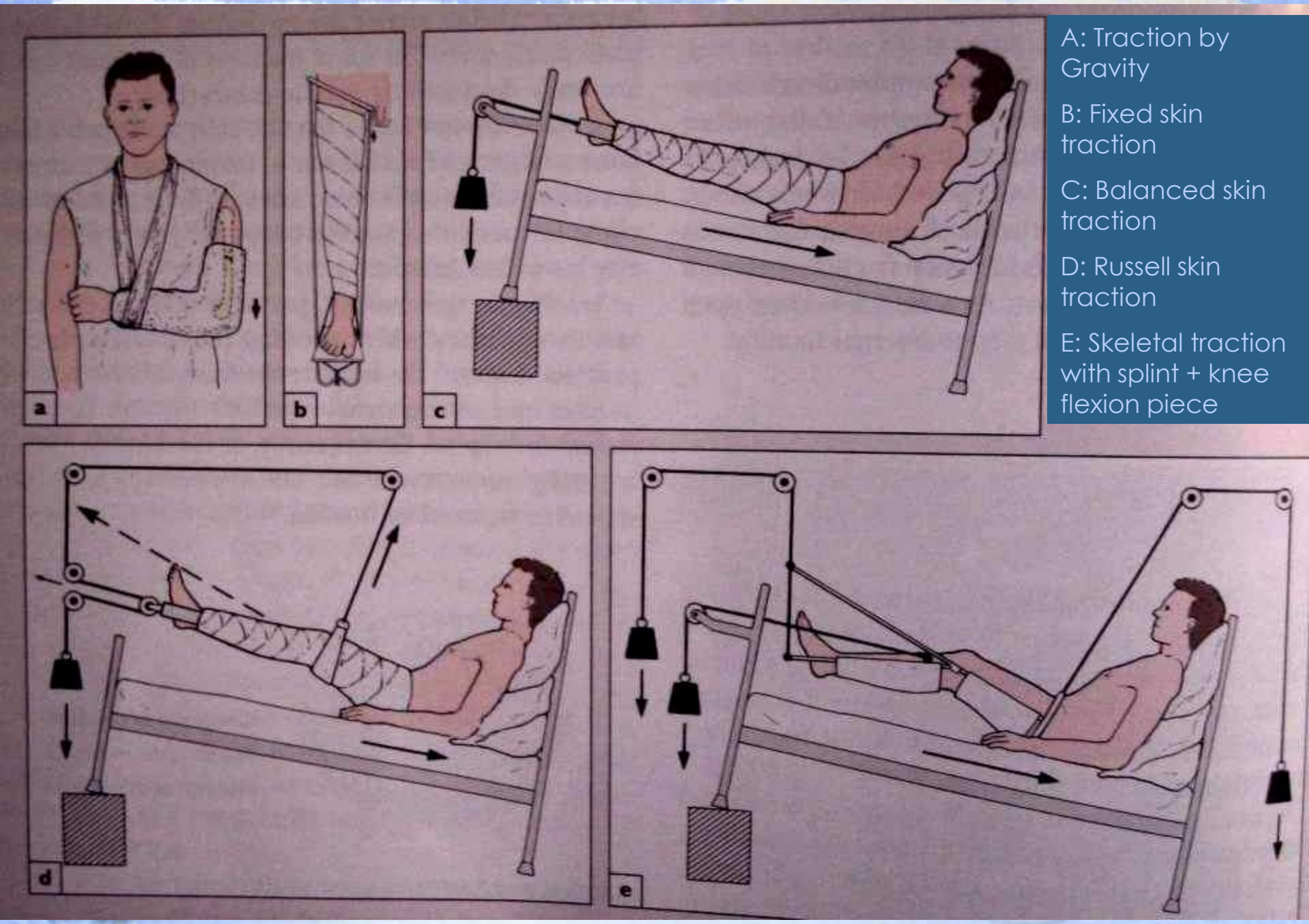
*Prevent or reduce skeletal deformities or muscle contractures

Mechanism of traction

- Every force has an equal and opposite force
- Applied in different ways
  - Fixed traction with a splint
  - Fixed traction using gravity
  - Sliding traction
  - Balanced traction

Classification

- Defined by force
  - Traction by gravity
  - Skin traction
  - Skeletal traction
- Defined by configuration
  - Fixed traction
  - Balance traction
  - Combined traction



A: Traction by Gravity

B: Fixed skin traction

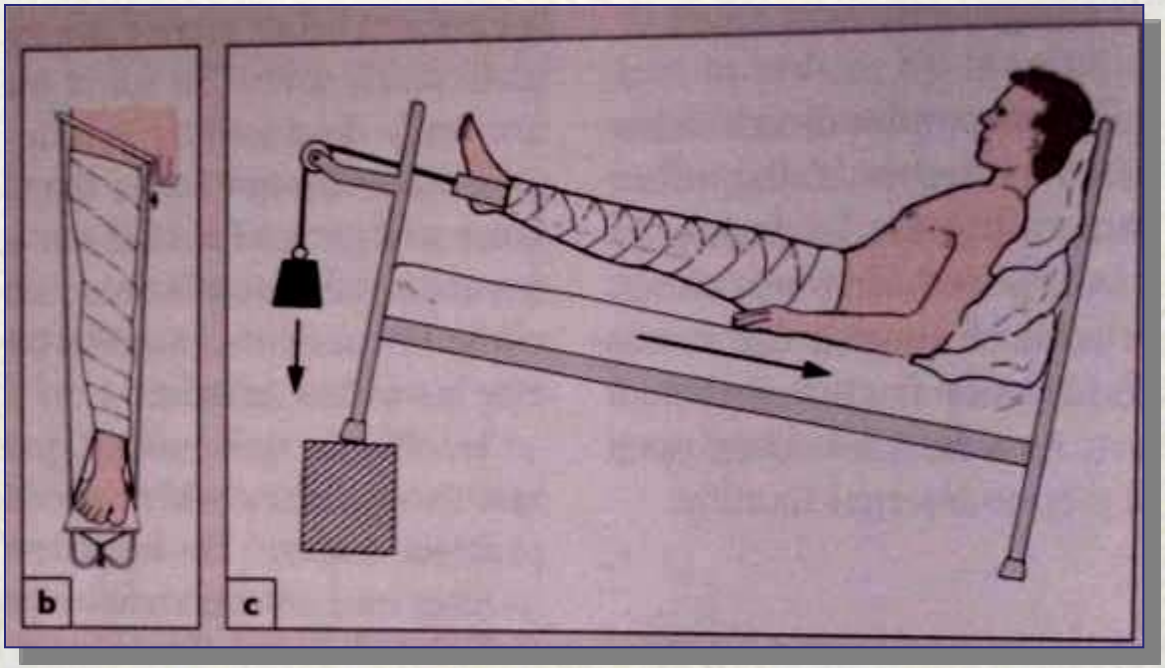
C: Balanced skin traction

D: Russell skin traction

E: Skeletal traction with splint + knee flexion piece

Skin traction

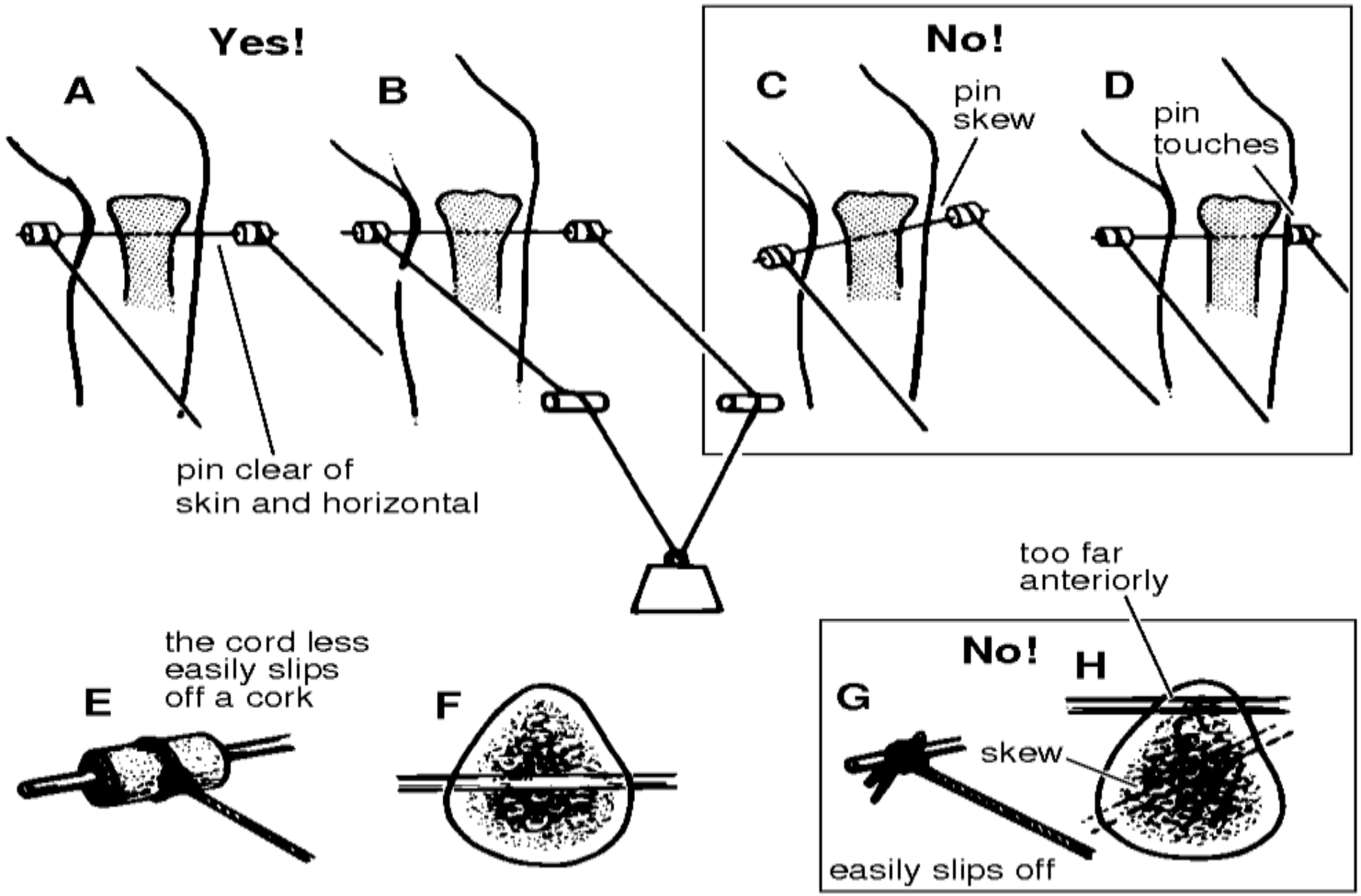
- 12 lb (5kg) is the upper limit



Skeletal Traction

- Max. 18kg(40lb) can be used
- Allow joint motion exercise
- Useful for femur fracture in paediatric

TIBIAL TRACTION – RIGHT AND WRONG



External fixation

Flexible and Rigid Intramedullary Nail

Compression plating

Children ≠ Small Adult

Thankyou