Principles of External Fixation

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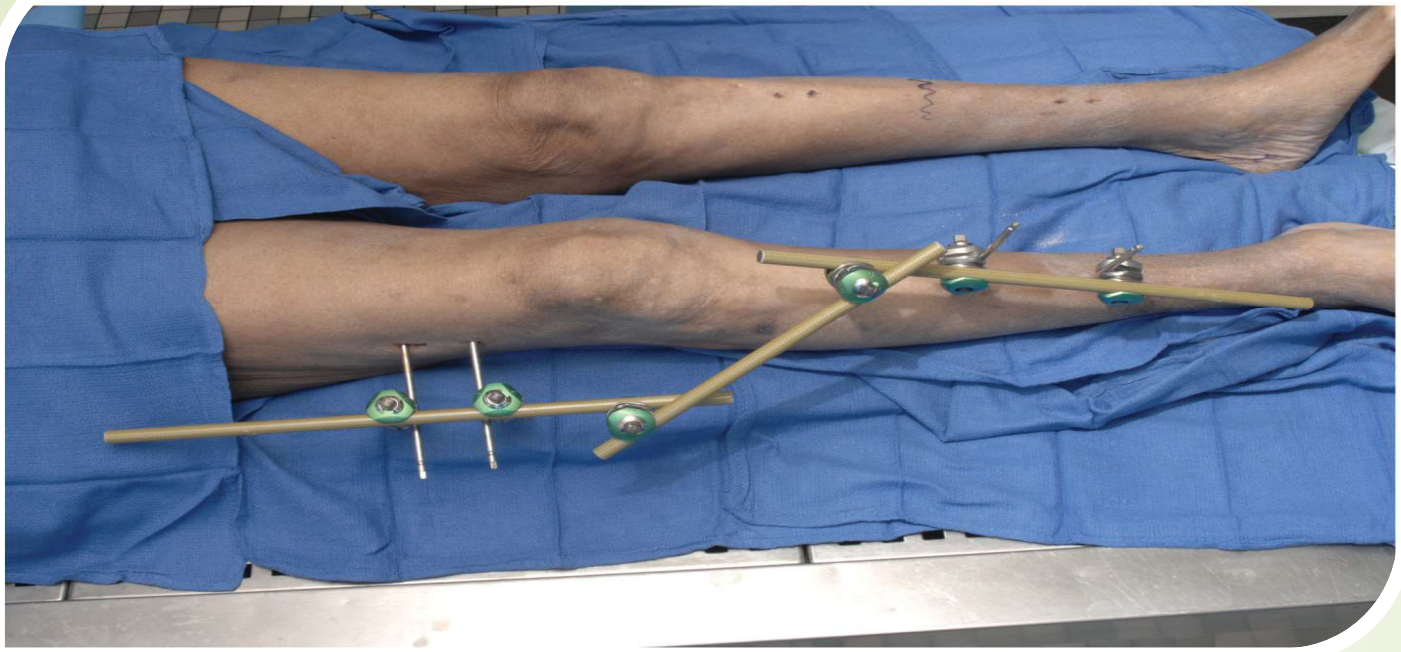
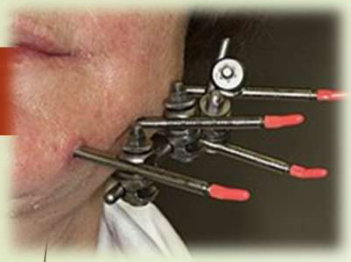
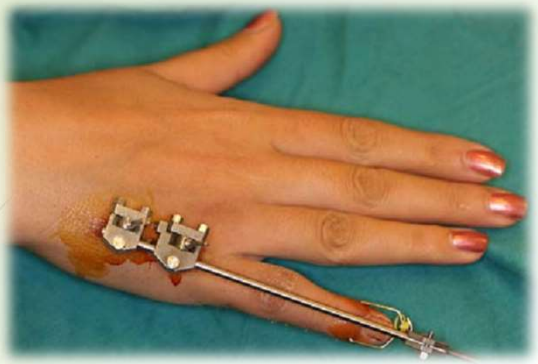


- External fixation: a procedure that stabilizes joints and bones by an external measures.
- External fixator : a device for stabilizing bones ….

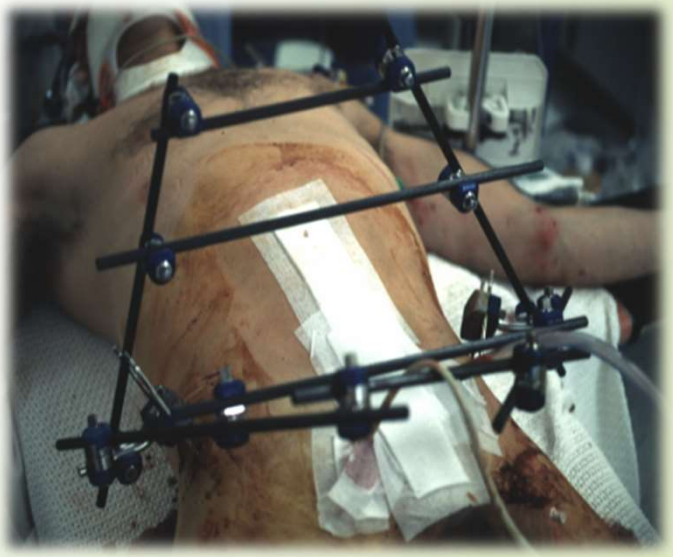



Indications

- **Definitive fracture care:**
  - Open fractures
  - Peri-articular fractures
  - Pediatric fractures
- **Temporary fracture care**
  - "Damage control"
    - Long bone fracture temporization
  - Pelvic ring injury
  - Peri-articular fractures
    - Pilon fracture
- **Malunion/ nonunion**
- **Arthrodesis**
- **Osteomyelitis**
- **Limb deformity/length inequality**
  - Congenital
  - Acquired

Advantages

- Minimally invasive
- Flexibility (build to fit)
- Quick application
- Useful both as a **temporizing** or **definitive** stabilization device
- Reconstructive and salvage applications
- Less worry of infection



Disadvantages

- Mechanical
  - Distraction of fracture site
  - Inadequate immobilization
  - Pin-bone interface failure
  - Weight/ bulk
  - Re-fracture
- Biologic
  - Infection (pin track)
    - May preclude conversion to IM nailing or internal fixation
  - Neurovascular injury
  - Tethering of muscle
  - Soft tissue contracture

Femur frame

Humerus frame

Components of External Fixator

Pins

Connecting rods

Clamps

Pins

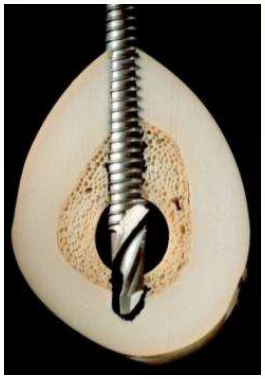
- The pin is the critical link between the bone and the frame.
- Pin diameter?
  - Pin must be < 1/3 bone diameter to prevent pin hole fractures;
- Bending stiffness
  - proportional to r^4
  - 5mm pin 144% stiffer than 4mm pin
- Pin Diameter Guidelines
  - Femur – 5 or 6 mm
  - Tibia – 5 or 6 mm
  - Humerus – 5 mm
  - Forearm – 4 mm
  - Hand, Foot – 3 mm

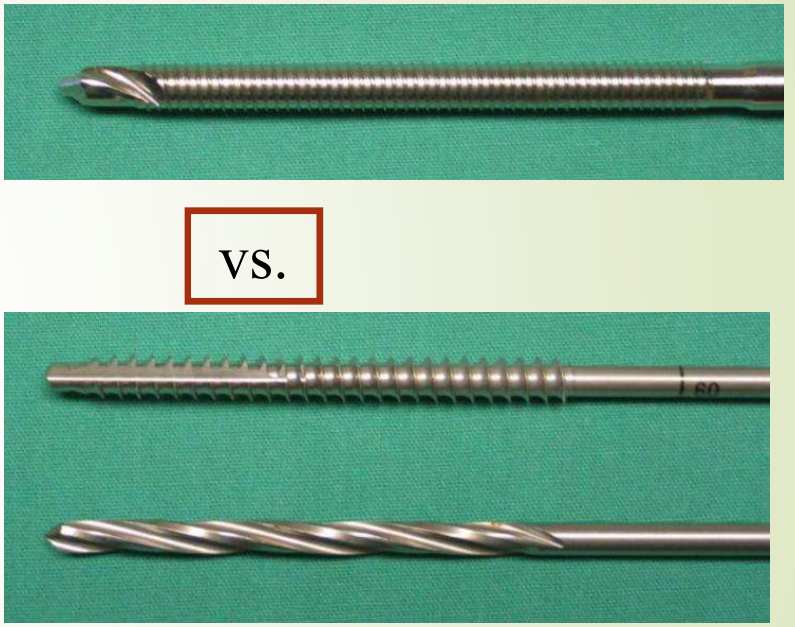
- Various diameters, lengths, and designs
  - 2.5 mm pin
  - 4 mm short thread pin
  - 5 mm predrilled pin
  - 6 mm tapered or conical pin
  - 5 mm self-drilling and self tapping pin
  - 5 mm centrally threaded pin

- Pin Geometry
  - Blunt pins
    - Straight
    - Conical
  - Self Drilling and Tapping

- Materials
  - Stainless steel
  - Titanium
    - More biocompatible
    - Less stiff

- Self drilling pin:
  - Short drill flutes
    - thermal necrosis
    - stripping of near cortex with far cortex contact
  - Quick insertion
  - Useful for short term applications

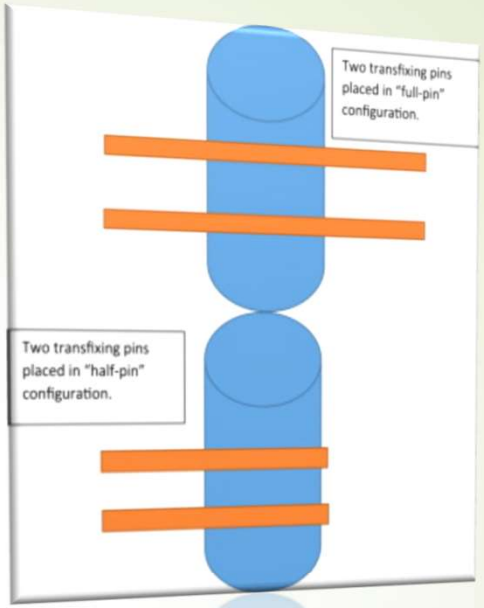


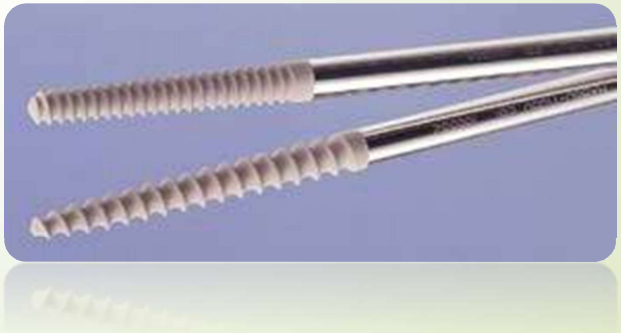


Pin Length

- Half Pins
  - single point of entry
  - Engage two cortices
- Trans-fixation Pins
  - Bilateral, uniplanar fixation
  - lower stresses at pin bone interface
  - Limited anatomic sites (neurovascular injury)
  - Traveling traction

- Pin coatings
  - (Chlorohexidine, Silver, Hydroxyapatite)
    - Improve fixation to bone
    - Decrease infection





Clamps

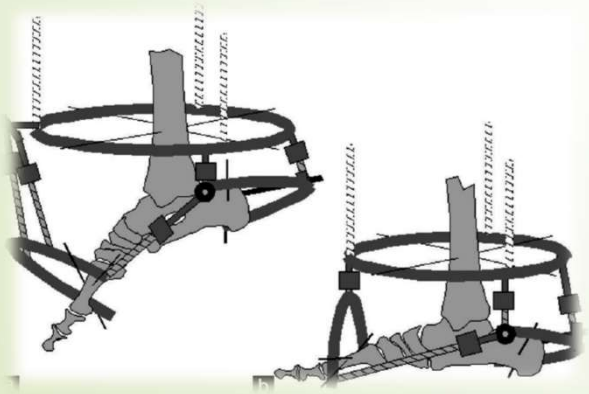
- Two general varieties:
  - Single pin to bar clamps
  - Multiple pin to bar clamps
- Features:
  - Multi-planar adjustability
  - Open vs closed end
- Principles
  - Must securely hold the frame to the pin
  - Clamps placed closer to bone increases the stiffness of the entire fixator construct

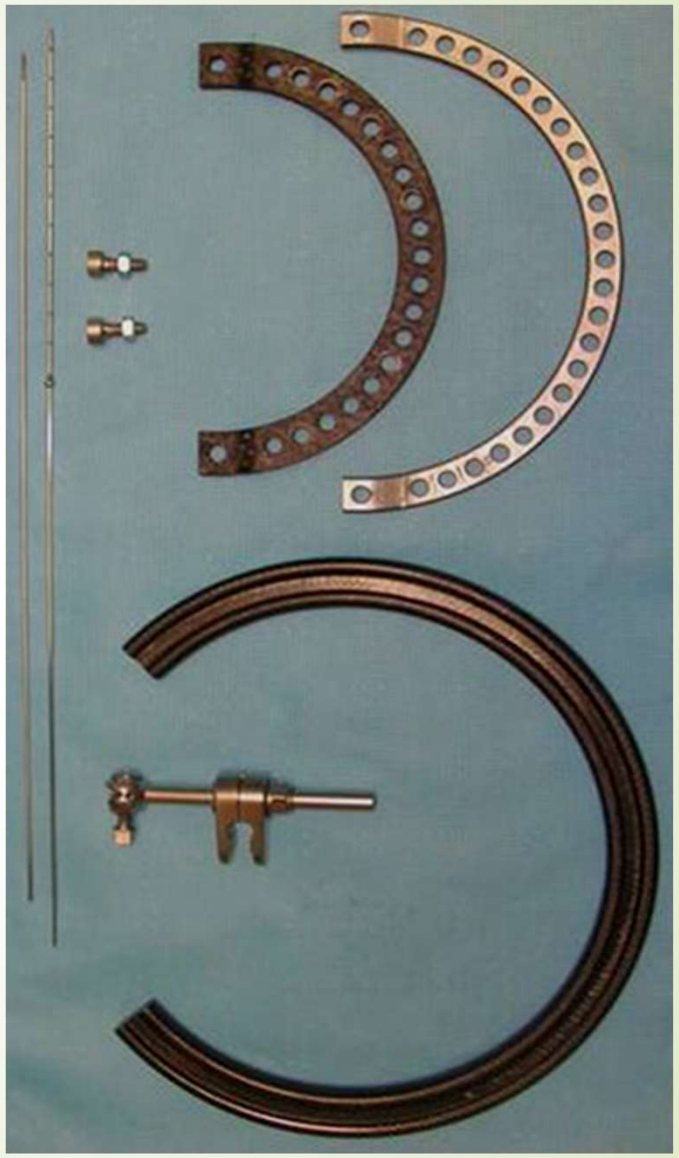
Connecting Rods and/or Frames

- Options:
  - materials:
    - Steel
    - Aluminum
    - Carbon fiber (radiolucent)
  - Design
    - Simple rod
    - Articulated
    - Telescoping
- Principle
  - increased diameter = increased stiffness and strength
  - Stacked (2 parallel bars) = increased stiffness

Ring Fixators

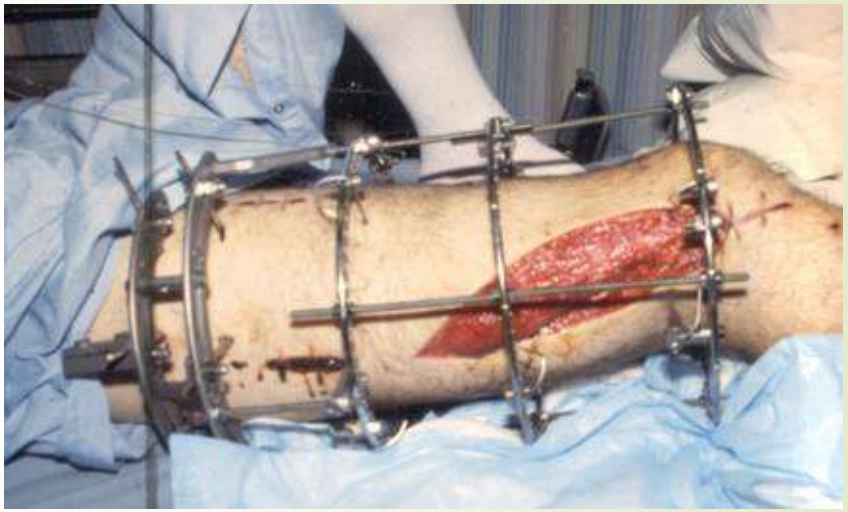
- Components:
  - Tensioned thin wires
    - olive or straight
  - Wire and half pin clamps
  - Rings
  - Rods
  - Motors and hinges





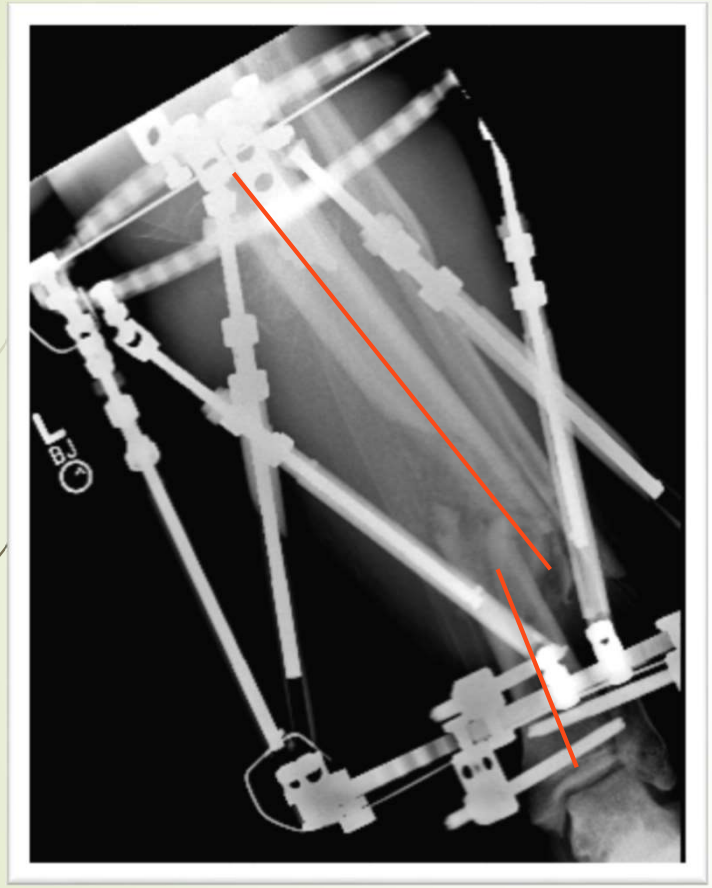
Ring Fixators

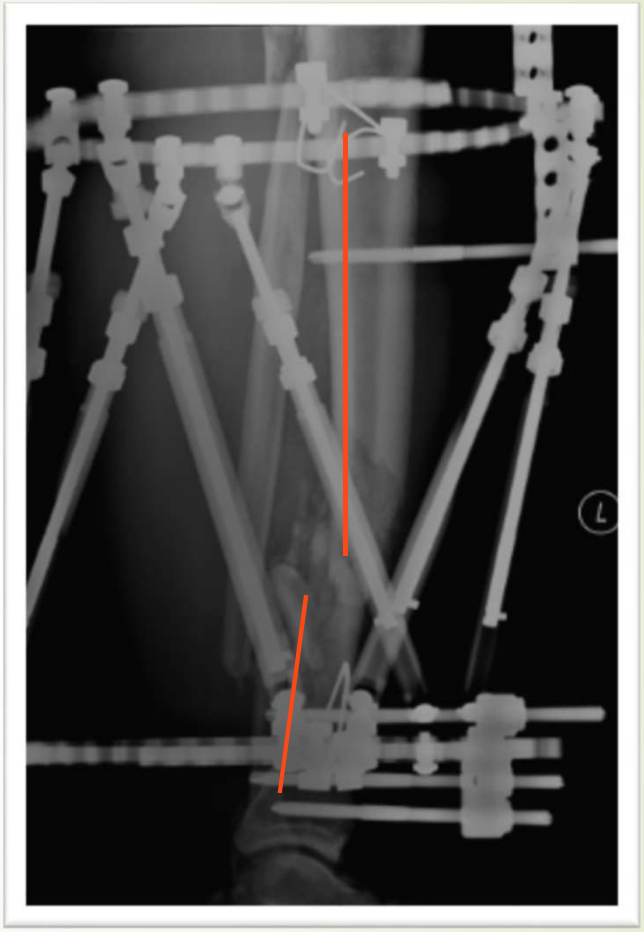
- Principles:
  - Multiple tensioned thin wires
  - **Place wires as close to 90^{o} to each other**
  - Half pins also effective
  - Use full rings (more difficult to deform)
- Can maintain purchase in metaphyseal bone
- Allows dynamic axial loading
- May allow joint motion



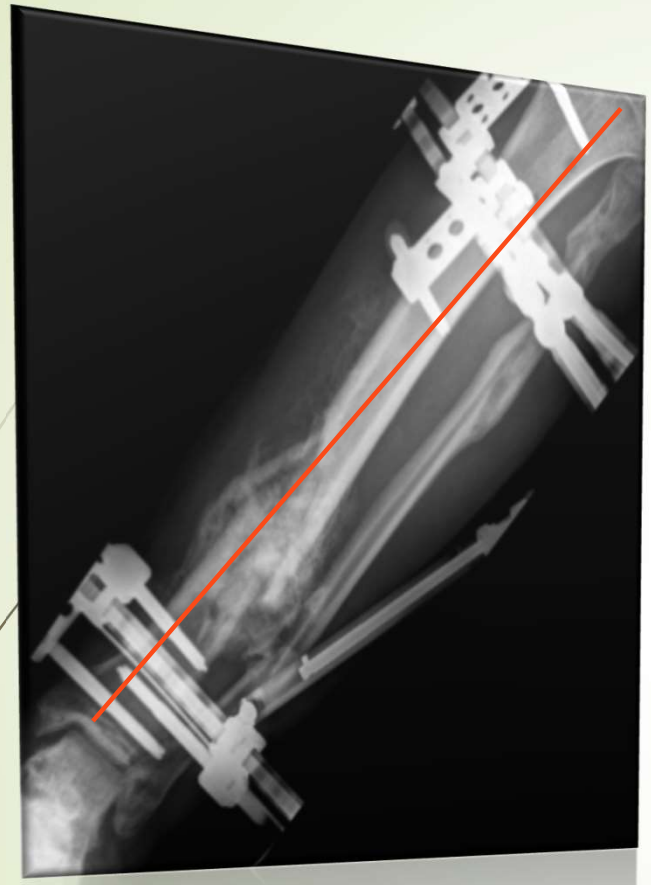
Multiplanar Adjustable Ring Fixators

- Application with wire or half pins
- Adjustable with 6 degrees of freedom
  - Deformity correction
    - acute
    - chronic

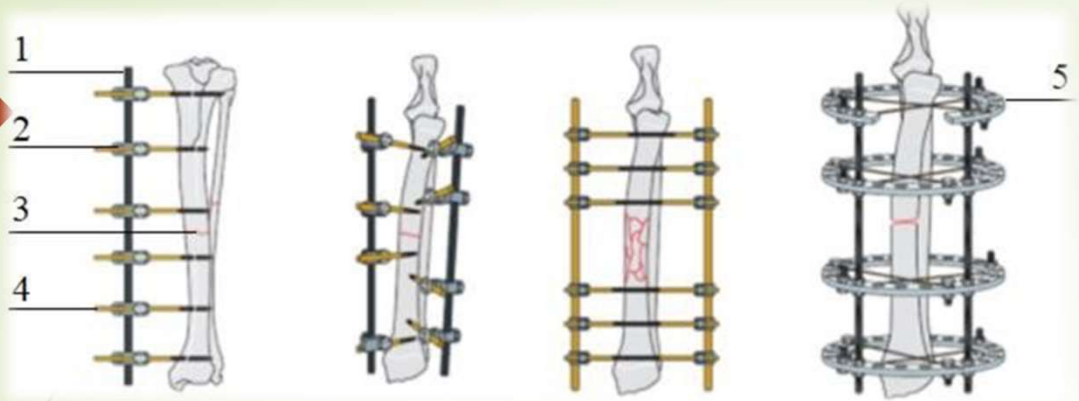




- Type 3A open tibia fracture with bone loss



- Following frame adjustment and bone grafting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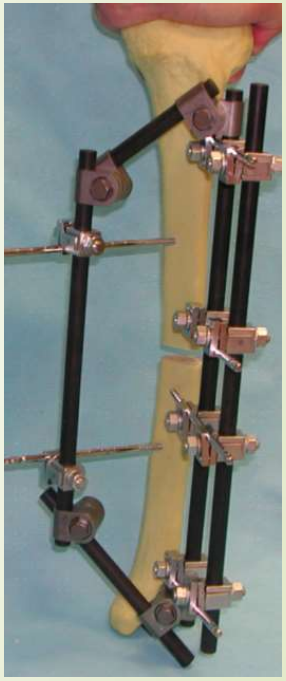
Frame Types

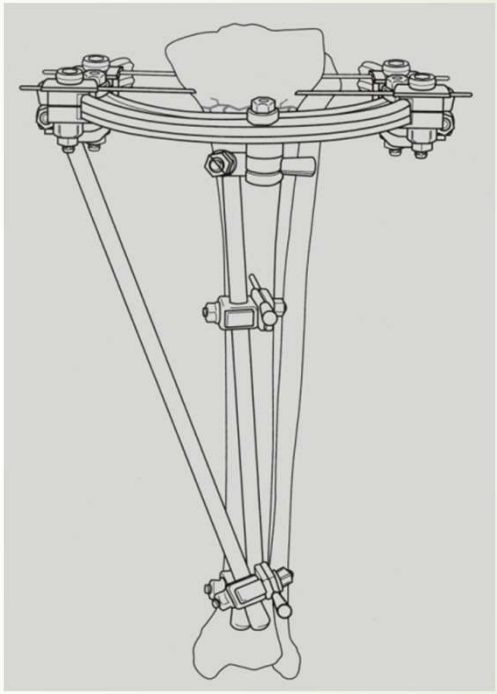
- Uniplanar
  - Unilateral
  - Bilateral
    - Pin transfixes extremity
- Bi-planar
  - Unilateral
  - Bilateral
- Circular (Ring Fixator)
  - May use Half-pins and/or transfixion wires
- Hybrid
  - Combines rings with planar frames



Unilateral uniplanar Unilateral biplanar

Hybrid Fixators

- Combines the advantages of ring fixators in periarticular areas with simplicity of planar half pin fixators in diaphyseal bone



From Rockwood and Green's, 5th Ed

Biomechanical Comparison Hybrid vs Ring Frames

- Ring frames resist axial and bending deformation better than any hybrid modification
- Adding 2nd proximal ring and anterior half pin improves stability of hybrid frame.
- Clinical application: Use full ring fixator for fracture with bone defects or expected long frame time

Standard Frame

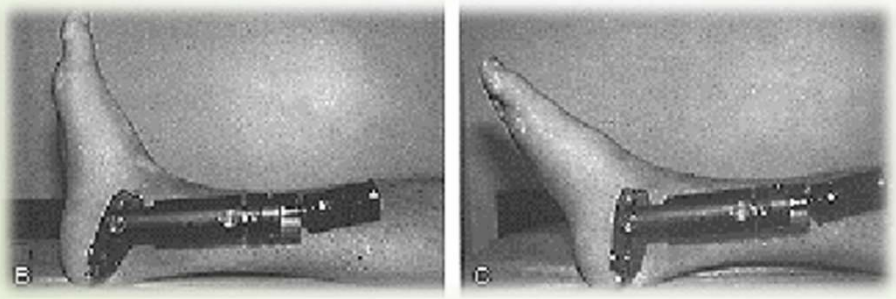
- Standard Frame Design
  - Diaphyseal region
  - Allows adjacent joint motion
  - Stable

Joint Spanning Frame

- Joint Spanning Frame
  - Indications:
    - Peri-articular fracture
      - Definitive fixation through ligamentotaxis
      - Temporizing
        - Place pins away from possible ORIF incision sites
    - Arthrodesis
    - Stabilization of limb with severe ligamentous or vascular injury: **Damage control**

Articulated Frame

- Articulating Frame
  - Limited indications
    - Intra- and peri-articular fractures or ligamentous injury
    - Most commonly used in the ankle, elbow and knee
  - Allows joint motion
  - Requires precise placement of hinge in the axis of joint motion



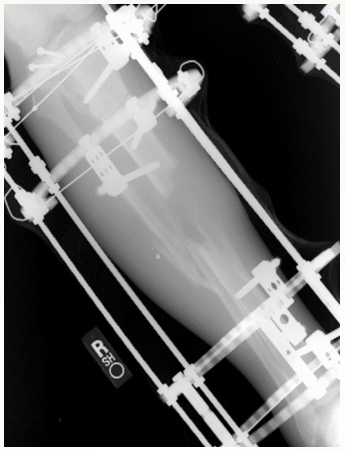
Correction of Deformity or Defects

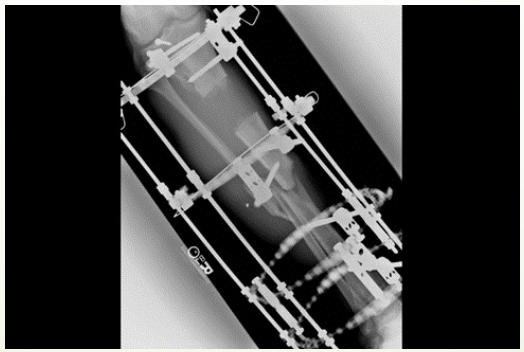
- May use unilateral or ring frames
- Simple deformities may use simple frames
- Complex deformities require more complex frames
- All require careful planning

3B tibia with segmental bone loss, 3A plateau,

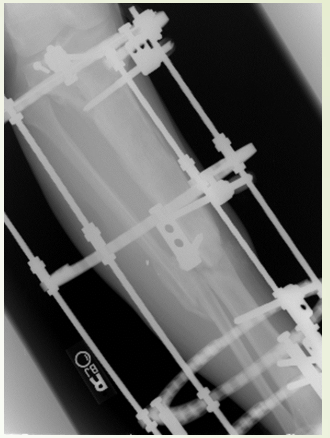
temporary spanning ex fix

Convert to circular frame, ORIF plateau

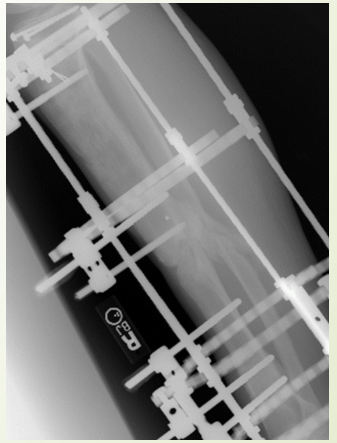




Corticotomy and distraction



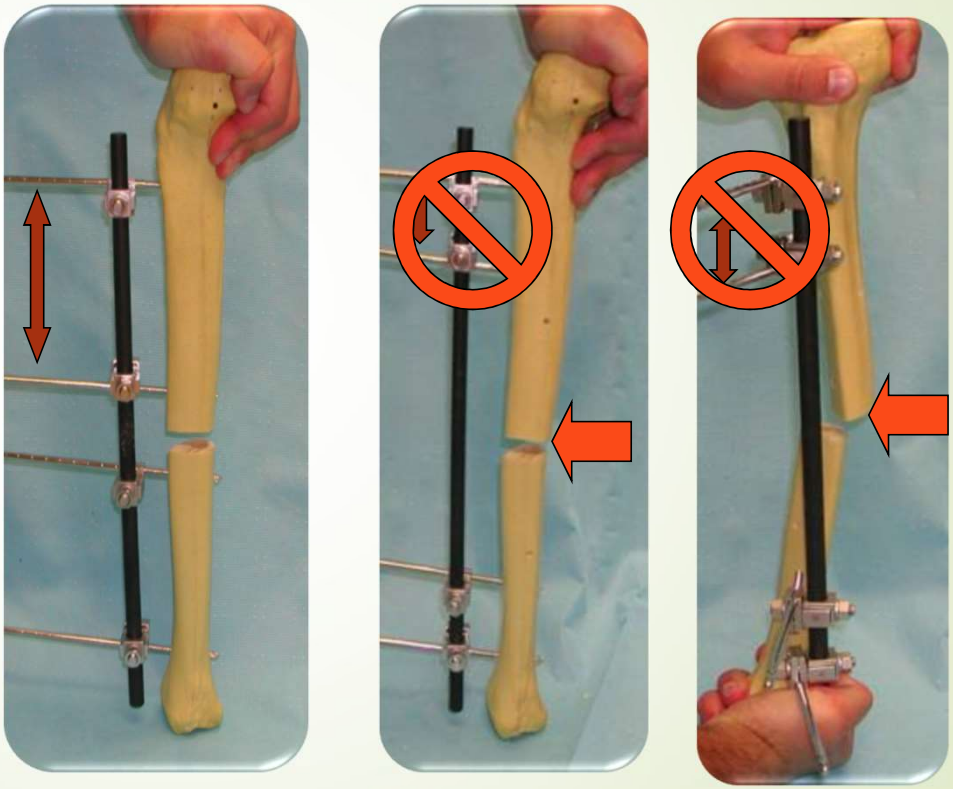
Consolidation



Healed

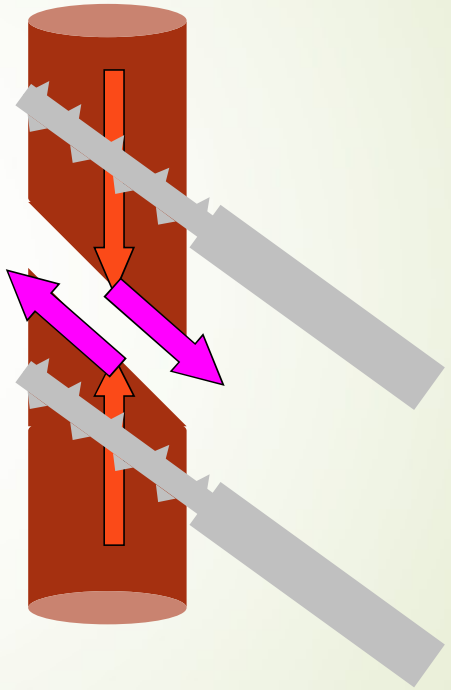
Fixator Mechanics: Pin Factors

- Larger pin diameter
- Increased pin spread
  - on the same side of the fracture
- Increased number of pins (both in and out of plane of construct)



Fixator Mechanics: Pin Factors

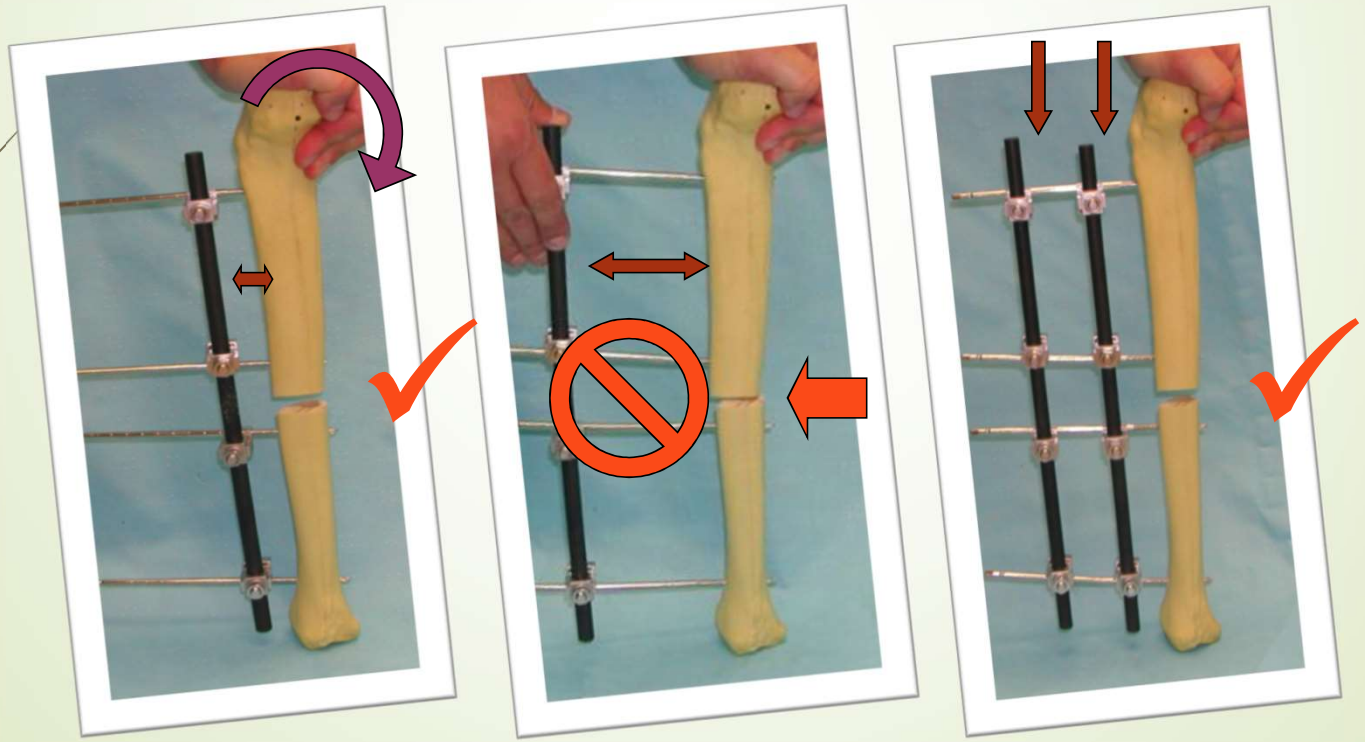
- Oblique fractures subject to shear
- Use oblique pin to counter these effects



Metcalfe, et al, JBJS B, 2005
Lowenberg, et al, CORR, 2008

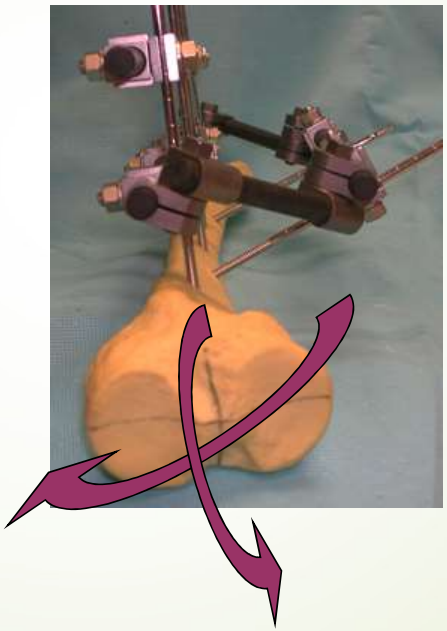
Fixator Mechanics: Rod Factors

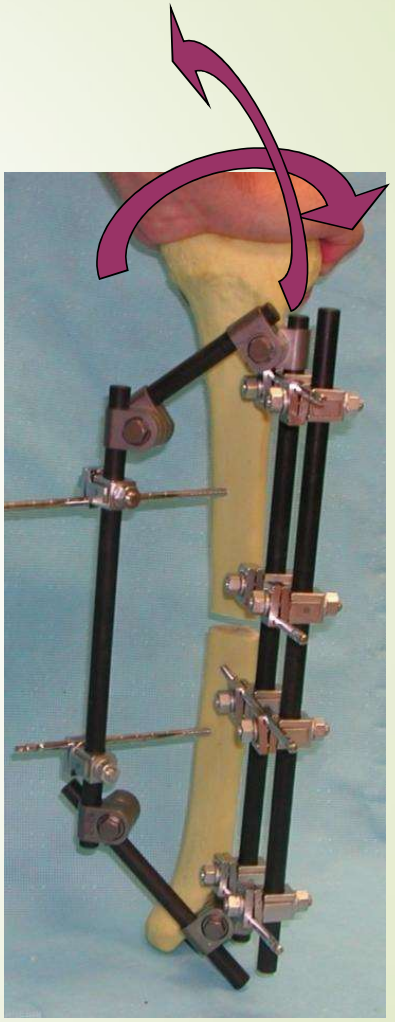
- Frames placed in the **same plane** as the applied load
- Decreased distance from bars to bone
- Stacking of bars



Biplanar Construct

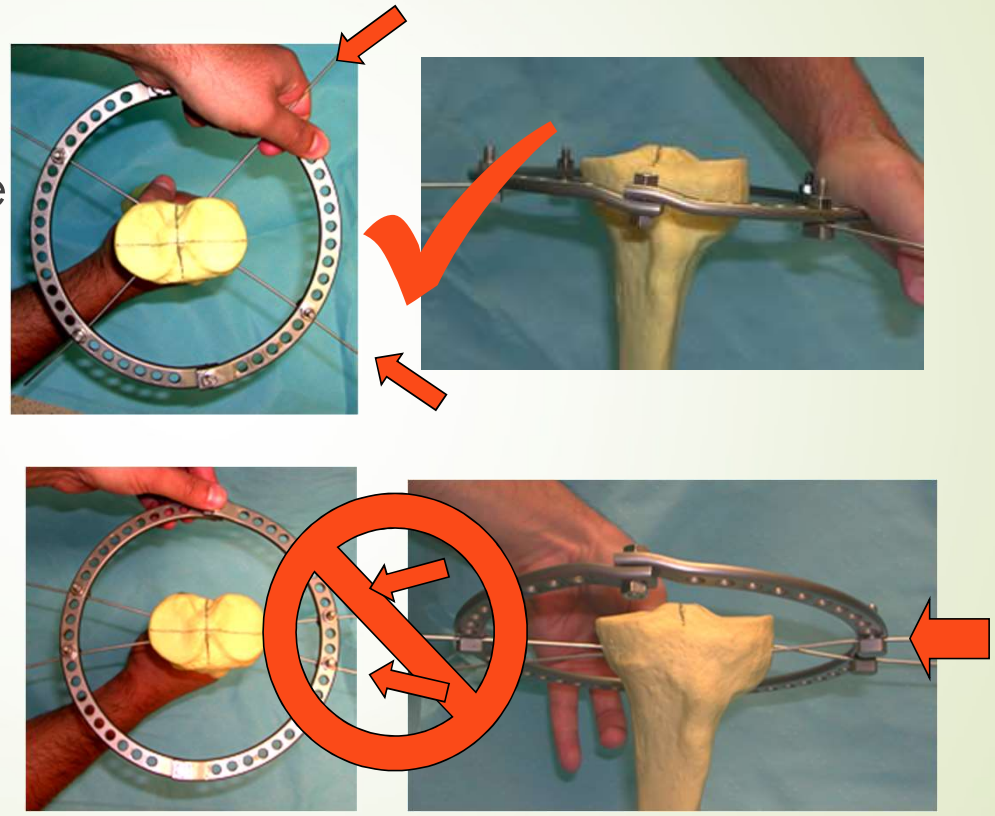
- Linkage between frames in perpendicular planes (DELTA)
- Controls each plane of deformation





Frame Mechanics: Ring Fixators

- Spread wires to as close to 90° as anatomically possible
- Use at least 2 planes of wires/half pins in each major bone segment

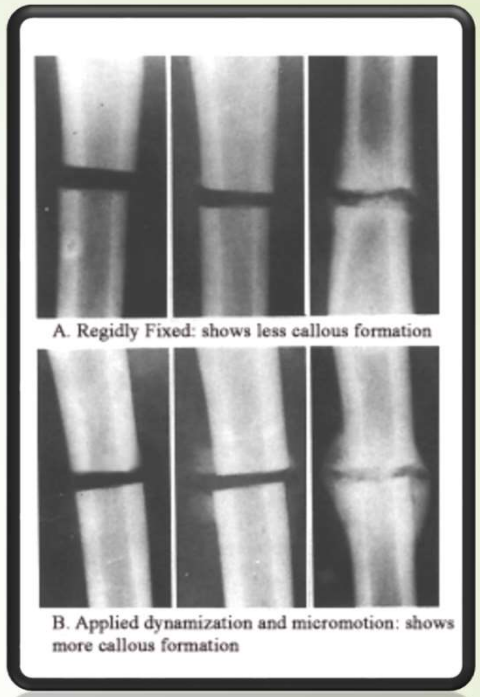


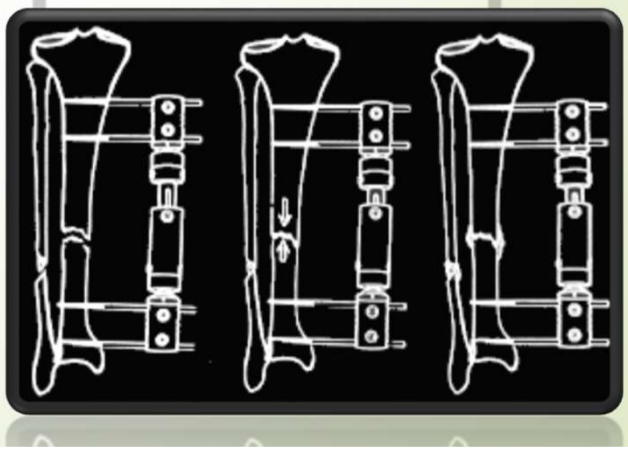
Modes of Fixation

- Compression
  - Sufficient bone stock
  - Enhances stability
  - Intimate contact of bony ends
  - Typically used in arthrodesis or to complete union of a fracture
- Neutralization
  - Comminution or bone loss present
  - Maintains length and alignment
  - Resists external deforming forces
- Distraction
  - Reduction through ligamentotaxis
  - Temporizing device
  - Distraction osteogenesis

Biology

- Fracture healing by stable yet less rigid systems
  - Dynamization
  - Micromotion
- micromotion = *callus formation*
- Dynamization = load-sharing construct that promote micromotion at the fracture site
- Controlled load-sharing helps to "work harden" the fracture callus and accelerate remodeling



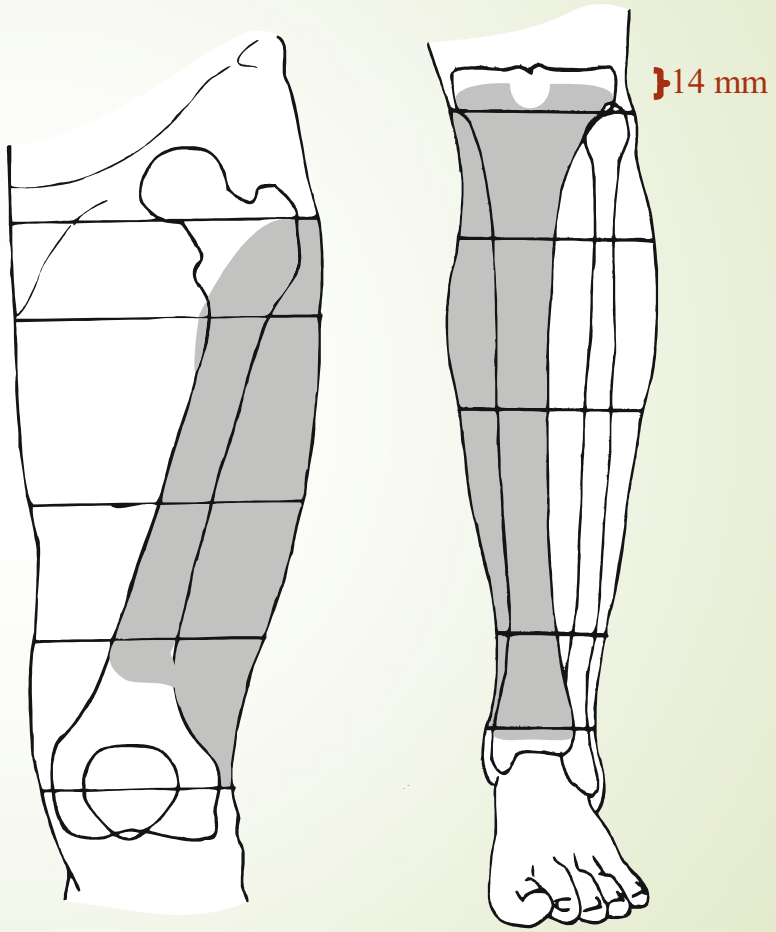


Anatomic Considerations

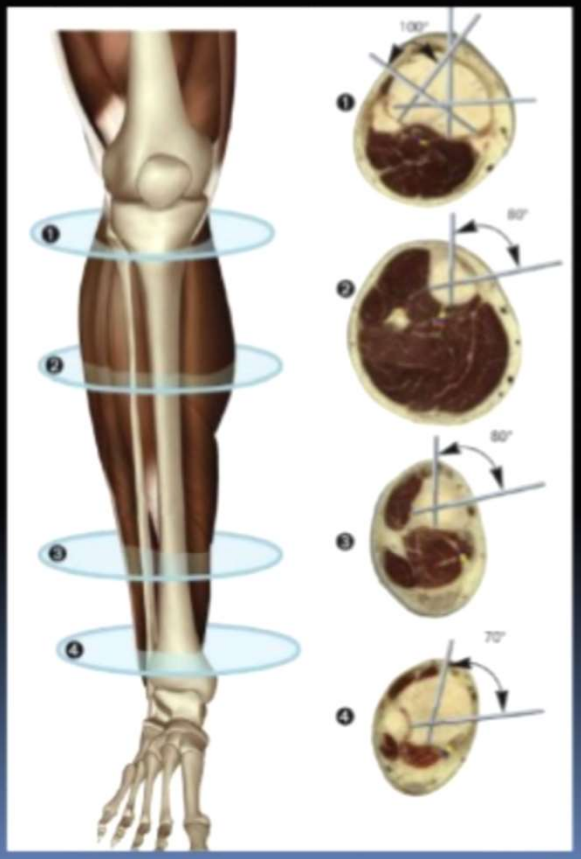
- Fundamental knowledge of the anatomy is critical
- Avoidance of major nerves, vessels and organs (pelvis) is **mandatory**
- Avoid joints and joint capsules
  - Proximal tibial pins should be placed 14 mm distal to articular surface to avoid capsular reflection
- Minimize muscle/tendon impalement (especially those with large excursions)

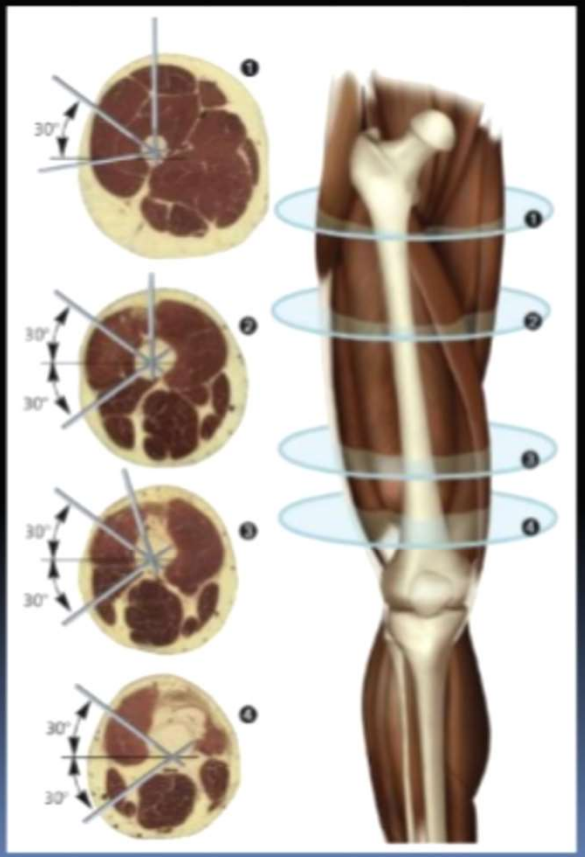
Lower Extremity "safe" sites

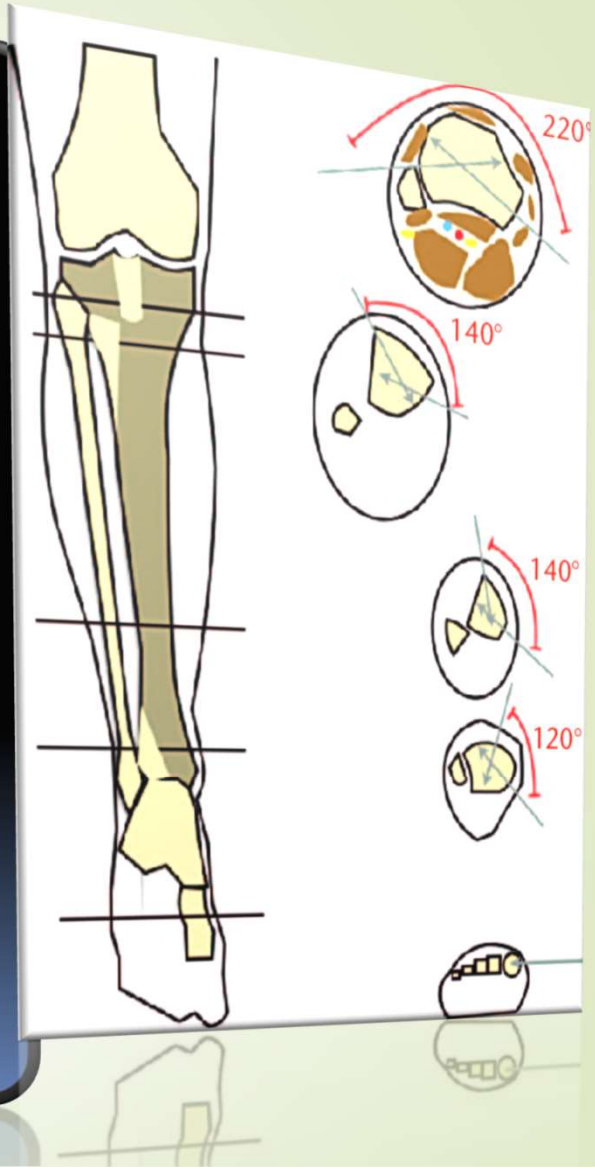
- Avoid
  - Nerves
  - Vessels
  - Joint capsules
- Minimize
  - Muscle transfixion



SAFE CORRIDORS

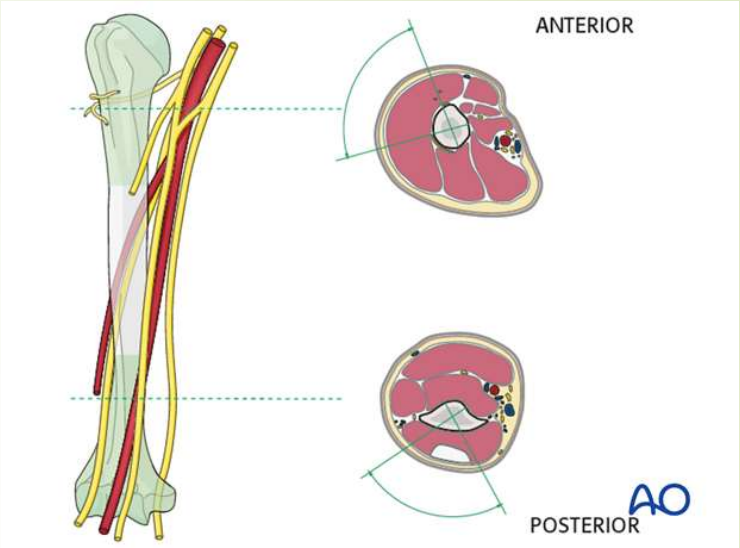


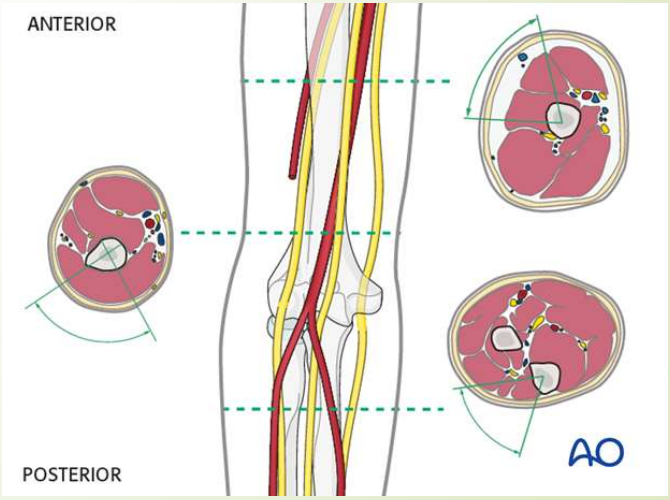




Upper Extremity "Safe" Sites

- **Humerus**: narrow lanes
  - Proximal: axillary nerve
  - Mid: radial nerve
  - Distal: radial, median and ulnar nerve
  - Dissect to bone, Use sleeves
- **Ulna**: safe subcutaneous border, avoid overpenetration
- **Radius**: narrow lanes
  - Proximal: avoid because radial nerve and PIN, thick muscle sleeve
  - Mid and distal: use dissection to avoid sup. radial nerve.





Damage Control and Temporary Frames

- Initial frame application rapid
- Enough to stabilize **but is not definitive frame!**
- Be aware of definitive fixation options
  - Avoid pins in surgical approach sites
- Depending on clinical situation may consider minimal fixation of articular surface at initial surgery

Conversion to Internal Fixation

- Generally safe within 2-3 weeks
  - Infection in tibia and femur <4%
- Rods or plates appropriate
- Use with caution with signs of pin irritation
  - Consider staged procedure
    - Remove and curette sites
    - Return following healing for definitive fixation
  - Extreme caution with established pin track infection

Complications

- Pin-track infection/loosening
- Frame or Pin/ Wire Failure
- Malunion
- Non-union
- Soft-tissue impalement
- Compartment syndrome

Pin-track Infection

- Most common complication
- 0 – 14.2% incidence
- 4 stages:
  - Stage I: Seropurulent Drainage
  - Stage II: Superficial Cellulitis
  - Stage III: Deep Infection
  - Stage IV: Osteomyelitis

- Prevention:
  - Proper pin/wire insertion technique:
    - Subcutaneous bone borders
    - Away from zone of injury
    - Adequate skin incision
    - soft tissue protection during insertion
    - Sharp drill bits and irrigation to prevent thermal necrosis
    - Manual pin insertion

Pin-track Infection

- Postoperative care:
  - Clean implant/skin interface
  - Saline
  - Gauze
  - Shower

- Treatment:
  - Stage I: aggressive pin-site care and oral cephalosporin
  - Stage II: same as Stage I and +/- Parenteral Abx
  - Stage III: Removal/exchange of pin plus Parenteral Abx
  - Stage IV: same as Stage III, culture pin site for offending organism, specific IV Abx for 10 to 14 days, surgical debridement of pin site

Pin Loosening

- Factors influencing Pin Loosening:
  - Pin tract infection/ osteomyelitis
  - Thermonecrosis
  - Delayed union or non-union
  - Bending Pre-load

- Prevention:
  - Proper pin/wire insertion techniques
  - Radial preload
  - Euthermic pin insertion
  - Adequate soft-tissue release
  - Bone graft early
  - Pin coatings
- Treatment:
  - Replace/remove loose pin

Frame Failure

- Incidence: Rare
- Theoretically can occur with recycling of old frames
- However, no proof that frames can not be re-used

Malunion

Intra-operative causes:

- Due to poor technique

- Prevention:
  - Clear pre-operative planning
  - Prep contralateral limb for comparison
  - Use fluoroscopic and/or intra-operative films
  - Adequate construct

- Treatment:
  - Early: Correct deformity and adjust or re-apply frame prior to bony union
  - Late: Reconstructive correction of malunion

Post-operative causes:

- Due to frame failure

- Prevention:
  - Proper follow-up with both clinical and radiographic check-ups
  - Adherence to appropriate weight-bearing restrictions
  - Check and re-tighten frame at periodic intervals

- Treatment:
  - Osteotomy/reconstruction

Non-union

- Union rates comparable to those achieved with internal fixation devices
- Minimized by:
  - Avoiding distraction at fracture site
  - Early bone grafting
  - Stable/rigid construct
  - Good surgical technique
  - Control infections
  - Early weight bearing
  - Progressive dynamization

Soft-tissue Impalement

- Tethering of soft tissues can result in:
  - Loss of motion
  - Scarring
  - Vessel injury
- Prevention:
  - Check ROM intra-operatively
  - Avoid piercing muscle or tendons
  - Position joint in NEUTRAL
  - Early stretching and ROM exercises

Compartment Syndrome

- Rare
- Cause:
  - Injury related
  - pin or wire causing intracompartmental bleeding
- Prevention:
  - Clear understanding of the anatomy
  - Good technique
  - Post-operative vigilance

Enhancement of Fixator Stability

- increasing pin diameter:
  - most important factor in fixator stability
- widely separated pins within single fragment;
- placement of pins near the fracture site;
- number of pins:
  - three pins usually provide axial stability even w/ segmental comminution;
  - little is gained w/ a 4th pin in single segment;
  - short fragments fixed w/ 2 pins in same plane will provide stability in plane of pins but will be relatively unstable in plane at a right angle to the pins;
- number of support bars:
- additional planes of fixation:
- a short fragment may not allow 3 pins in single plane but may allow additional pins in a different plane;
- unilateral external fixators must stabilize the frx from an eccentric off axis position, and are most able to control frx site bending and shear when there is frx site opposition;
- multiplane fixation or circular wire fixators help limit frx site bending and shear and allow load sharing at the frx site;
- - proximity to the extremity: (decreasing bone to support bar distance)
- - fibular fixation.

Methods to Manipulate an External Fixator to Increase Stability

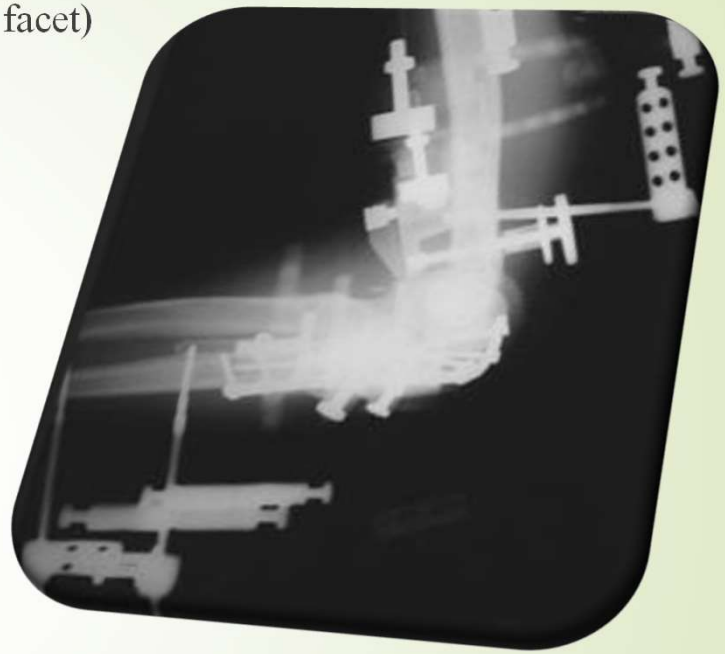
Increase

- Diameter of pins
- Number of pins used
- Pin spread
- Number of planes pins are placed
- Diameter of rods
- Number of rods

Decrease

- Pin-to-fracture distance
- Bone-to-rod distance

- Case: 43 y.o. male
  Unstable elbow
  fracture-dislocation (olecranon, coronoid anteromedial facet)



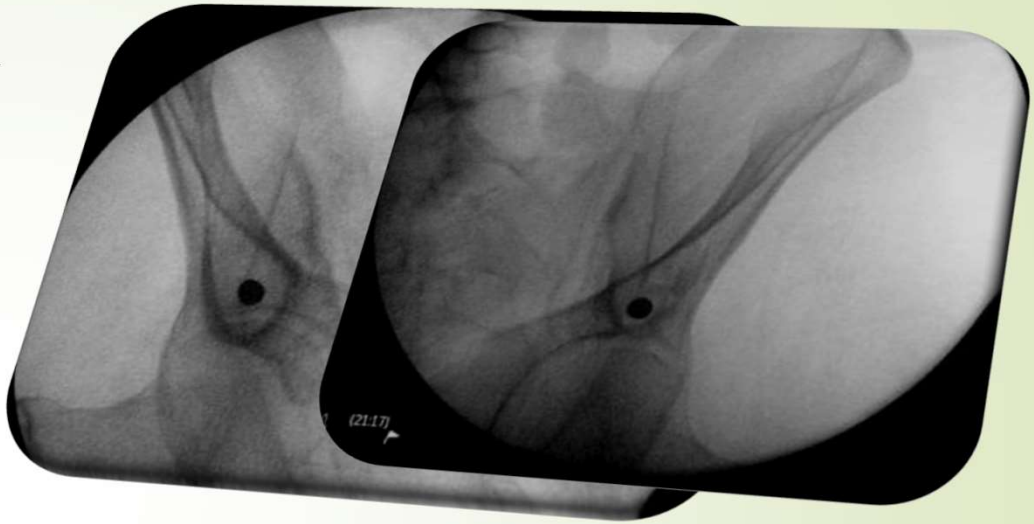
ORIF, ligament repair → Hinged elbow fixator x3 months

(for persistent ligamentous instability, and to protect fixation)

- Case: 70 y.o. female, Metaphyseal and articular comminution
  Poor bone density

Spanning ex-fix
Percutaneous reduction and pinning

- Case: 71 y.o. female, MVC, restrained passenger
  TBI, rib Fxs, prolonged intubation
  LC-2 with bladder disruption, L distal radius Fx



Bladder repair through midline incision, with suprapubic catheter left behind

Q?

Thank you