PRINCIPLES OF EXTERNAL FIXATION

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Revised by Roman Hayda M.D. 2008

OVERVIEW

- Historical perspective
- Generations of frame types
- Components of external fixation
- Biomechanics of frame stability and fracture healing
- Clinical applications
- Complications

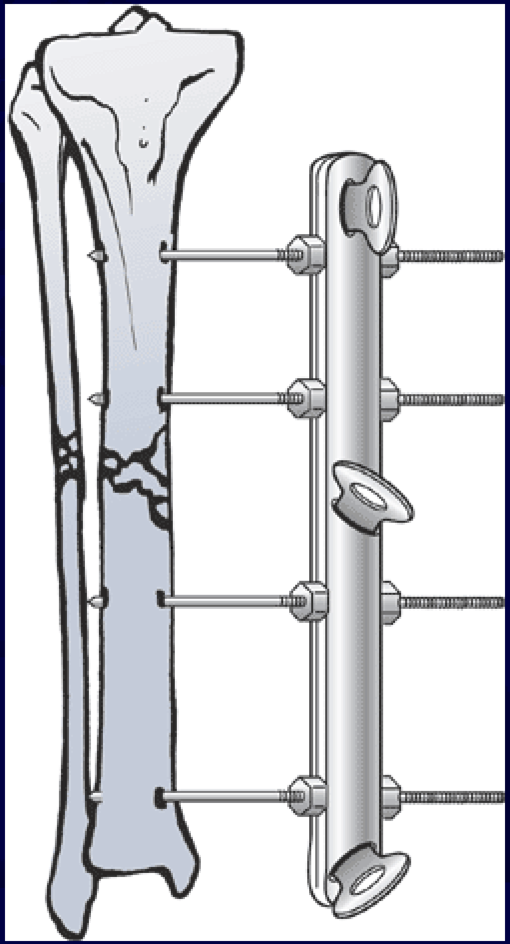
GOALS

- Understand different types of frame construction
- Understand the limitations and advantages
- Understand the biomechanics of different frame types
- Putting it all together to best match the patient and goal

GOAL IS TO CREATE A STABLE CONSTRUCT WITH LOW SHEAR AND TORQUE AND HIGH MICROMOTION AT LEVEL OF FRACTURE

HISTORICAL PERSPECTIVE

- Unilateral frame (Late 1800s-1900s)
- First generation frames classic A frame
- Subsequent frame generations created to improve upon shortcomings
- Uniplanar frames (2nd Gen.)
  - Subject to cantilever bending
  - Biplanar with improved biomechanical properties
- Ring fixator (1950s) (3rd Gen.)
  - Ilizarov
  - Superior biomechanically and implemented with improved results for definitive care.



Lambotte's original frame 1902
Rockwood and Green, 6th ed p. 258

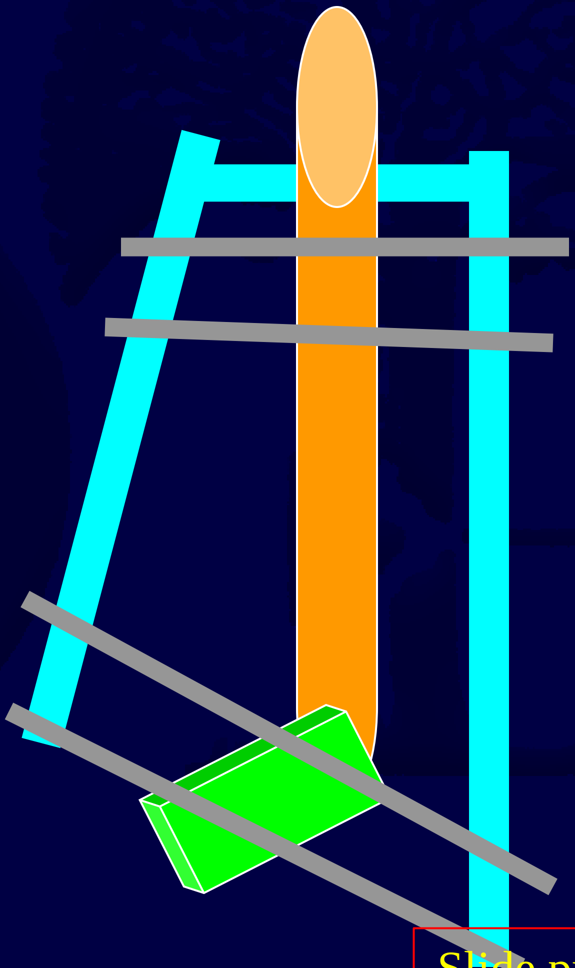
HISTORICAL PERSPECTIVE cont.

- **Articulated External fixation (4th gen.)**
  - Allow for joint range of motion
  - Modified unilateral frame
- **Hexapod (5th gen.)**
  - Taylor spatial frame (TSF)
  - 6 degrees of freedom (6 struts in multi-planar configuration)
  - Deformity correction
  - Computer software to facilitate correction
- **Hybrid ring (6th gen.)**
  - Improved ease of use
  - Mates the advantage of metaphyseal fixation with ease of use of half pins
  - Not biomechanically superior to full ring

1^{st} Generation

- Classic Rigid “A – Frame” fixation
- “Too Rigid”
- Poor results gave external fixation a bad name

1st Generation



Slide provided by David Lowenberg M.D

1st Generation

- In reality: *Not too rigid*

  No axial motion

  Too much wobble with AP bending

Slide provided by David Lowenberg M.D

2nd Generation

- The classic “Unilateral Fixator”
- Gained great acceptance
- Became the workhorse of external fixators

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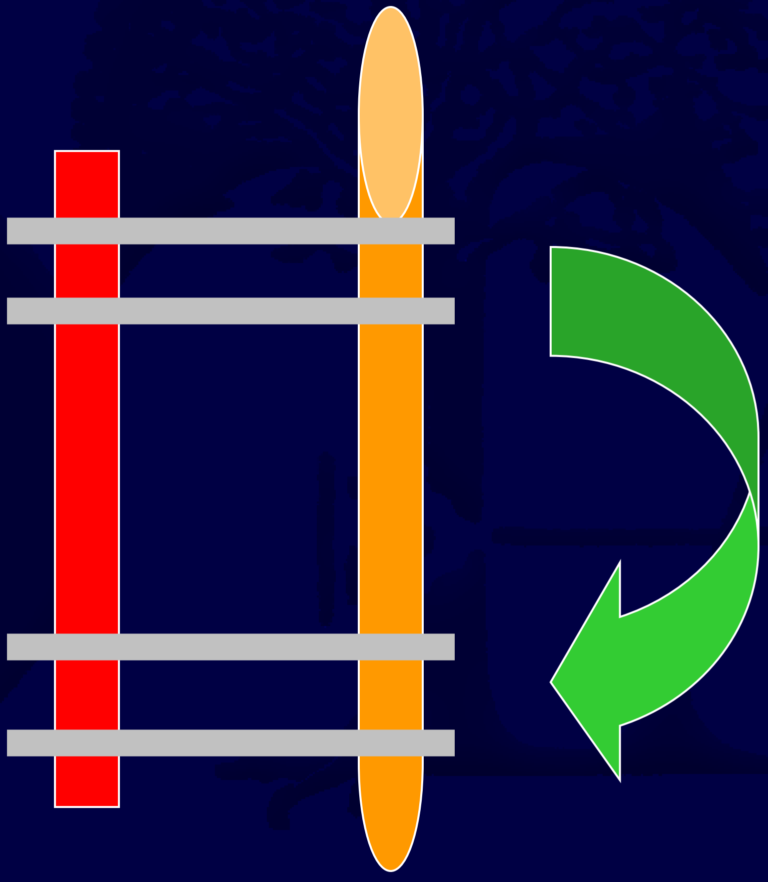
2^{nd} Generation ("unilateral")



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3^{rd} Generation

- Circular external fixation
- Prototype = Ilizarov Fixator
- Revolutionized external fixation based on fine wire fixation combined with multiplanar fixation

Circular Fine Wire Fixators

- Allows axial micromotion
- Stable to angulation and rotation
- Good peri-articular fixation

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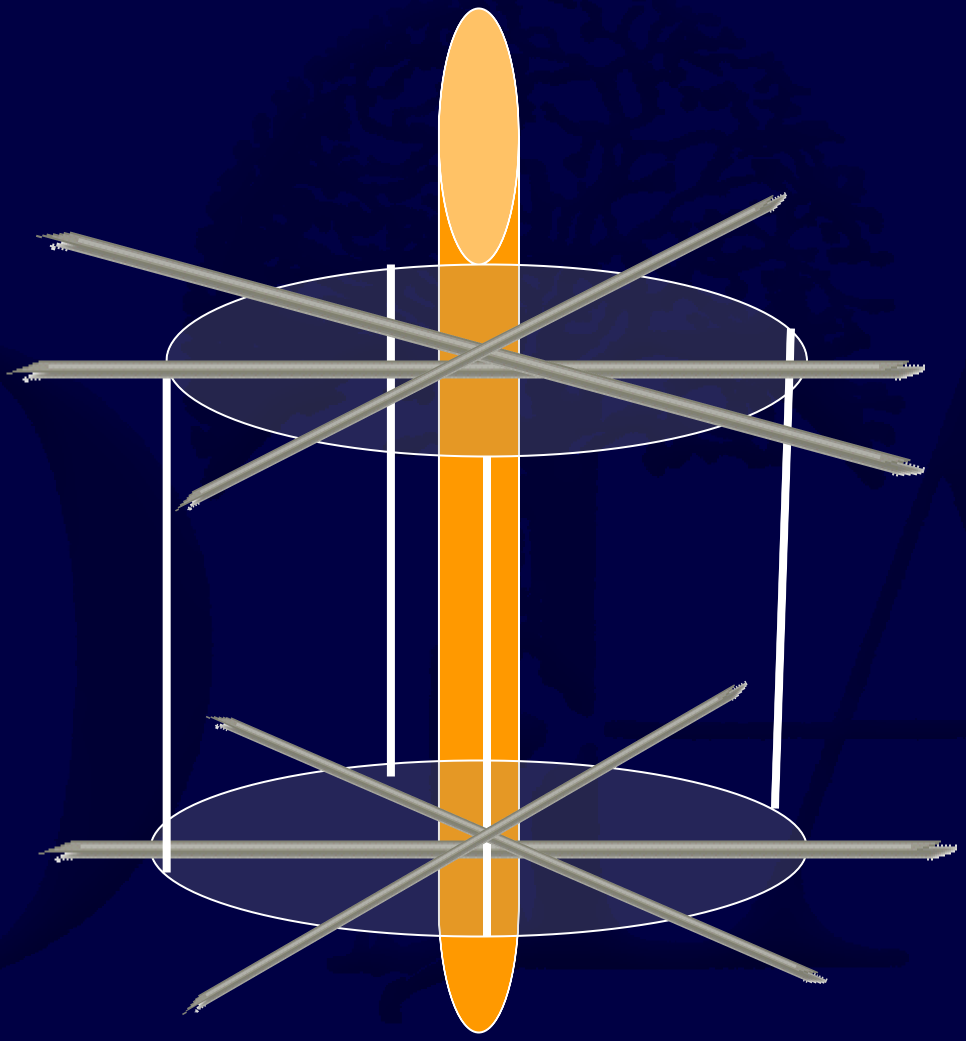
Circular External Fixation



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4th Generation

- Mobile unilateral external fixators
- Possess hinges and the ability to transport bone

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4th Generation

- Tried to incorporate the benefits and versatility of circular fixation with the ease of unilateral fixator design.
- In essence, added moving parts to 2nd generation designs.

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4th Generation -- *Problems*

- Ignored basic biomechanical constraints.
- Did not alter issues of bending, shear, and torque.

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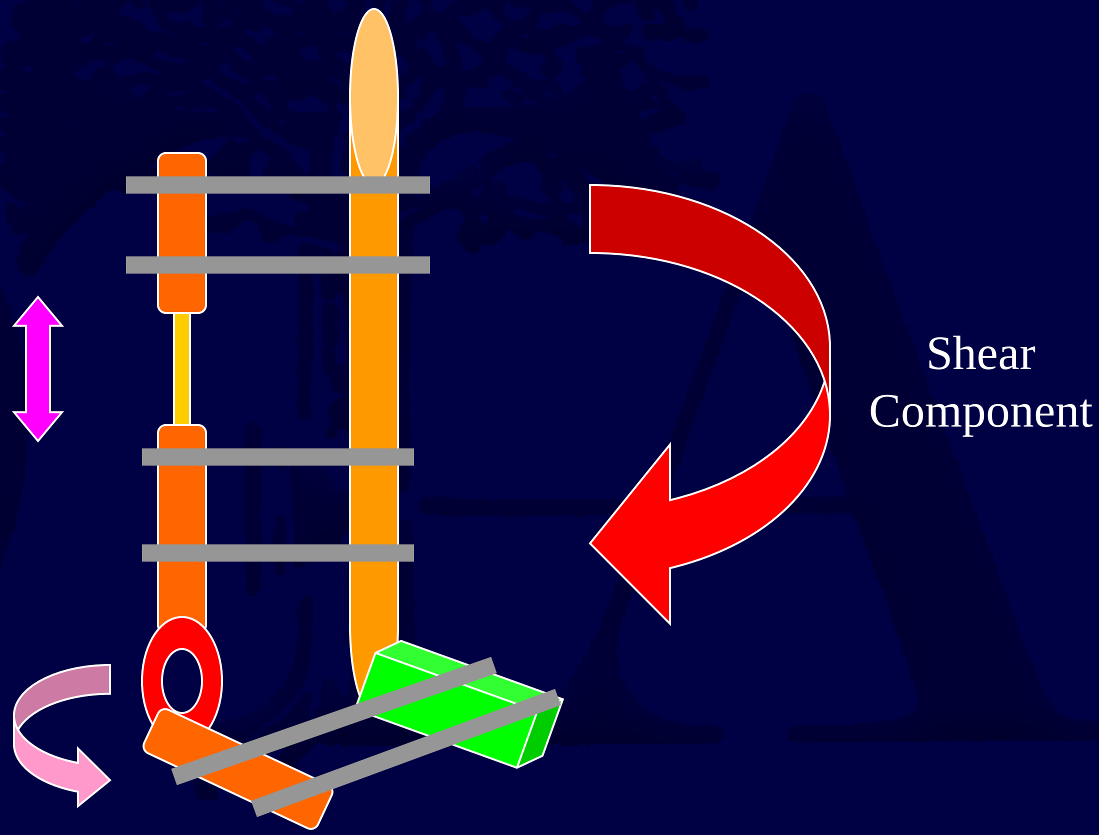
4th Generation



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5th Generation

- **Multiplanar Fixation with Multiaxial Correction**

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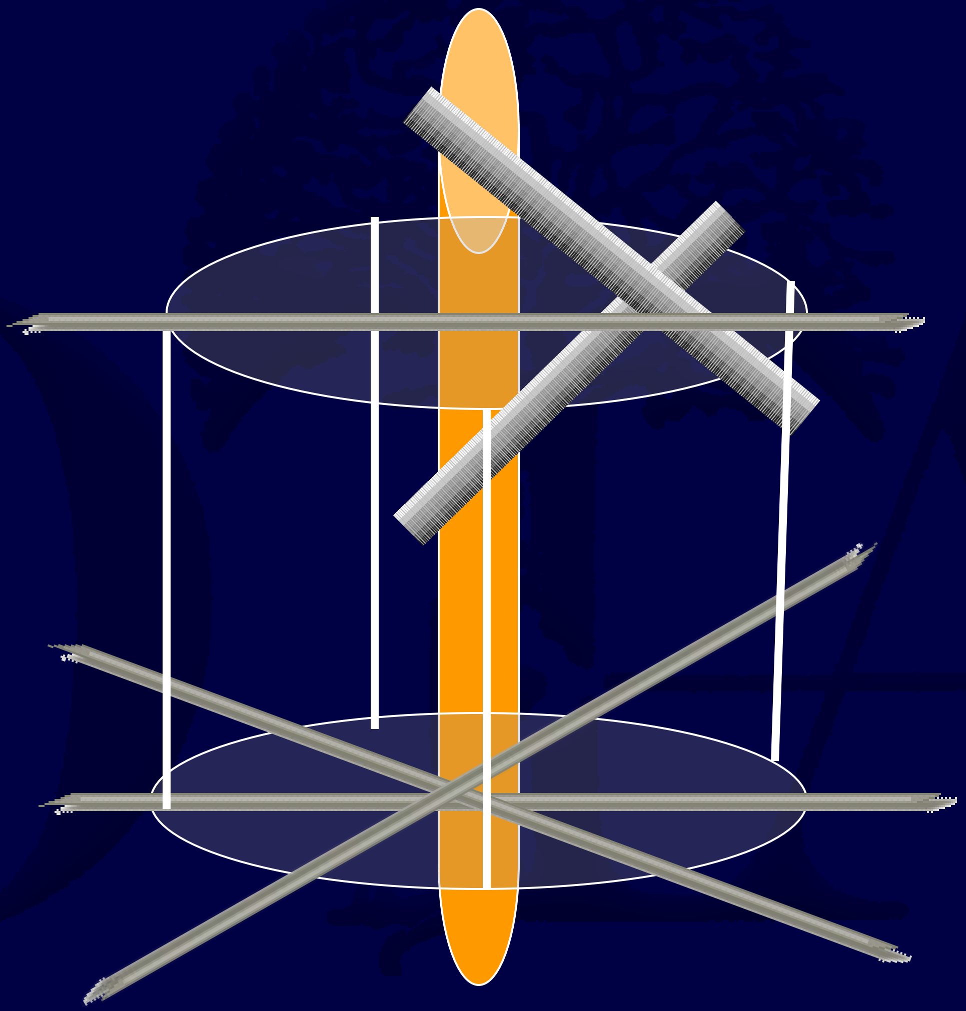
Multiplanar External Fixation



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“Hybrid Fixation”

- Need to understand biomechanical principles
- Don’t repeat same mistakes

Bottom Line

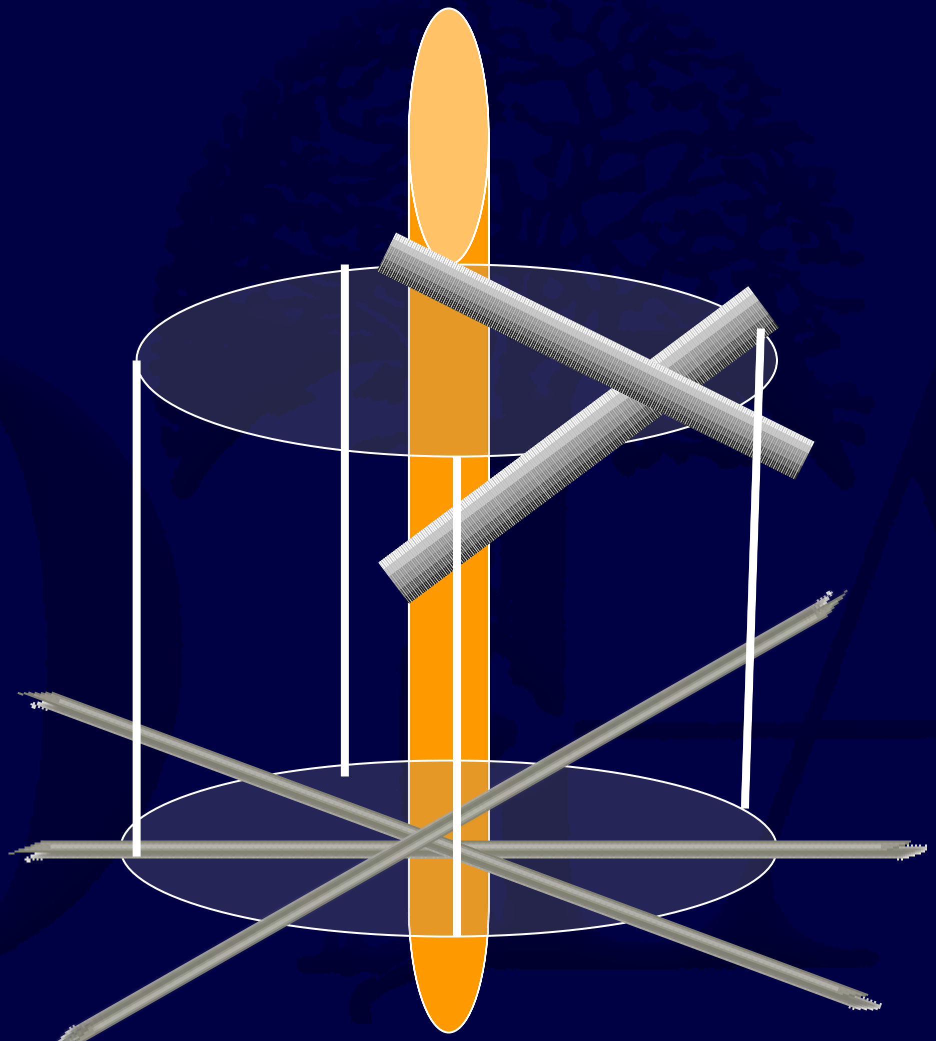
- **“Classic” Hybrid Fixation has no role in current orthopaedic practice (poor biomechanics)**
- **Current “Hybrid Fixation” involves <u>MULTIPLANAR</u> Fixation with a combination of epiphyseal/metaphyseal wires and diaphyseal half pins**

Slide provided by David Lowenberg M.D

“Classic” Hybrid Fixation

Slide provided by David Lowenberg M.D

Current "Hybrid Fixation"



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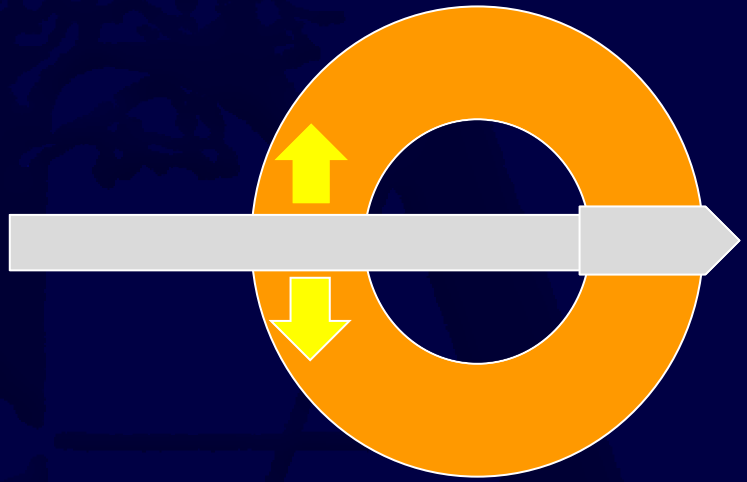
FRAME COMPONENTS

- Uniplanar/Biplanar (Traditional Frame)
  - Pins
  - Clamps
  - Connecting rods
- Ring/Hybrid/Hexapod
  - Rings
  - Transfixion wires
  - Half pins
  - Struts
  - Misc small parts

PINS

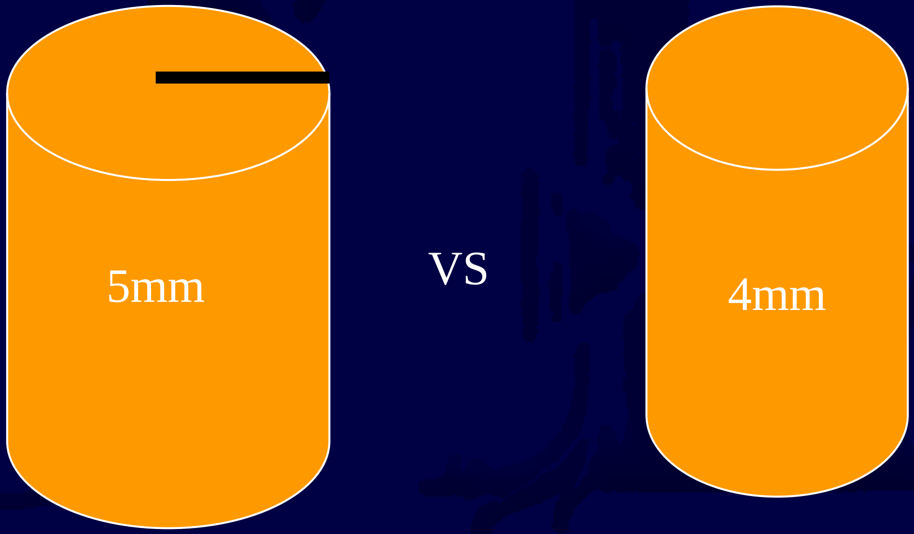
- Key link
- Pin/bone interface is critical
- Pin stability dependent on radial preload
  - Use appropriate size drill
- Pin loosening is a common problem
- Loosening brings risk of increased



Radial pre-load

PINS cont.

- The single most important factor with frame strength is increasing pin size
- Frame bending stiffness proportional to radius⁴
  - Example 5mm pin is 144% stiffer versus 4mm pin



Use the largest size pin that is appropriate

PIN OPTIONS

Many options

- 2-6mm sizes
- Self drilling/tapping
- Blunt tip
- Conical
- Fine thread
- Course thread
  - Cancellous bone

Material

- Titanium
- Stainless

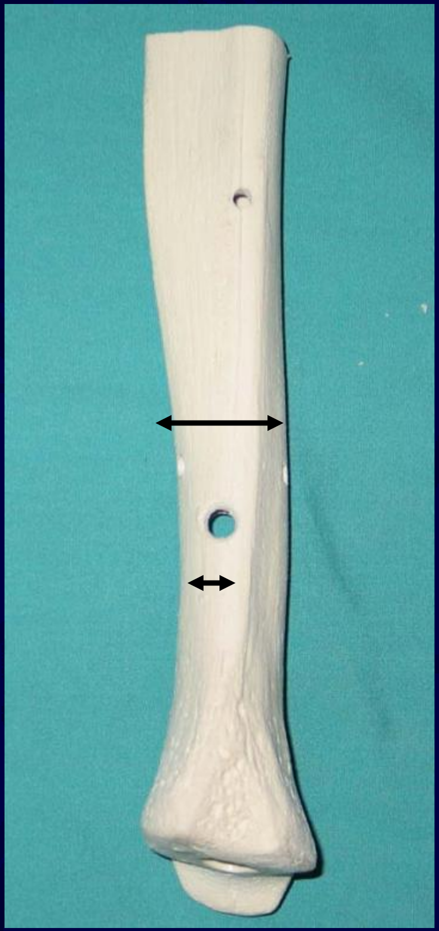
Coatings

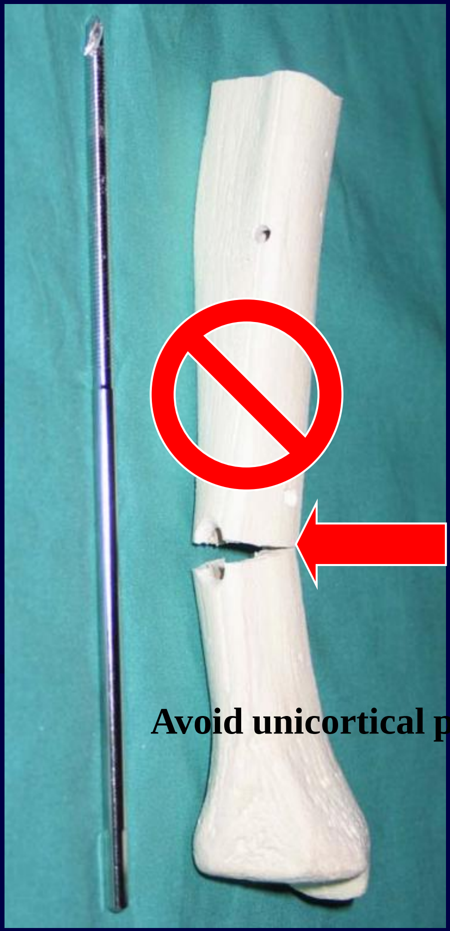
- Non-coated
- Titanium
- Hydroxyapatite

PIN DIAMETERS

GENERAL GUIDELINES

- –Femur – 5 or 6 mm
- –Tibia – 5 or 6 mm
- –Humerus – 5 mm
- –Forearm – 4 mm
- –Hand, Foot – 2.5-3 mm



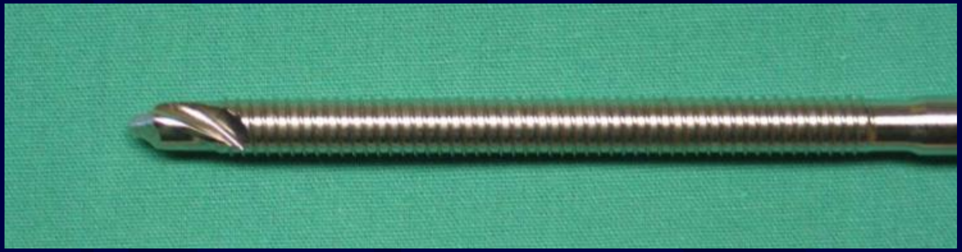


Photos courtesy of Matthew Camuso

Use the appropriate pin size for the application

SELF DRILLING/SELF TAPPING

- Advantages
  - Single stage insertion
  - Fast
  - OK for short term use
- Disadvantages
  - Short drill flutes resulting in possible
    - Thermal necrosis
    - Stripping near cortex
      - Loss of radial pre-load
    - Decreased torque to pull out over time (loosening)



BLUNT PINS

- Multi stage insertion
- Preservation of near cortex
- Tapered pins
  - Improved radial pre-load
  - Beware of advancing and then backing up, loss of radial pre-load with early loosening

Thermal necrosis possible with any type of pin. Irrigate and adhere to proper technique with insertion.

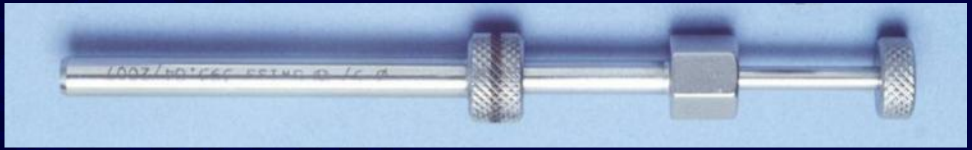
PIN COATINGS

- Hydroxyapatite (HA) vs titanium vs uncoated
  - HA with superior retention of extraction torque
  - Decreased infection
    - 0/50 pts in pertrochanteric region (Moroni JSBS-A, 05')
  - 13x higher extraction torque vs uncoated
  - 2x higher extraction torque vs titanium
  - Insertion torque and extraction torque equal with HA coated pins
  - Highly consider HA pins for extended use and or definitive fracture care.
- Possible future coatings
  - Bisphosphonate
  - Antibiotic coated

Moroni A, et al, Techniques to Avoid Pin Loosening and Infection in External Fixation. JOT. 16: 189-195, 2002

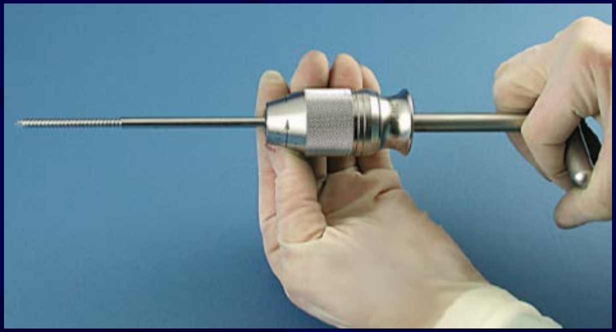
Moroni A, et al, Dynamic Hip Screw versus External Fixation for Treatment of Osteoporotic Pertrochanteric Fractures, J Bone Joint Surg Am. 87:753-759, 2005.

PIN INSERTION TECHNIQUE



1. Incise skin
2. Spread soft tissues to bone

3. Triple sleeve first in and last out
4. Irrigate while drilling

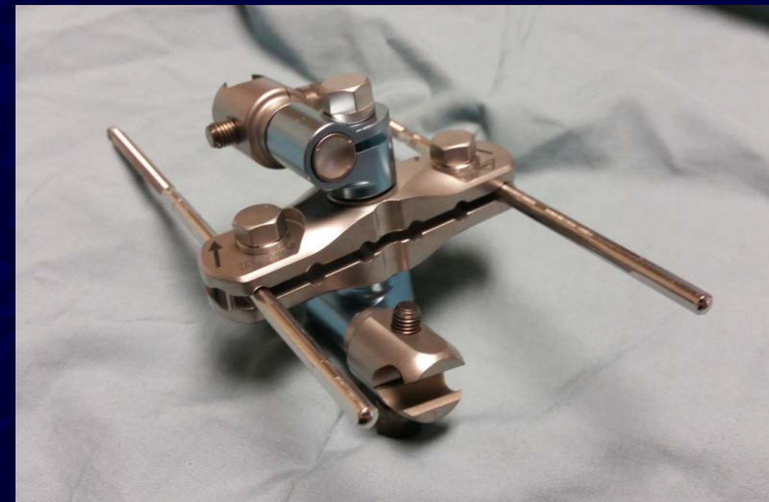


5. Place appropriate pin using sleeve
6. Place pin bi-cortical

Avoid soft tissue damage and bone thermal necrosis

CLAMPS

- Clamp types
  - Pin to bar
  - Multiple pin to bar clamps
  - Bar to bar etc
- Features:
  - Newer generation of clamps with increased adjustability
    - Allows for variable pin placement (multiplanar)
  - MR compatible?
  - Consider cost of construct, keep it simple



Key : place clamp and rod close to bone

RODS

- Many options
  - Rod material
    - Stainless
    - titanium
    - mostly carbon
  - Design
    - Simple rod
    - Monobar
    - Articulated
    - Telescoping

Frame strength increased with increasing rod diameter

RODS cont.

- Carbon vs Stainless
  - –Radiolucency
  - –↑ diameter = ↑ stiffness
  - –Carbon 15% stiffer in load to failure
  - –frames with carbon fiber are only 85% as stiff ? ? ? **?Weak link is clamp to carbon bar?**

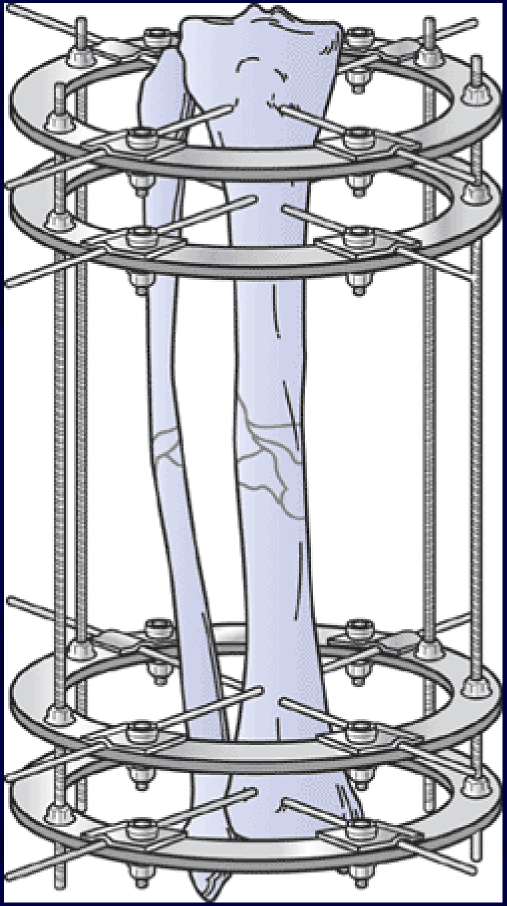
Added bar stiffness
≠
increased frame stiffness

Kowalski M, et al, Comparative Biomechanical Evaluation of Different External Fixator Sidebars: Stainless-Steel Tubes versus Carbon Fiber Bars, JOT 10(7): 470-475, 1996

RING COMPONENTS

- **Components:**
  - **Transfixion wires**
    - **olive or straight**
  - **Wire and half pin clamps**
  - **Half rings**
  - **Rods**
  - **Struts**
  - **Motors and hinges**

Frame strength increased with decreasing ring size and increasing wire tension and size



Rockwood and Green, 6th ed. Fig. 7-6 p. 260

UNIPLANAR/UNILATERAL

- **Useful for temporary fixation**
- **Useful in diaphyseal region**
- **Limited roles for definitive fixation**
  - **Distal radius**
  - **Tibia**
  - **Pediatric fxs**

Beware of common pitfalls (pins far from fracture, too small of pins, single stacked frame, bars far from skin

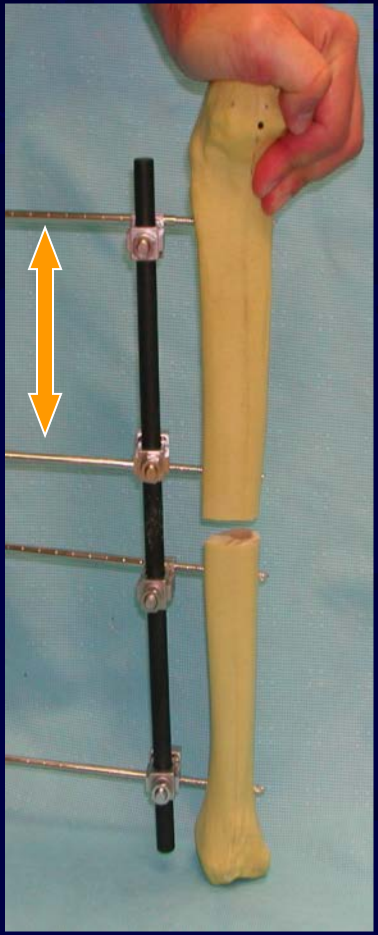
UNIPLANAR

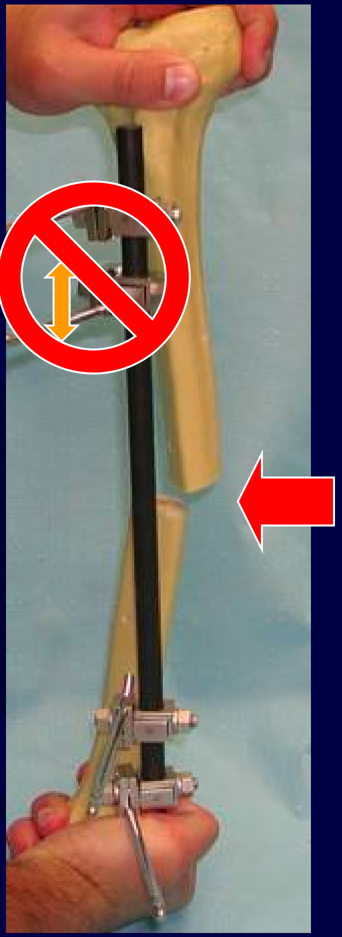
- Unrestricted joint motion
- Unilateral or Bilateral
- DISADVANTAGES
  – Cantilever bending at fracture resulting in high shear and torque
  – Unable to immediately weight bear
  – “Non union maker” historically

BIOMECHANICS

Stability improved with:

- Increased pin diameter
- Increased pin spread
- Increased number of pins
- Decreased distance from pin to fracture

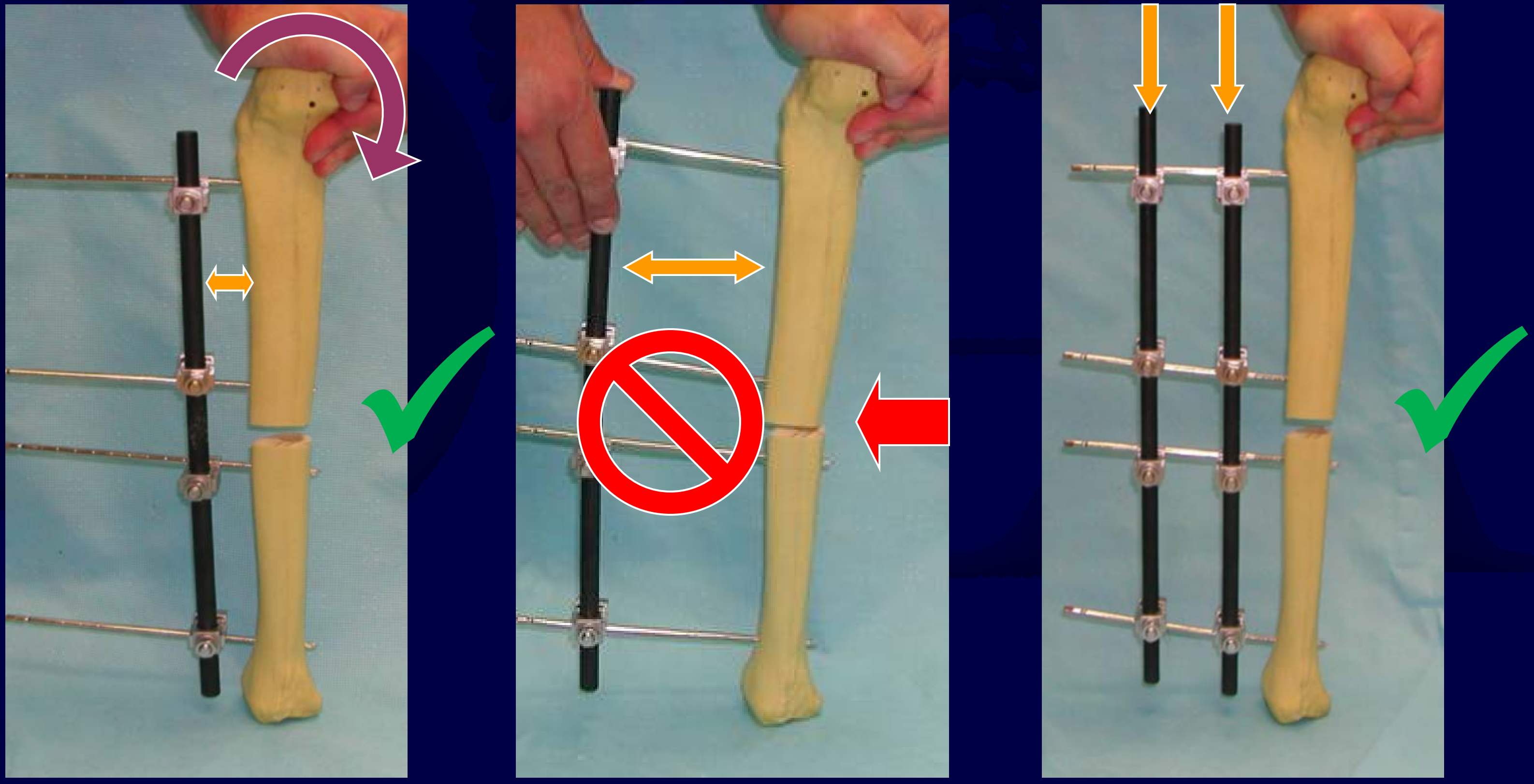




Minimize cantilever bending and sheer at fracture

BIOMECHANICS:ROD FACTORS

- Frames placed in the same plane as the applied load
- Decreased distance from bars to bone
- Double stacking of bars
- Allow for sufficient space for soft tissue swelling



UNIPLANAR BILATERAL

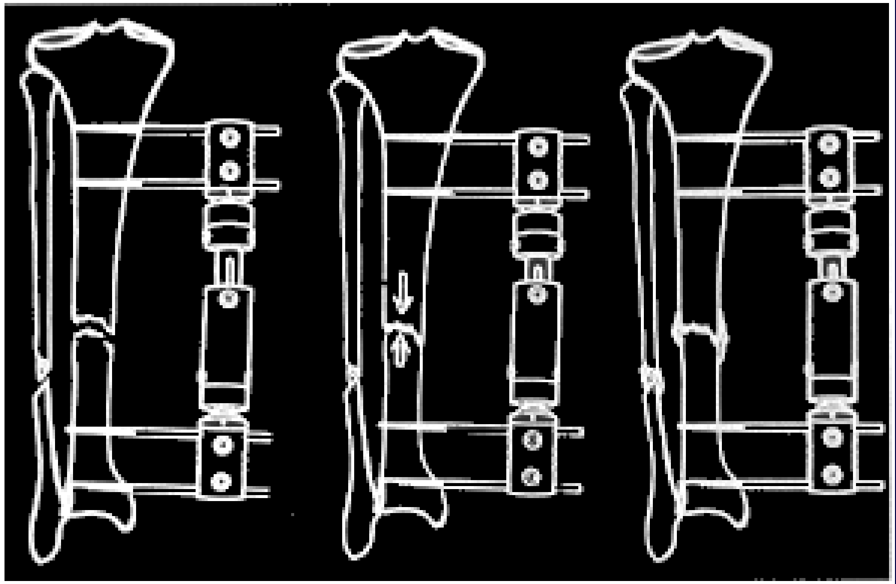
- Bilateral frame with improved share loading at pin/bone interface
- Decreased cantilever bending at fracture
- Limited applications secondary to tissue transfixion and risk or neurovascular injury

Travelling traction
Uniplanar/Bilateral

Photo courtesy of Matthew Camuso

DYNAMIZATION

- **Dynamization = load-sharing construct that promotes micromotion at the fracture site**
- **Controlled load-sharing helps to "work harden" the fracture callus and accelerate remodeling**
- **Serially destabilize frame over time to allow for increased controlled axial compression**

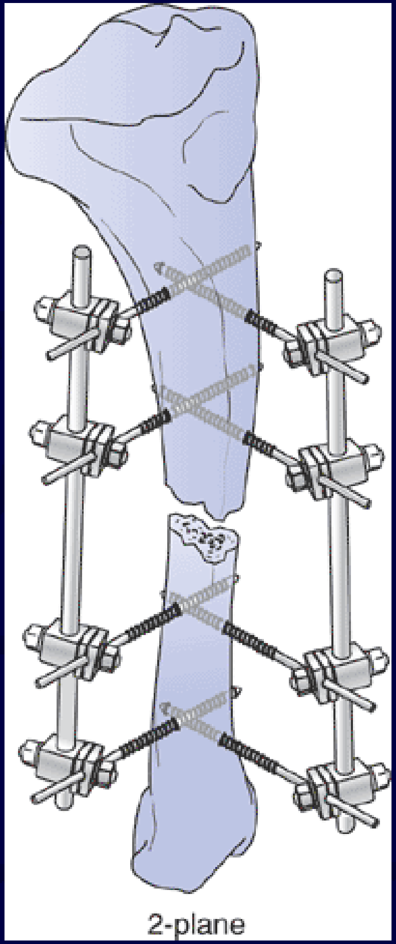


(Figures from: Rockwood and Green, Fractures in Adults, 4th ed, Lippincott-Raven, 1996)

Kenwright and Richardson, JBJS-B, '91
Quicker union less refracture
Marsh and Nepola, '91
96% union at 24.6 wks

BIPLANAR

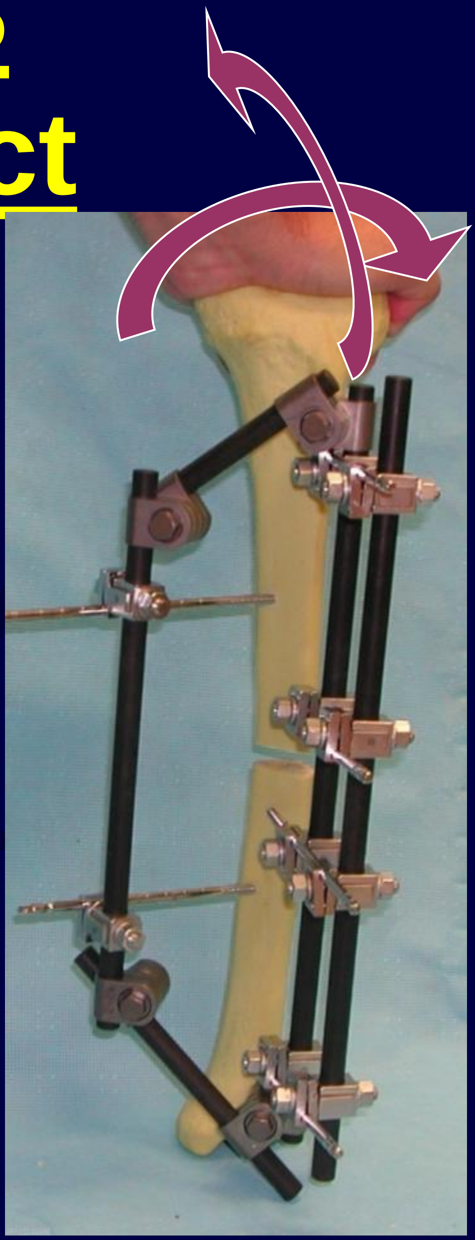
- Improved axial and sagittal stability
- Avoids NV injury vs uniplanar/bilateral
- Major limitations is still cantilever bending
  - Common for temporary fixation
  - Limited applications for definitive care



Rockwood and Green, 6th ed. Fig. 7-14. p. 264

BIOMECHANICS
Biplanar Construct

- Linkage between frames in perpendicular planes (DELTA)
- Controls each plane of deformation
- Reduced shear/torque at fx
- Shear
  - Uniplanar>biplanar >hybrid>circular



UNIPLANAR/BIPLANAR SUMMARY

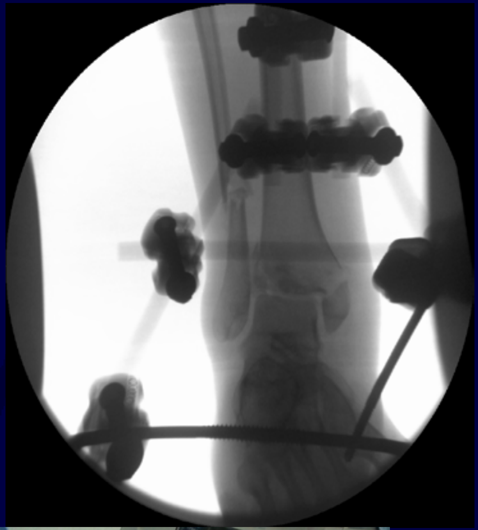
- Use the largest size pin that is appropriate
- Rods close to the bone
- Decrease the distance from pin to fracture
- Increase distance between pins adjacent to fracture
- Double stack
- Pins at 90 degrees increase frame strength
- Dynamization improves fracture healing

Most important factor in increasing frame strength is increasing pin size (R^4)

TEMPORIZING JOINT SPANNING

- **Periarticular fractures**
- **Modified uniplanar/biplanar**
- **Useful when soft tissue injury**

•Relative reduction by capsuloligamentotaxis



JOINT SPANNING

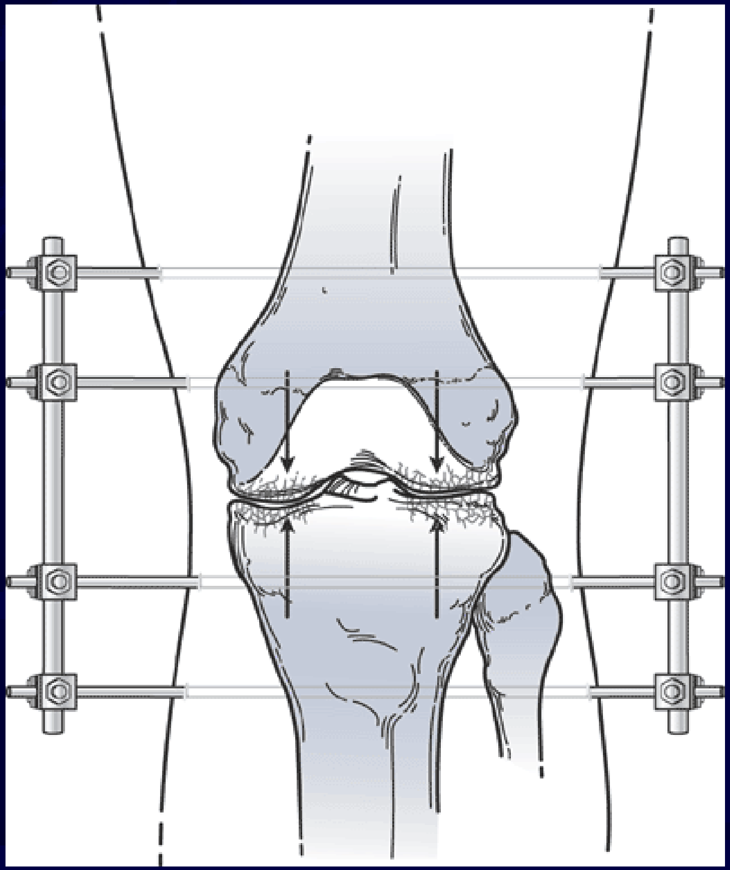
- **Avoid transfixing muscle**
- **Disadvantages**
  - **Pin tract infection**
  - **Pin loosening**
  - **Loss of reduction**
  - **Joint stiffness**
  - **Foot equinus**
    - **Consider pinning midfoot**

JOINT SPANNING

- Can be utilized for definitive fixation for distal radius fracture
- Beware of pin placement proximally
  - Superficial radial nerve

JOINT SPANNING

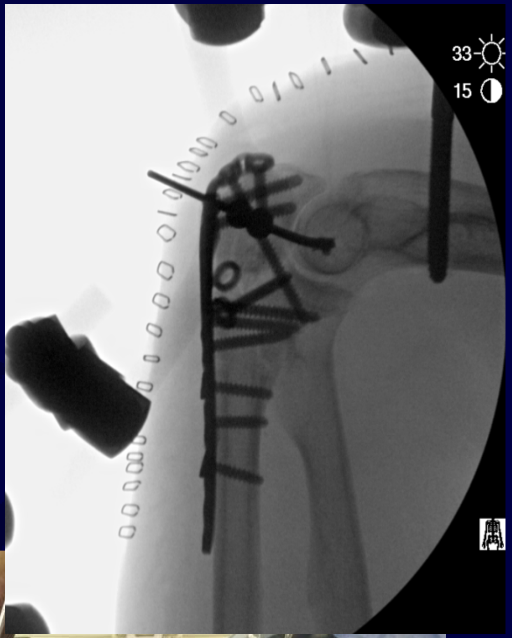
- Uniplanar/biplanar frames used successfully for knee/ ankle arthrodesis as salvage
- Construct should be dynamized over time
- Minimize shear forces



Rockwood & Green, 6th ed.
Fig. 7-8, p. 261

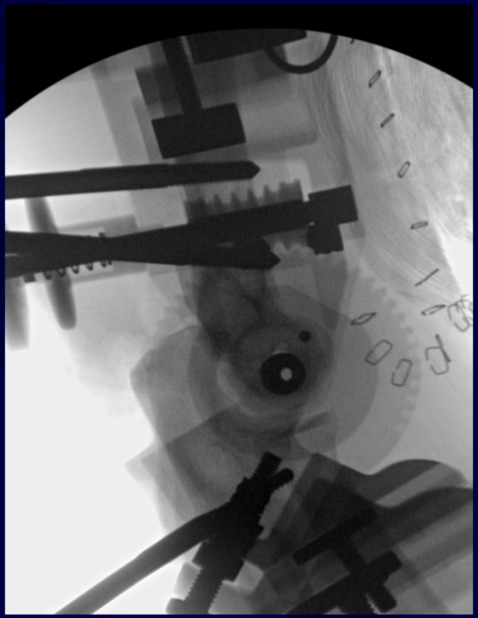
ARTICULATING HINGE

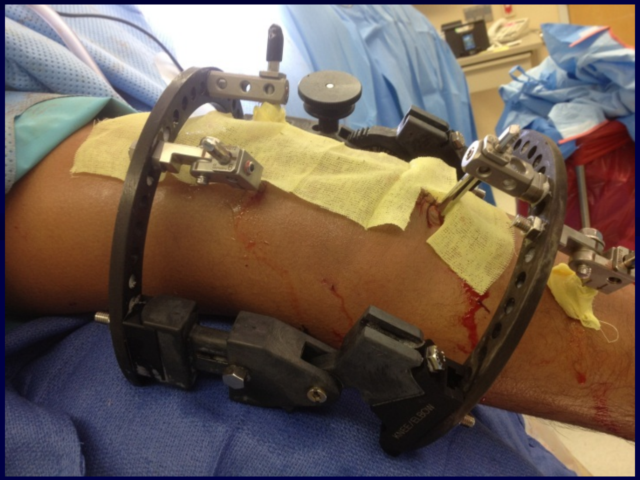
- Uniplanar or biplanar
- Peri-articular injuries
- Ligamentous injury
- Vascular injury
- Most common in elbow, knee and ankle
- Adjunct to internal fixation and ligamentous repair
- Avoid overbuilding to allow for motion



ARTICULATING FRAME

- May need different size pins (5mm humerus, 4mm ulna)
- Build frame from joint center of rotation
- Avoid pinning down muscles with long excursion
- Disadvantage: Potential high complication risk
    - Pin tract infection
    - Nerve injury
    - Broken pin
    - Loss of joint reduction
    - Iatrogenic ulna fracture



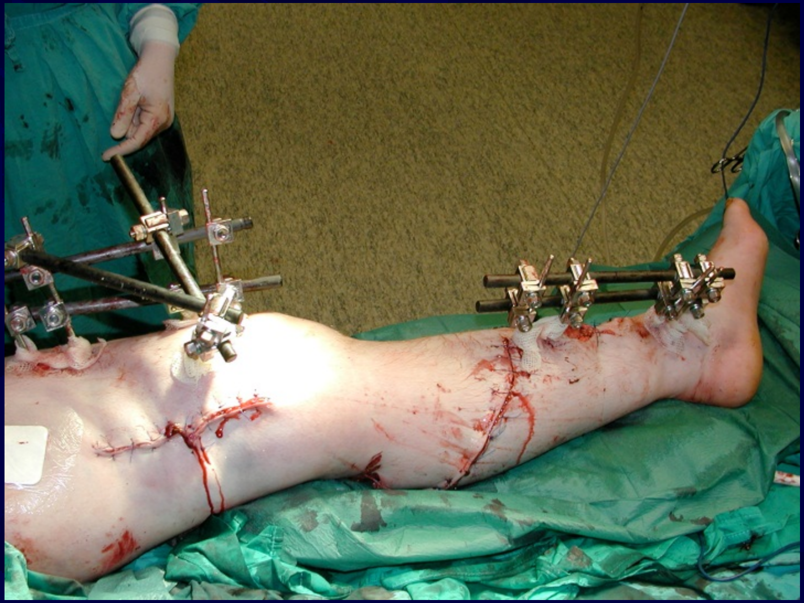


Ring D.,Bruinsma E.,Jupiter.,Complications of Hinged External Fixation Compared With Cross-pinning of the Elbow for Acute and Subacute Instability. CORR, 472: 2044-2048, 2014.

DAMAGE CONTROL SURGERY

Pape et al. Annals of Surgery 2007

- Developed to focus on initial hemorrhage control, followed by definitive care
- Minimize 2nd hit
- Convincing results have not warranted randomized studies
- Positive result with unstable pelvic ring injuries



DAMAGE CONTROL ORTHOPAEDICS

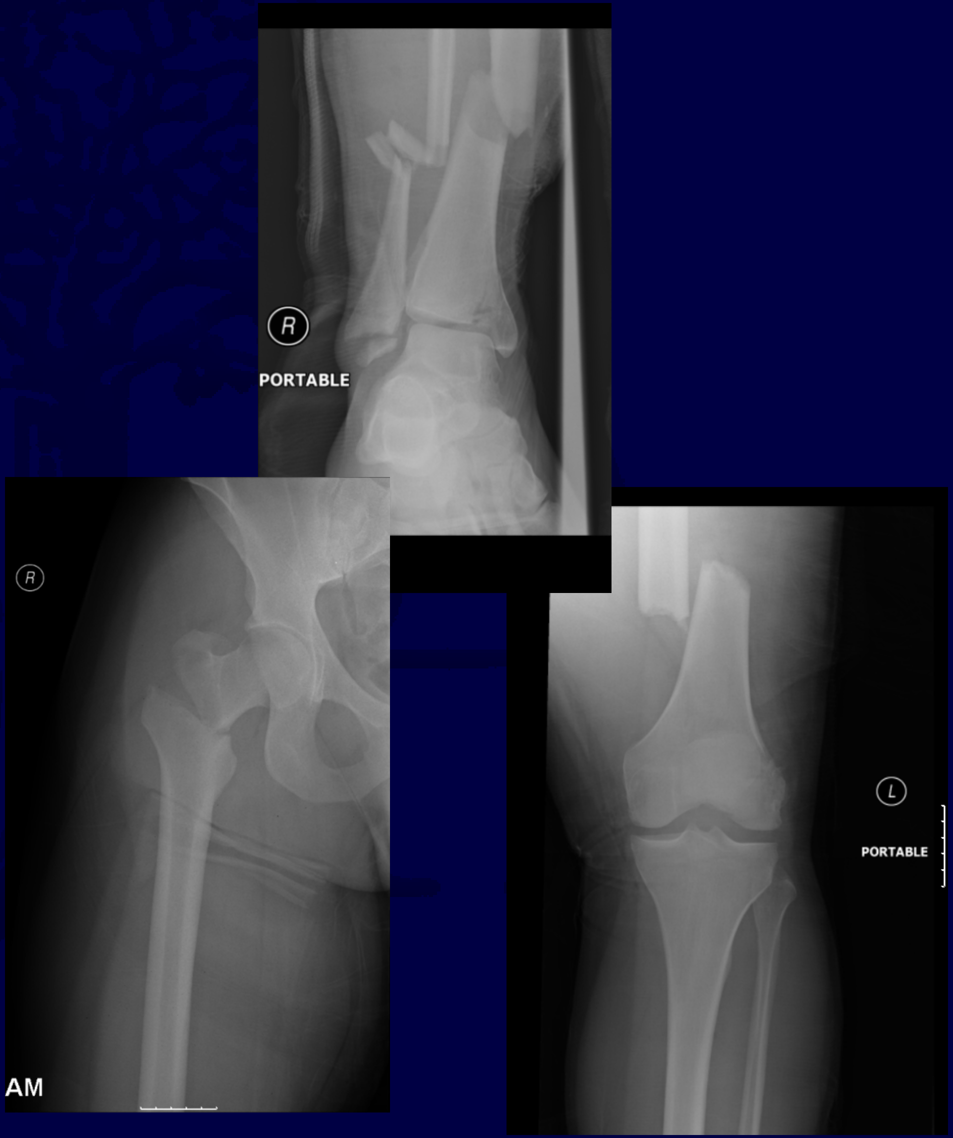
External Fixation as a Bridge to Intramedullary Nailing for Patients with Multiple Injuries and with Femur Fractures: Damage Control Orthopedics

Thomas M. Scalea, MD, Sharon A. Boswell, RN, CEN, Jane D. Scott, ScD, MSN, Kimberly A. Mitchell, MS, Mary E. Kramer, RN, and Andrew N. Pollak, MD

- First coined in 2000 by Scalea et al.
  - Shock Trauma Experience
- Methodology of addressing rapid temporary stabilization and resuscitation prior to definitive stabilization
- Practiced for many decades despite recent popularity

DAMAGE CONTROL cont.

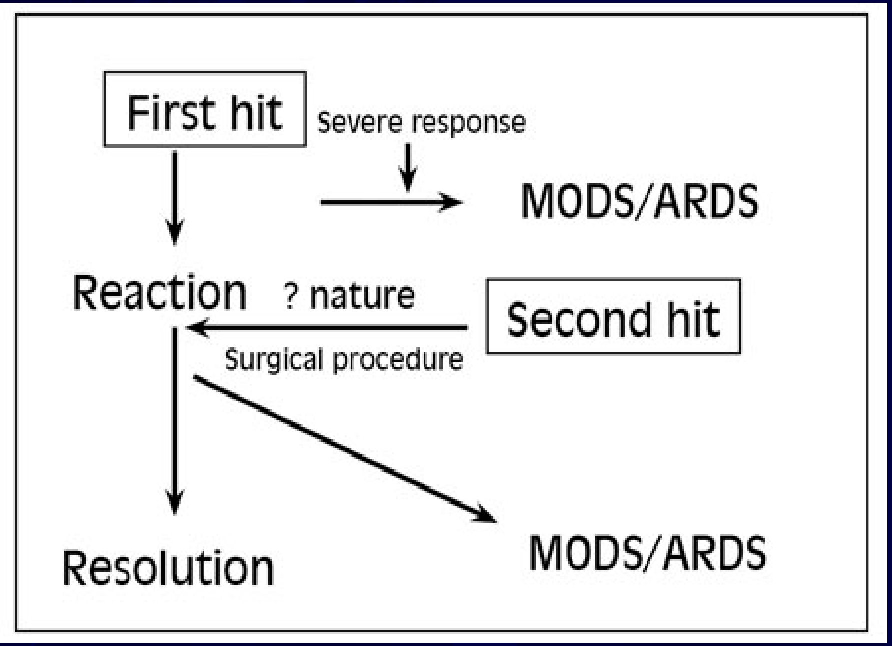
- Prioritize injuries
- Goal is rapid frame stabilization and not definitive fixation
- Avoid fixation pins crossing surgical approach paths
- Adhere to fixation principles
- Consider team approach to decrease surgical time



SECOND HIT THEORY

Hildebrand et al. Injury 2004

- **First hit= initial trauma and associated resuscitation**
- **Second hit= surgical intervention**
- **We can control the second insult**



Injury 2004

Impact of the Method of Initial Stabilization for Femoral Shaft Fractures in Patients With Multiple Injuries at Risk for Complications (Borderline Patients)

<u>Pape et al. Annals of Surgery 2007</u>

Randomized controlled and blinded

94 acute IMN

71 Damage Control/External fixation

Almost 7X increased acute lung injury when IMN in the “borderline pt”

No significant increase in SIRS, ARDS, MODS, post-op course, complications when controlled for ISS

Changes in the Management of Femoral Shaft Fractures in Polytrauma Patients: From Early Total Care to Damage Control Orthopedic Surgery

Hans-Christoph Pape, MD, Frank Hildebrand, MD, Stephanie Pertschy, MD, Boris Zelle, MD, Rayeed Garapati, MD, Kai Grimme, MD, and Christian Krettek, MD

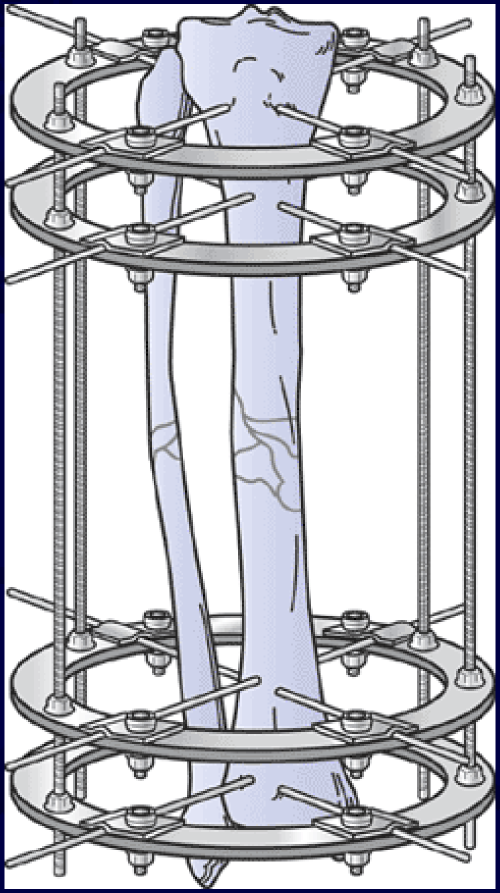
- **Retrospective cohort study**
  - **ETC (1981-89)**
  - **INT (1990-92)**
  - **DCO (1993-2000)**
- **Higher ARDS rate in IMN (15%) vs ETC (9.1%)**
  - **No change in mortality**
- **Incidence of MODS/MOF decreased significantly in all groups from 81-2000**

DAMAGE CONTROL SUMMARY

- **Rapidly stabilize pelvis and long bone injuries**
- **Peri-articular fxs secondarily**
- **Avoid crossing surgical planes with pin fixation**
- **Goal is stabilization, may require later frame adjustment**
- **Don’t confuse speed with carelessness, adhere to principles**

RING FIXATORS

- Controlled compression
- Decreased shear and increased micromotion
- Improved peri-articular fixation
- Allow for weight bearing
- Low infection risk
- Increasing role for high energy open tibia fractures with bone loss and or soft tissue loss



Rockwood & Green, 6th ed.
Fig. 7-6. p. 260

BIOMECHANICS OF RING FIXATION

- Ring fixator with increased coronal, sagittal stability (4-7X)
- Increased micromotion (1.75X) with increased rate of union vs unilateral
- Increasing axial load results in decreased micromotion “trampoline effect”

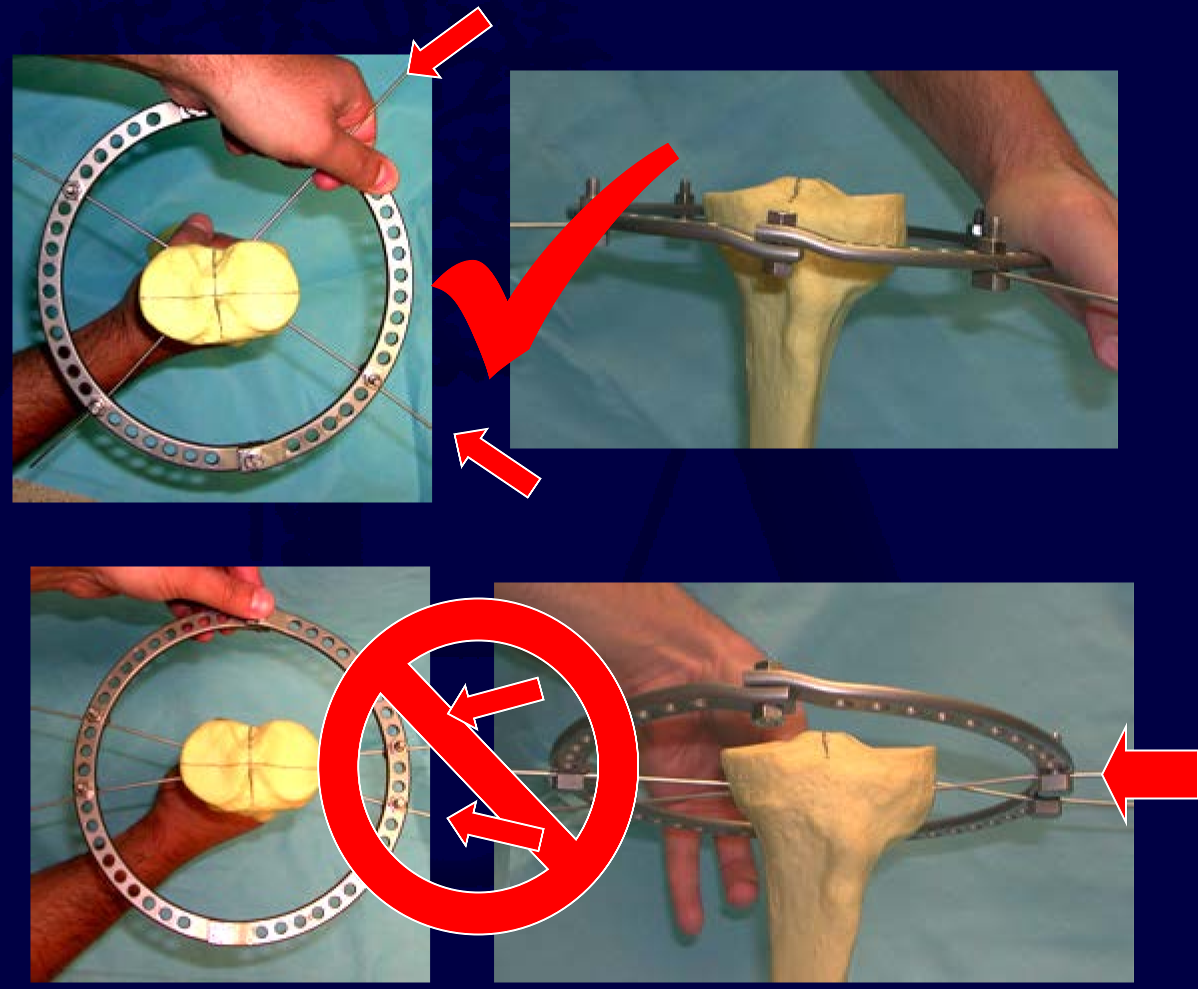
Lowenberg et al. Principles of tibial fracture management with circular external fixation. Clin. Orthops N. Am. 45:191-206. 2014

RING FIXATORS
Key Principles

- Increasing frame strength with:
  - Wires as close to 90^{o} to each other
  - Increasing pin diameter
  - Increasing tension (90-130kg)
  - Decreased ring size
  - Increased number of rings/wires
  - Decreasing distance of ring to fracture

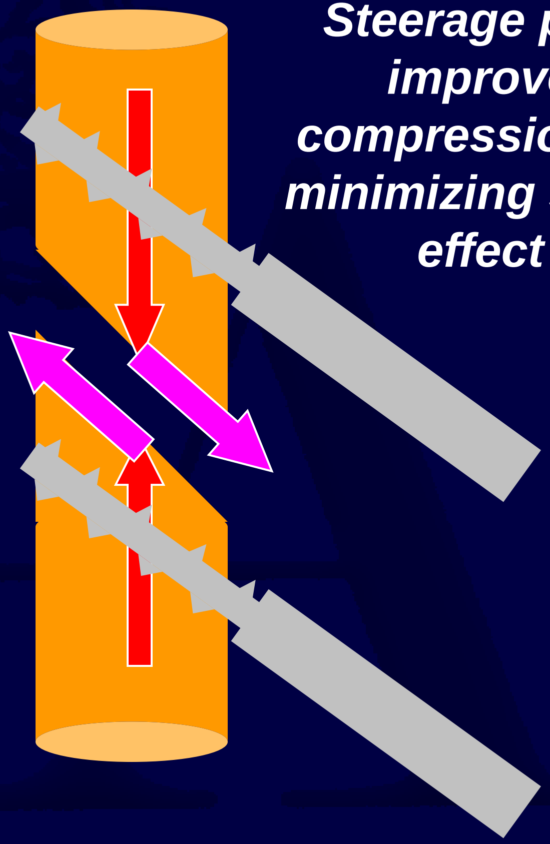
Frame Mechanics: Ring Fixators

- Spread wires to as close to 90^{o} as possible
- Use at least 2 planes of wires/half pins in each major segment
- Less than 60 degrees, risk of sliding bone segment



BIOMECHANICS cont.
Pin Factors

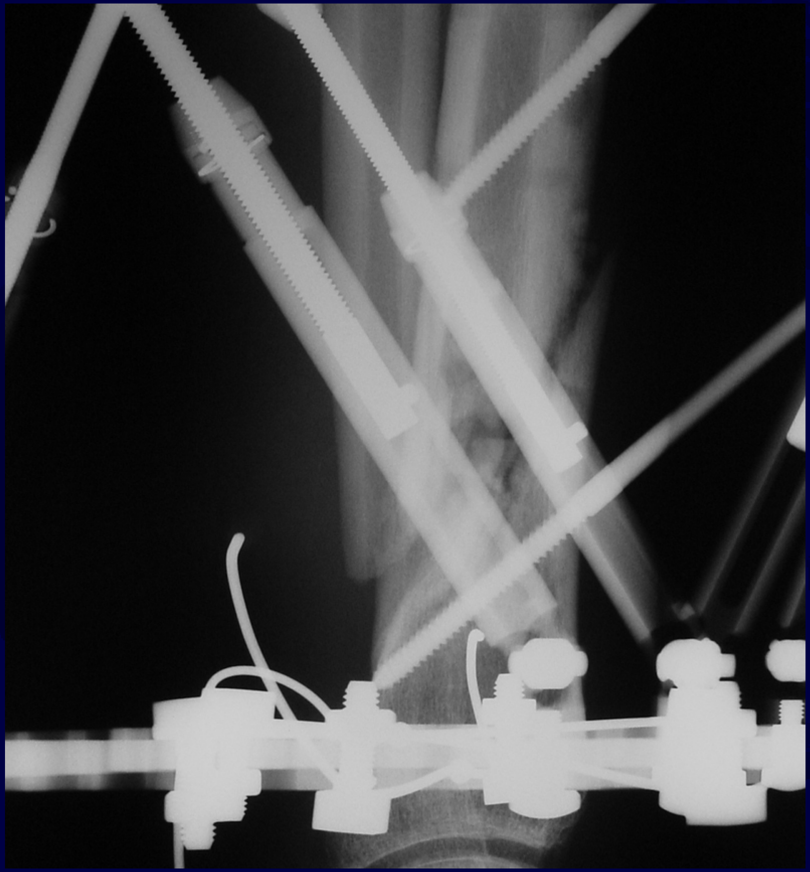
- **Oblique fxs subject to sheer**
- **Use oblique pin to counter these effects**
- **Beware of greater than 30 degree fracture obliquity**



Steerage pins improve compression by minimizing sheer effect

Metcalfe, et al, JBJS B, 2005
Lowenberg, et al, CORR, 2008
Lowenberg, et al, Orthop Clin North Am, 2014

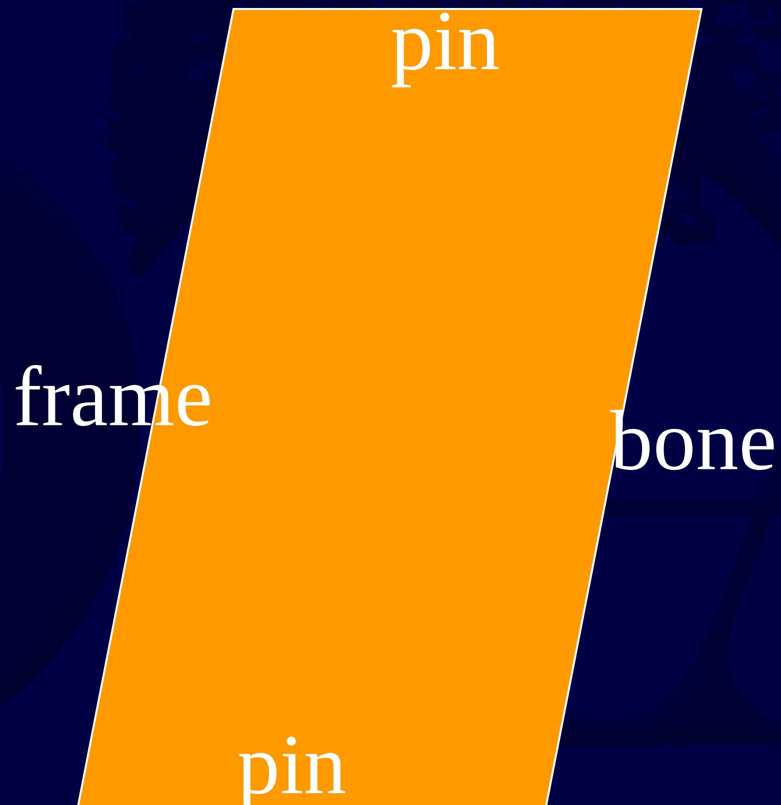
Steerage Pins



- First described by Dr. Charles Taylor.

Slide provided by David Lowenberg M.D

Steerage Pins



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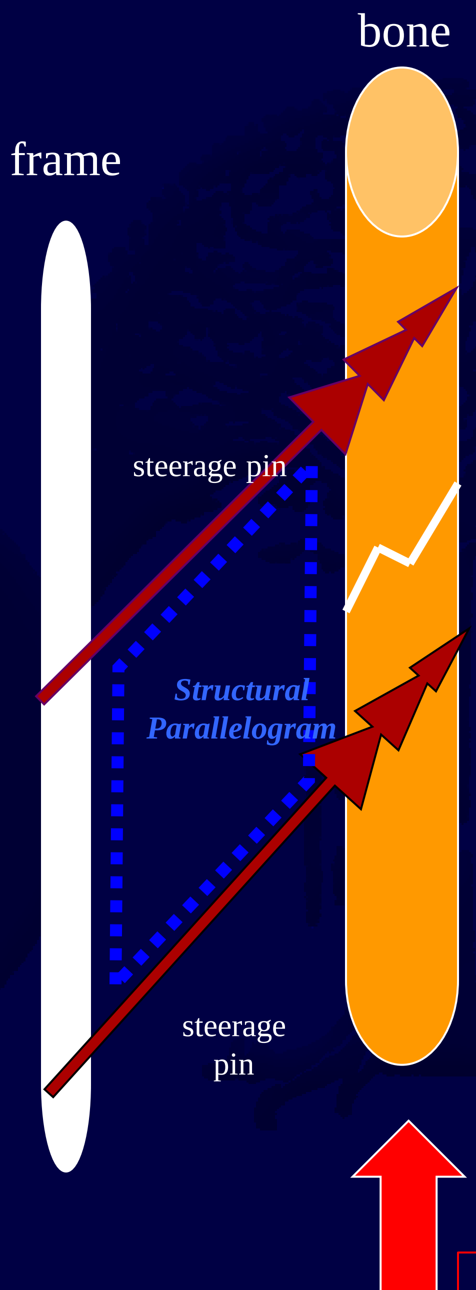

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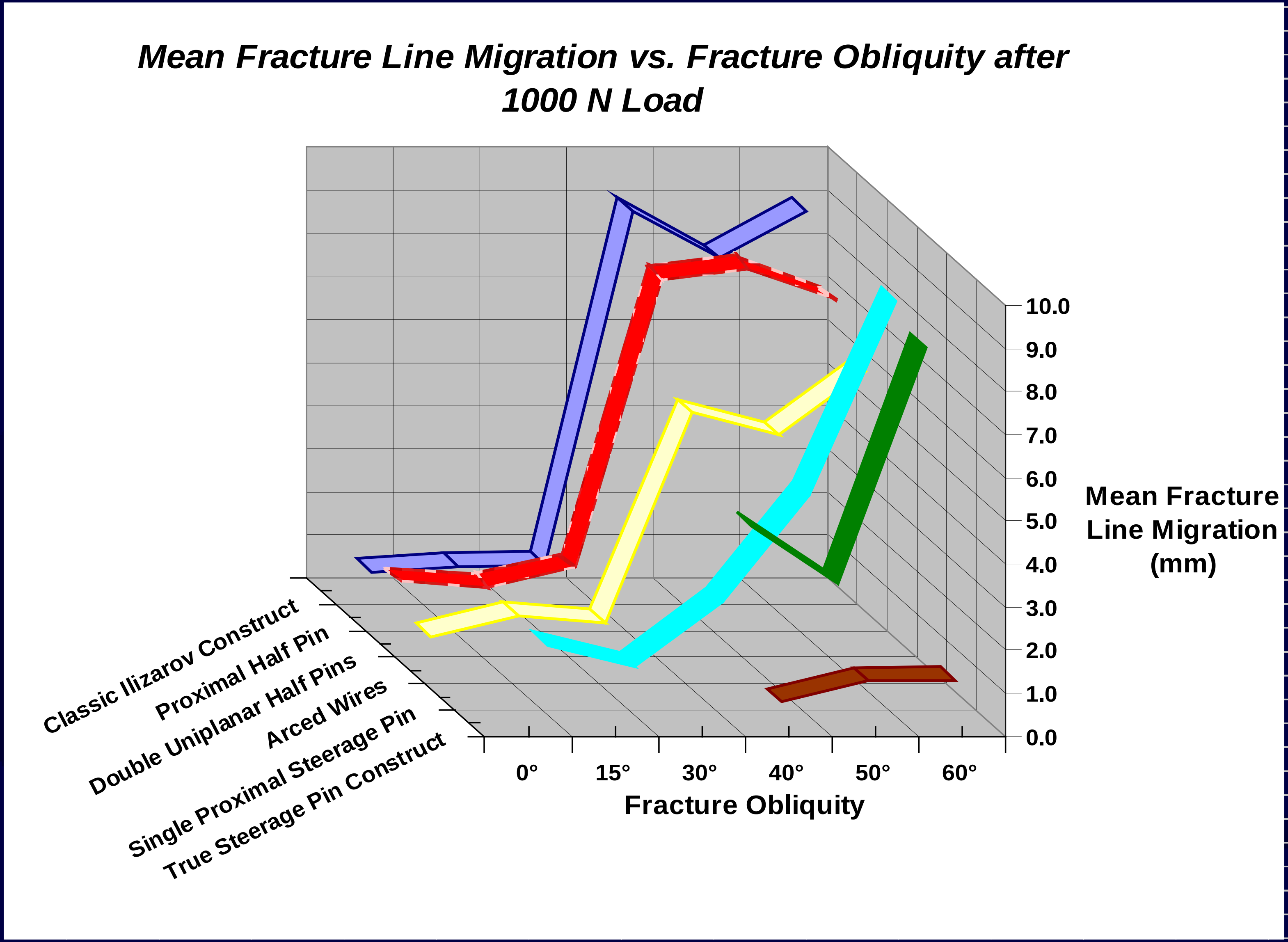

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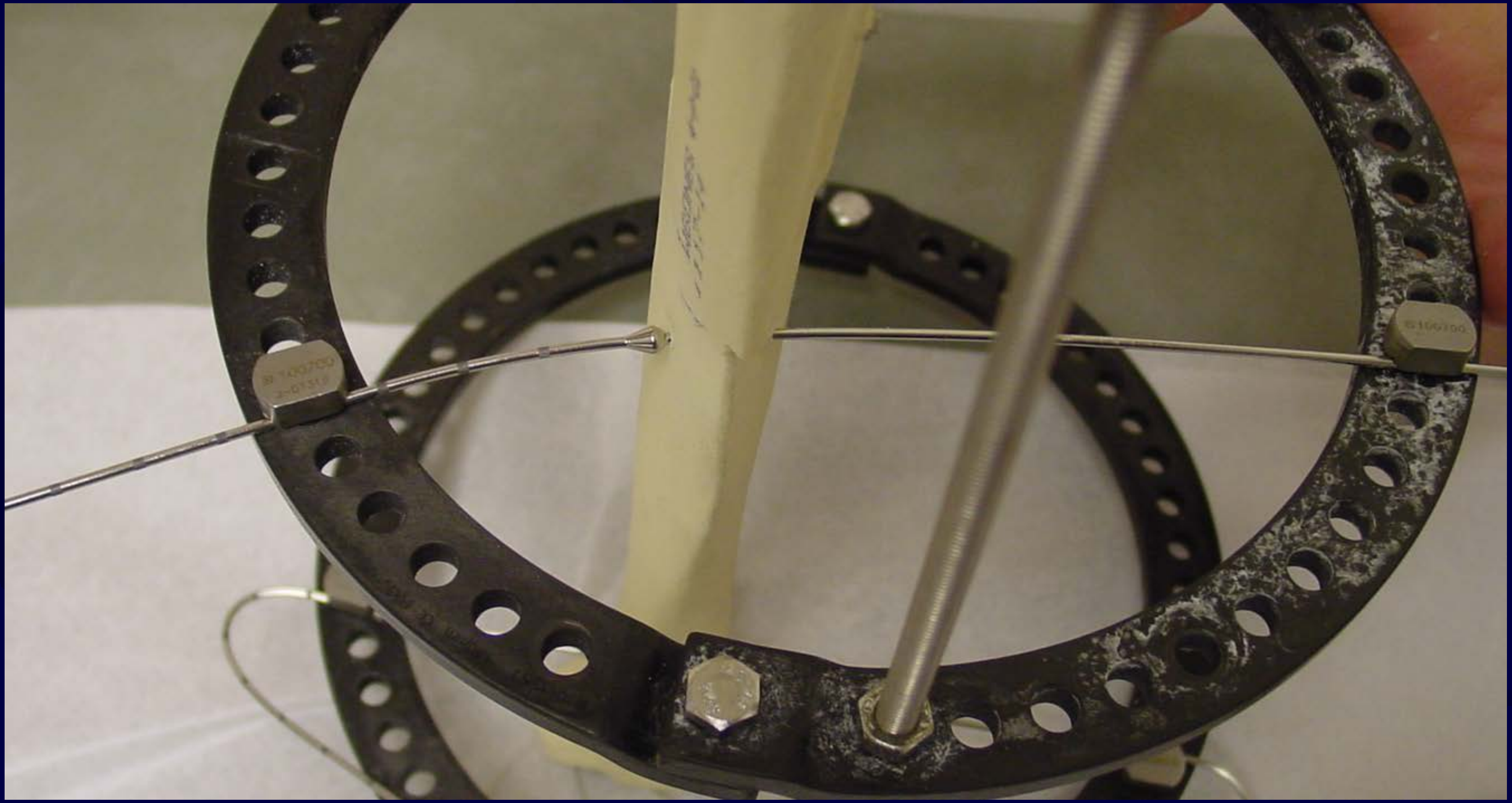
Arced Wires



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Conclusions

Lowenberg, et al

- **Shear becomes a factor in fracture stability at >30 degrees of fracture obliquity (*"30 – 60 Rule"*).**
- **Arced wires can help, but there is an inherent need to convert shear to compression by creation of a parallelogram at the fracture site.**

Conclusions

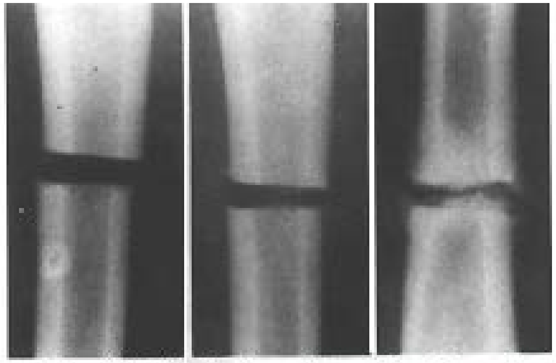
Lowenberg, et al

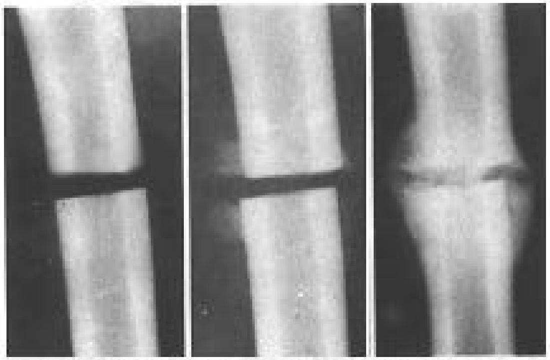
- **With increasing fracture obliquity, improve the frame/fixation geometry.**
- **Steerage pins are your friend.**

Slide provided by David Lowenberg M.D

BIOLOGY

- **Relative stability**
- **Fracture healing by stable yet less rigid systems**
  - **Dynamization**
  - **Micromotion**
  - **Uniform compression**
- **Callus formation**


A. Regidly Fixed: shows less callous formation


B. Applied dynamization and micromotion: shows more callous formation

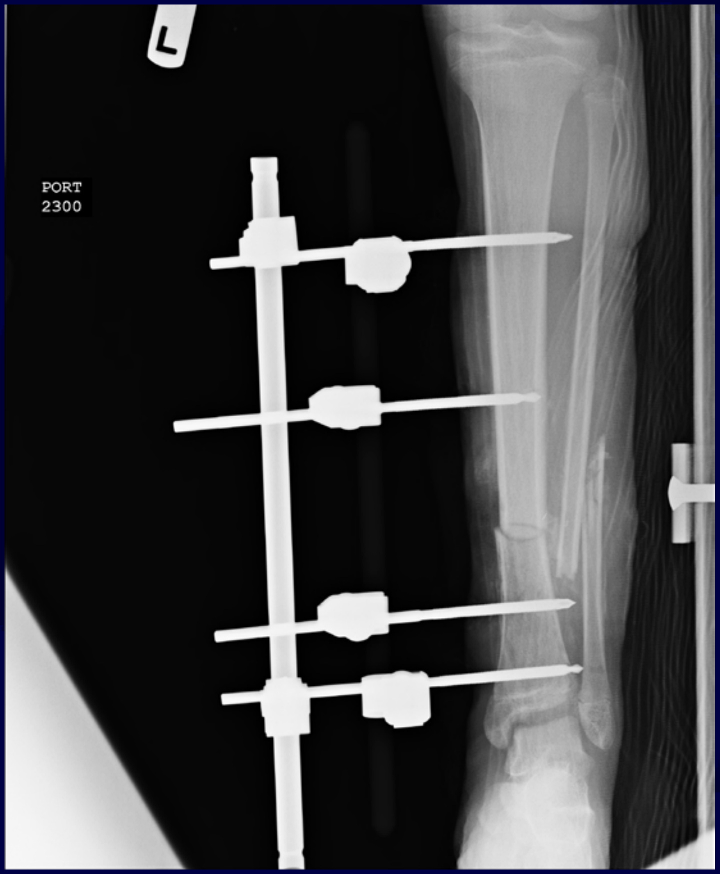
Kenwright, CORR, 1998
Larsson, CORR, 2001

(Figures from: Rockwood and Green, Fractures in Adults, 4th ed, Lippincott-Raven, 1996)

SALVAGE

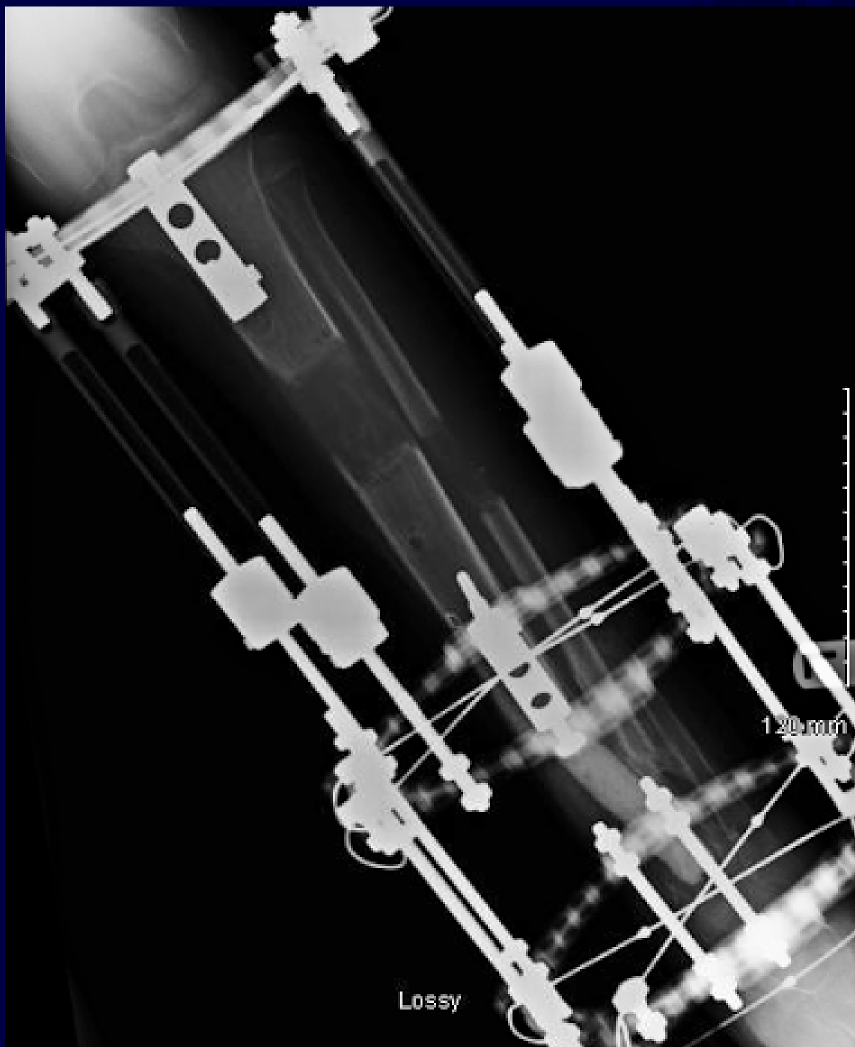
- Ring frame useful as salvage for segmental bone loss or severe soft tissue loss
- May acutely shorten limb to allow soft tissue coverage
- Later conversion to distraction ring frame, bone transport and grafting

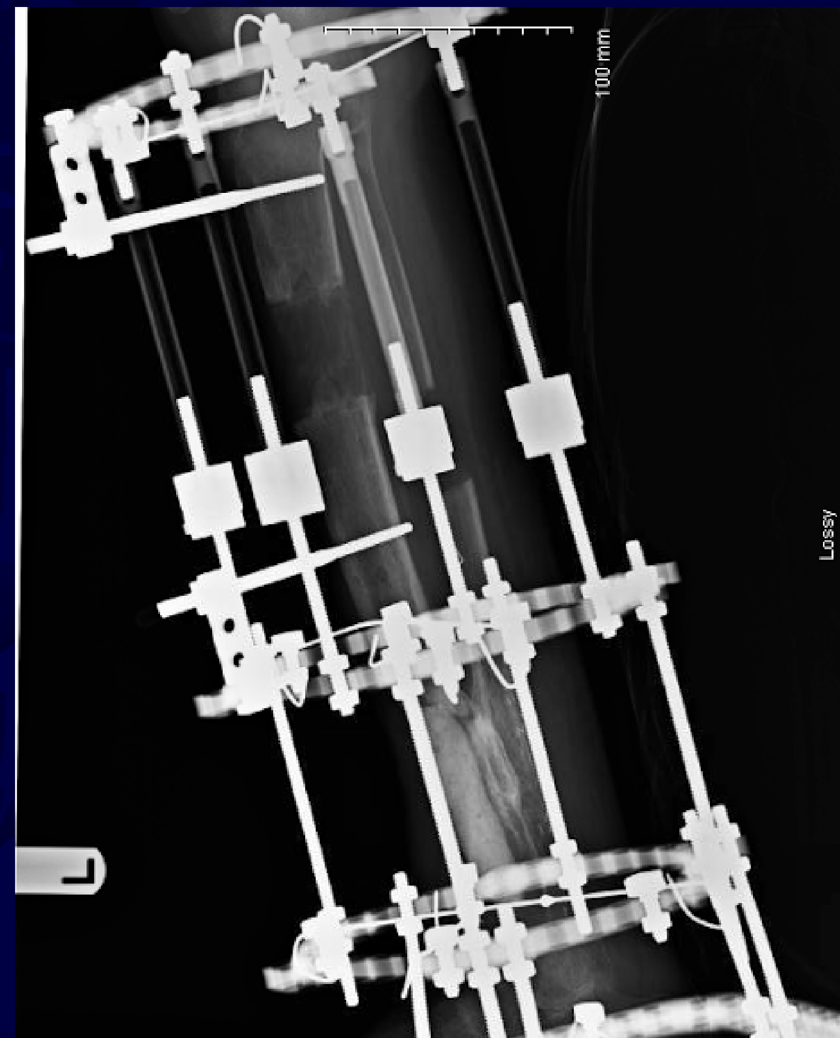
CONVERSION TO DISTRACTING RING



12 y/o with 3B open tibia, segmental bone loss from Haiti earthquake

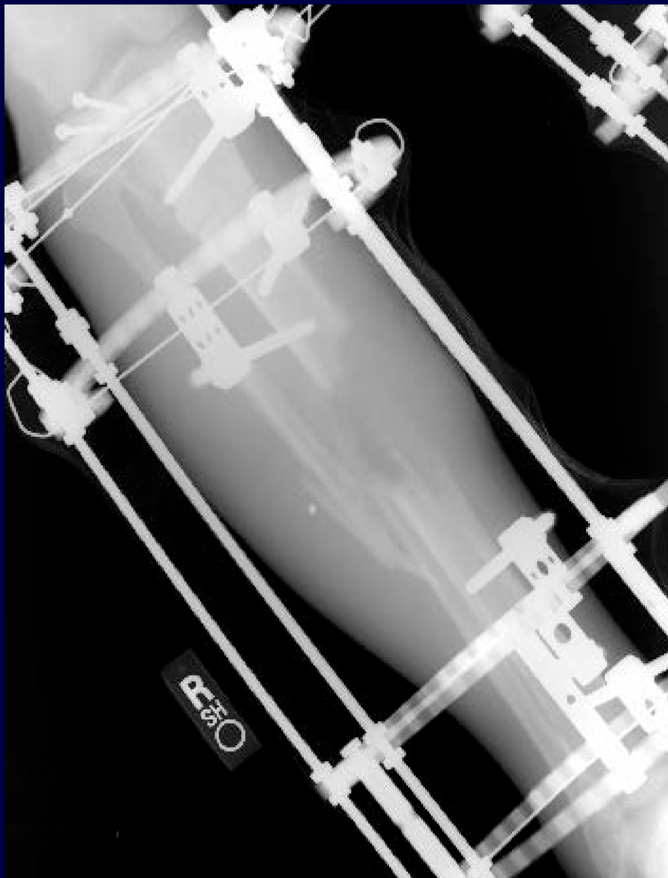
DISTRACTION OSTEOGENESIS

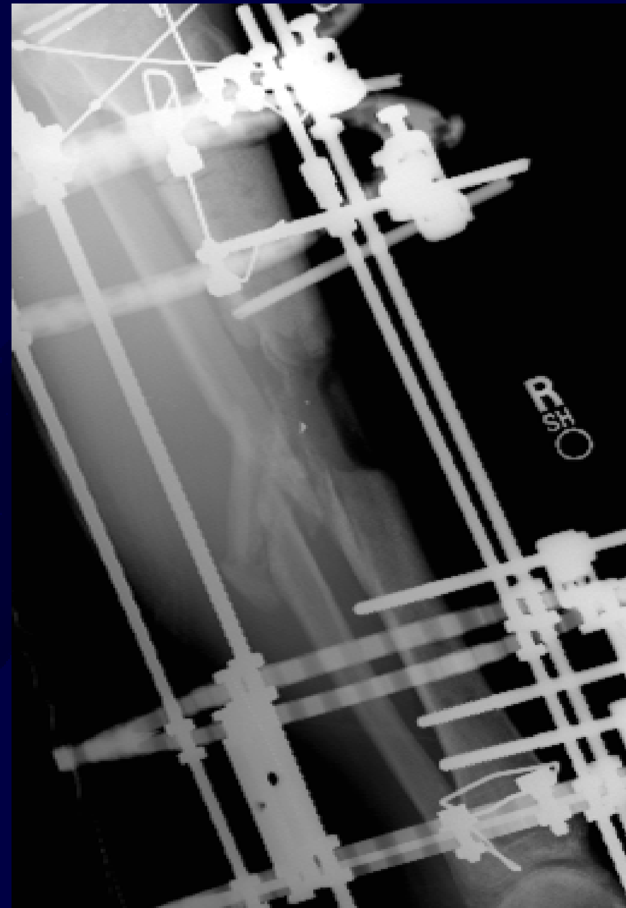




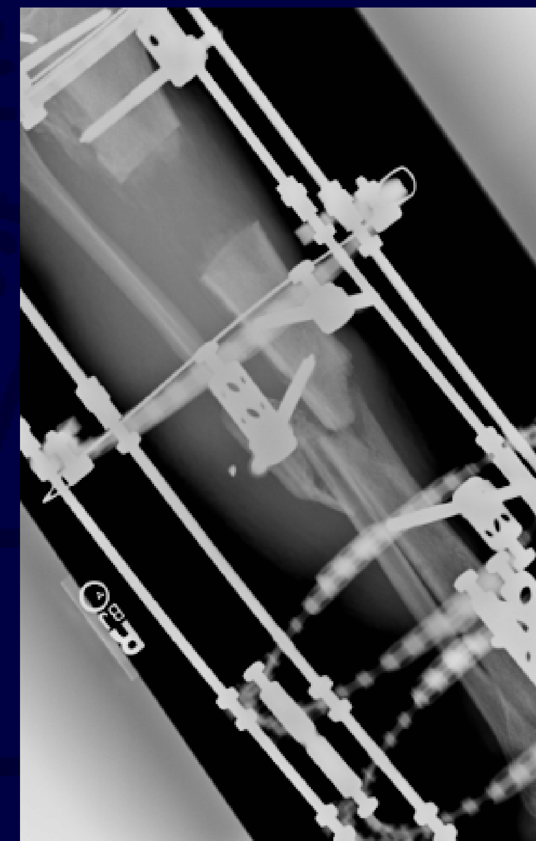
DOCKING

3B tibia with segmental bone loss, 3A plateau, temporary spanning ex fix

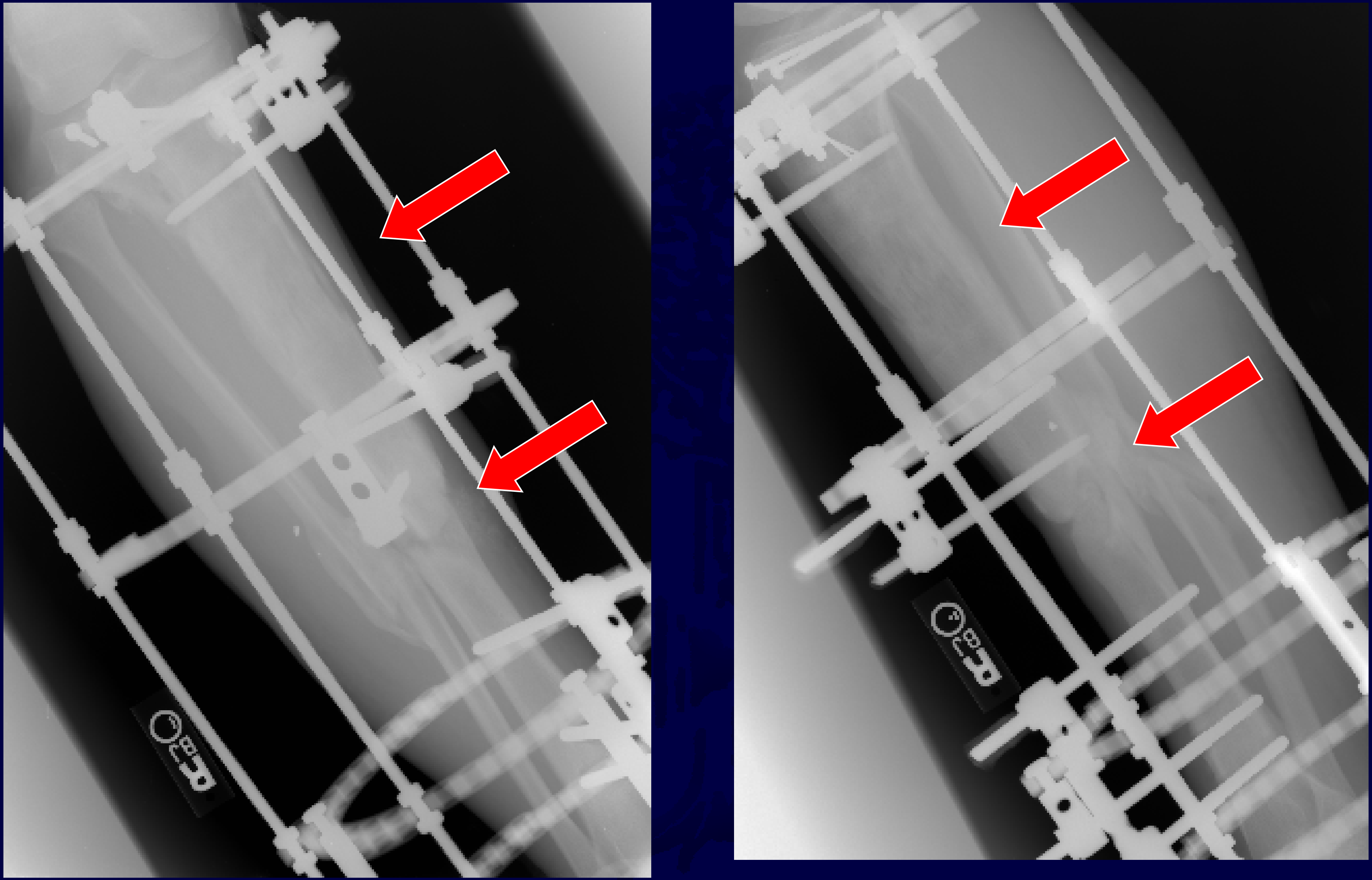




- Converted to circular frame, limited open reduction and internal fixation of tibial plateau with screws/wires



- Corticotomy and transport



Consolidation

***note: docking site bone grafted**

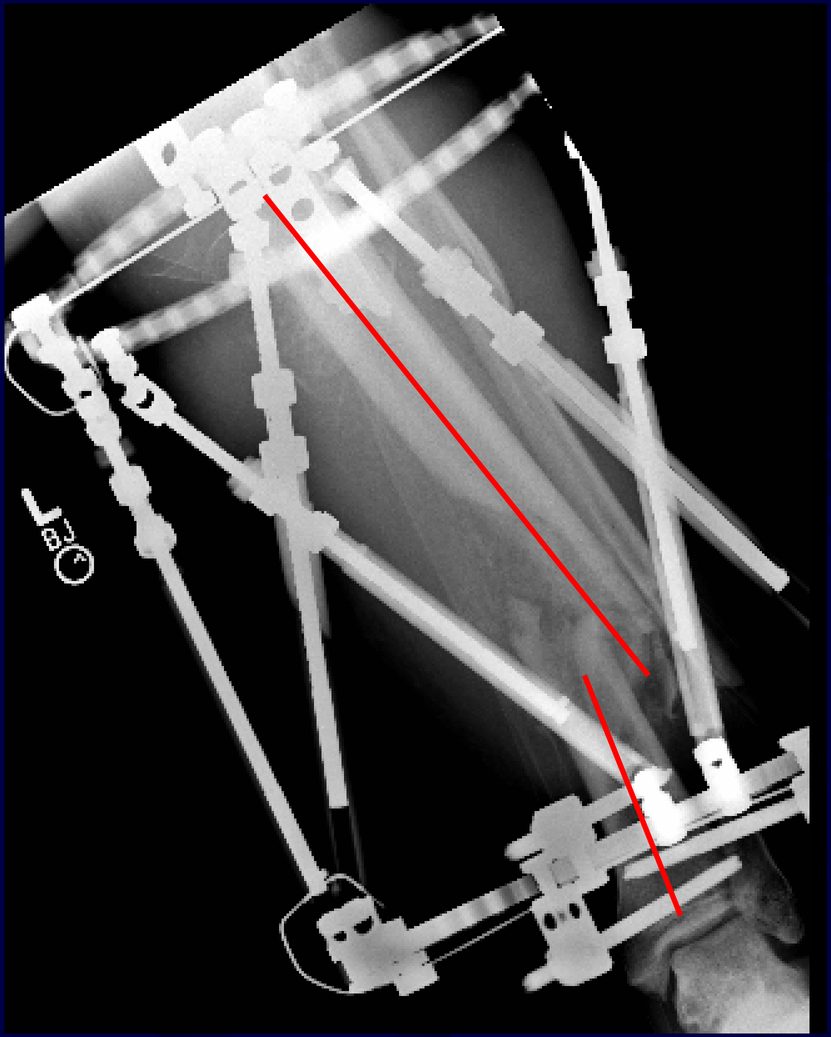
Union

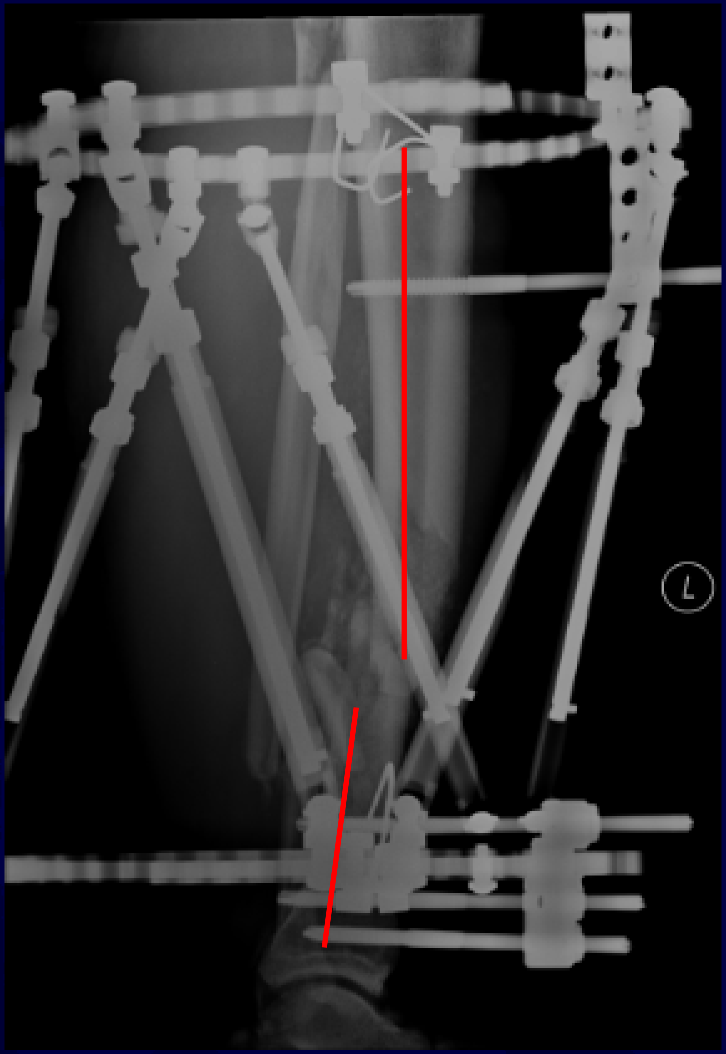
JOINT ARTHRODESIS

- Knee fusion
- Ankle fusion
- Serial compression and dynamization
- Salvage in a poor host, failure of prior fusion site and or soft tissue complications

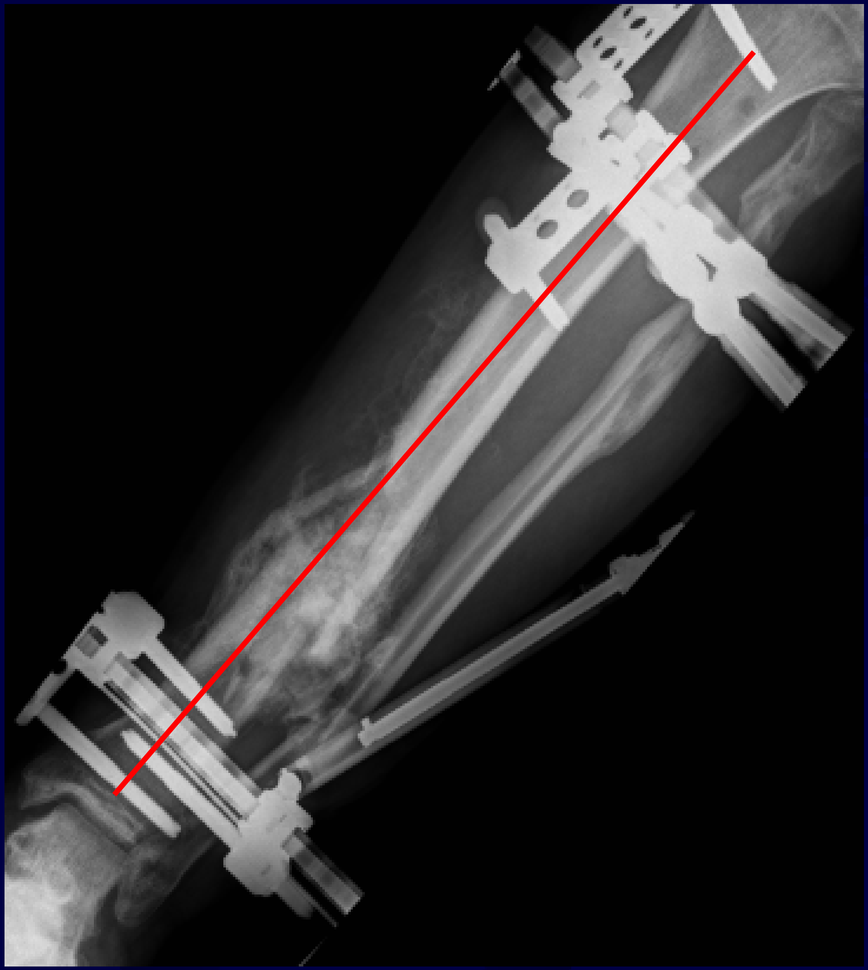
DEFORMITY CORRECTION

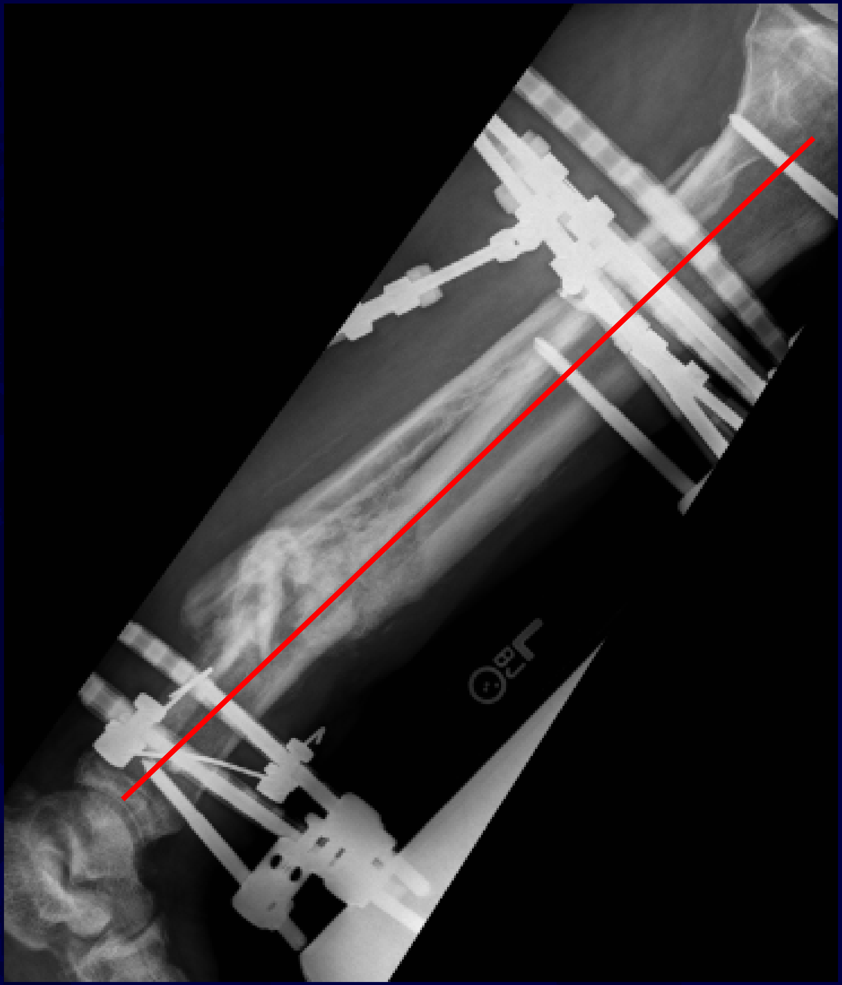
- **Hexapod frame**
  - **Taylor Spacial Frame (TSF)**
- **Application with wire or half pins**
- **Adjustable with 6 planes/degrees of deformity correction**
  - **Deformity correction**
    - **acute**
    - **chronic**





Type 3A open tibia fracture with bone loss

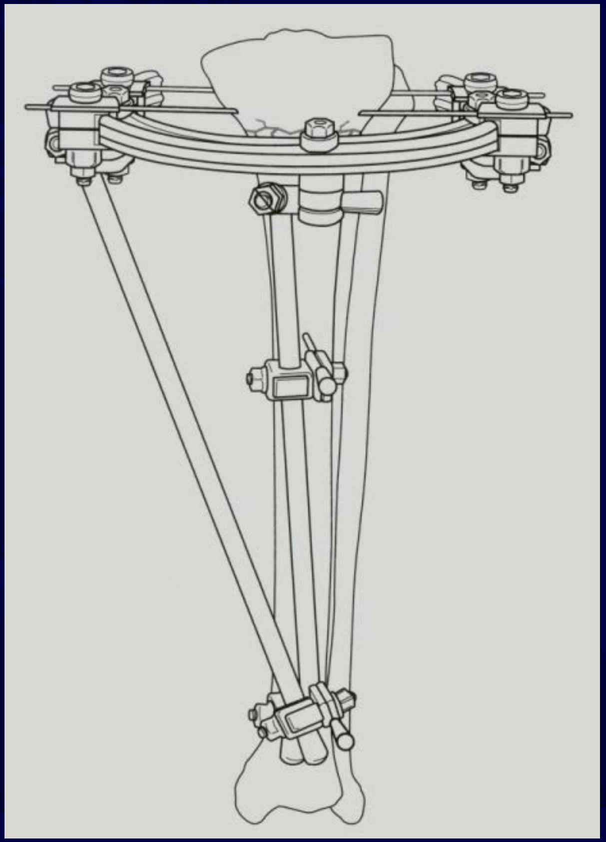




Following frame adjustment and bone grafting

HYBRID

- Combines the advantages of ring in periarticular areas with simplicity of planar half pins in diaphysis
- Disadvantage of increased sheer secondary to half pin use vs full circular ring frame
- Main advantage is for convenience



From Rockwood and Green's, 5th Ed

HYBRID VS FULL RING

- **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**

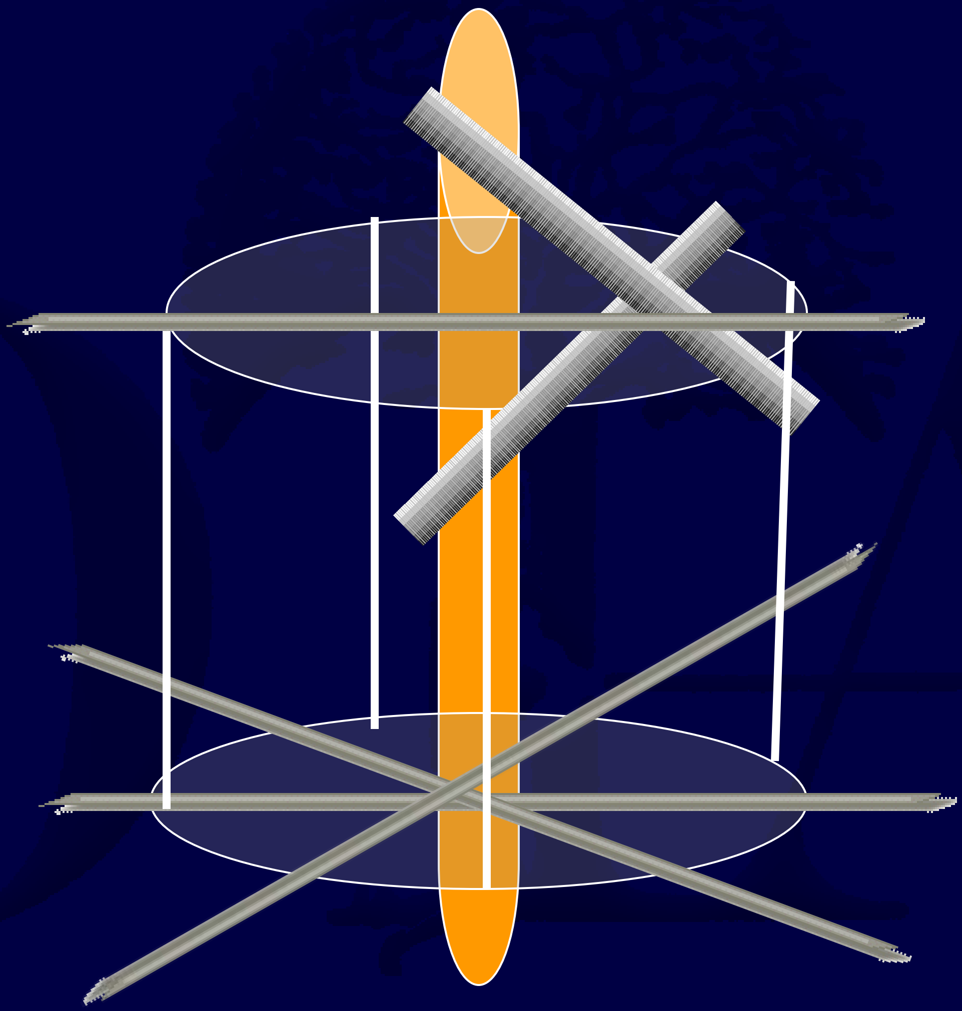
Clinical application: Use full ring fixator for fx with bone defects or expected long frame time

Pugh et al, JOT, '99
Yilmaz et al, Clin Biomech, 2003
Roberts et al, JOT, 2003

“Classic” Hybrid Fixation

Slide provided by David Lowenberg M.D

Multiplanar External Fixation



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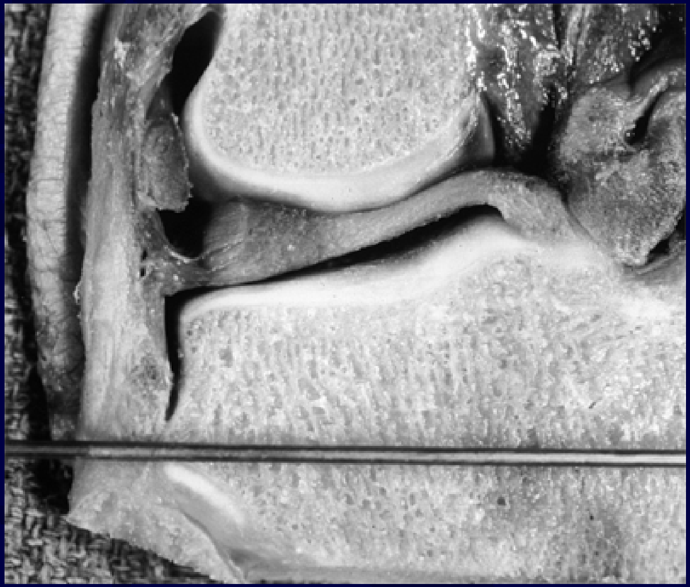
Anatomic Considerations

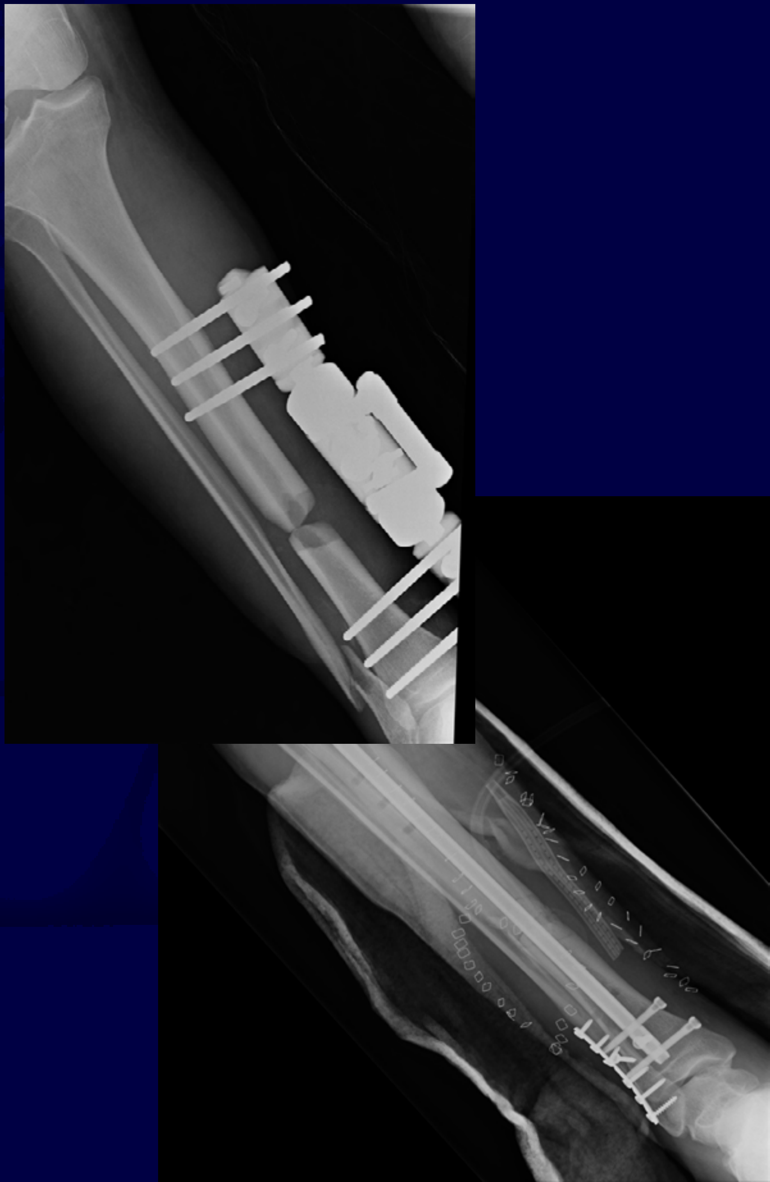
- Cross sectional anatomy knowledge is critical
- Avoidance of major nerves, vessels and organs (pelvis) is <u>mandatory</u>
- Avoid joints and joint capsules
  - Proximal tibial transfixion pins should be placed >14 mm distal to articular surface to avoid capsular reflection
- Minimize muscle/tendon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



Rockwood & Green, 6th ed. Fig 7-35 A. p. 286

Conversion of Ex Fix to ORIF

- Generally safe within 2-3 wks
  - Bhandari, JOT, 2005
    - Meta analysis: all but one retrospective
    - 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
  - Maurer, ’89
    - 77% deep infection with h/o pin infection



Conversion of Ex Fix to Nail

Nowotarski et al. JBJS 2000

1507 femur fractures

- **59 fxs tx'd with ex-fix and then IMN**
- **1.7 percent infection rate**
- **11% re-operation rate**

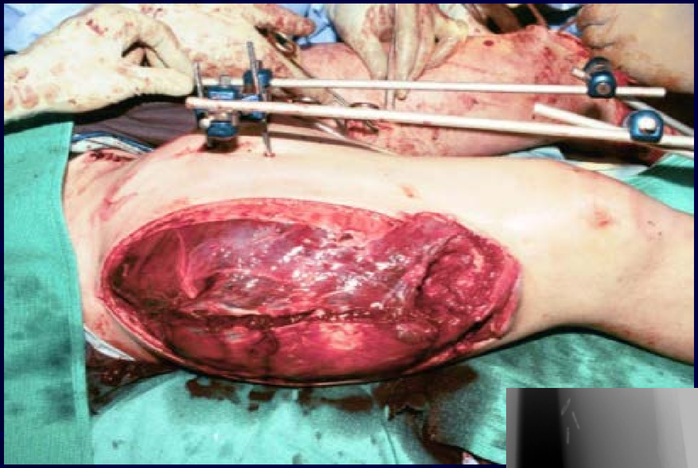
"immediate ex-fix followed by early closed IMN is a safe treatment…. in selected multiply injured patients"

Conversion should occur before 2 wks

EVIDENCE

Femur fx

- Nowotarski, JBJS-A, ’00
  - 59 fx (19 open), 54 pts,
  - Convert at 7 days (1-49 days)
  - 1 infected nonunion, 1 aseptic nonunion
- Scalea, J Trauma, ’00
  - 43 ex-fix then nailed vs 284 primary IM nail
  - ISS 26.8 vs 16.8
  - Fluids 11.9l vs 6.2l first 24 hrs
  - OR time 35 min EBL 90cc vs 135 min EBL 400cc
  - Ex fix group 1 infected nonunion, 1 aseptic nonunion



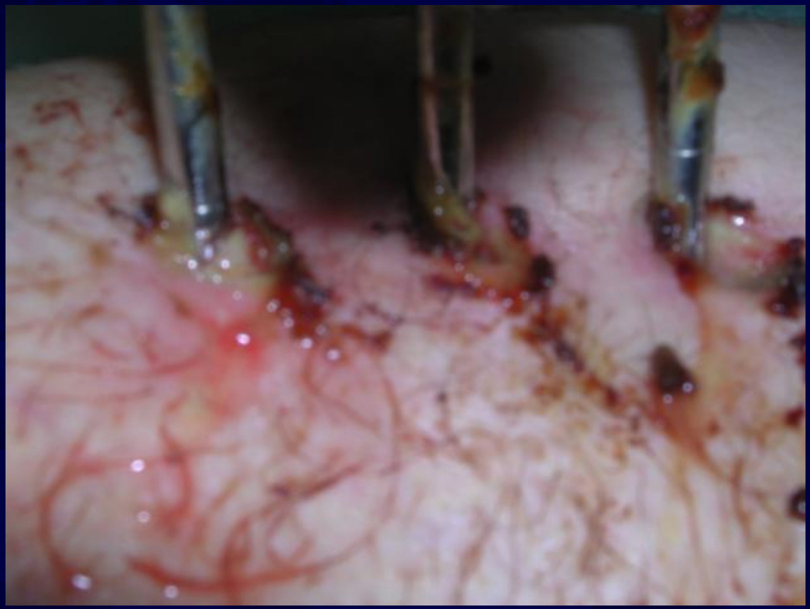
Bilat open femur, massive compartment syndrome, ex fix then nail

COMPLICATIONS

- #1 is Pin-track infection
- #2 is Pin loosening
- Frame or Pin/Wire Failure
- Malunion
- Non-union
- Soft-tissue impalement (stiffness)
- Iatrogenic fracture from pin site
- Compartment syndrome (rare)

PIN-TRACT INFECTION

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



DAHL PIN SITE CLASSIFICATION

- Treatment
  - Stage I: aggressive pin-site care and oral antibiotics
  - 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

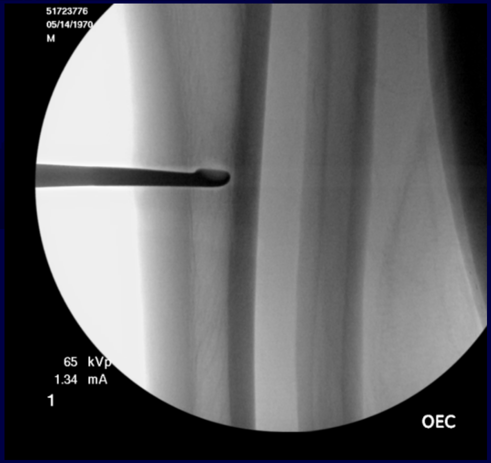
PIN-TRACT INFECTION

	Union	Fx infection	Malunion	Pin Infection
Mendes, '81	100%	4%	NA	0
Velazco, '83	92%	NA	5%	12.5%
Behrens, '86	100%	4%	1.3%	6.9%
Steinfeld, '88	97%	7.1%	23%	0.5%
Marsh, '91	95%	5%	5%	10%
Melendez, '89	98%	22%	2%	14.2%

PIN-TRACT INFECTION

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

Thermonecrosis



PIN LOOSENING

- Factors influencing Pin Loosening:
  - Infection/osteomyelitis at pin site
  - Thermonecrosis
  - Fracture healing
  - Bending Pre-load
    - Unilateral frames
    - Half pins with prolonged axial load

MALUNION

Intra-operative causes:

– 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

MALUNION cont.

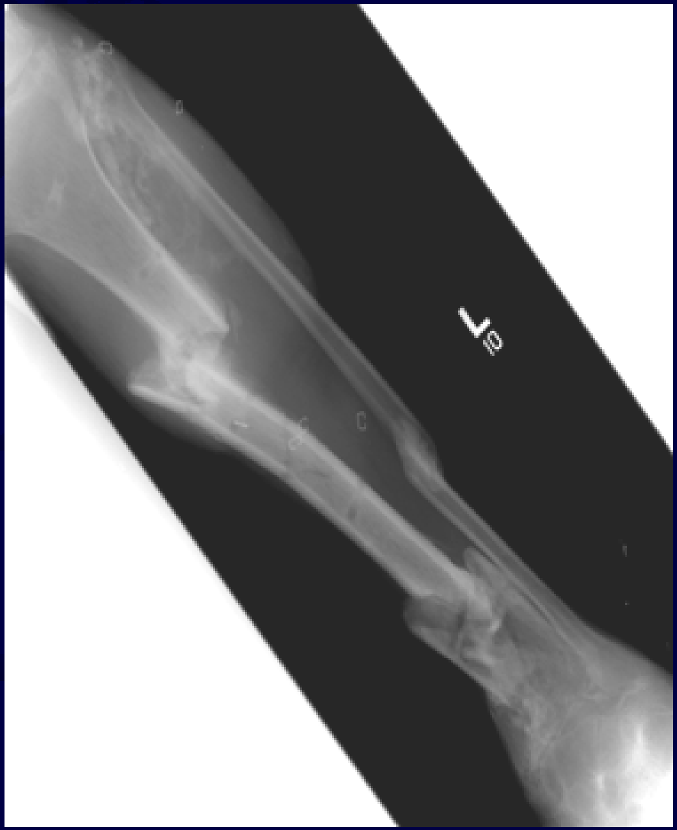
Post-operative causes

- Frame failure

- **Prevention**
  - Serial follow-up with both clinical and radiographic check-ups
  - Adherence to appropriate weight-bearing restrictions
  - Check and re-tighten frame at periodic intervals
  - Ensure correct frame adjustment schedule and prescription
- **Treatment**
  - Osteotomy/reconstruction

NON UNION

- **Non union increased with use of unilateral>hybrid frame>ring fixator**
- **Non union increased with increased sheer at fracture**
- **Minimize risk:**
  - Avoiding distraction
  - Early bone grafting
  - Stable/rigid construct
  - Good surgical technique
  - Control infections
  - Early wt bearing
  - Progressive dynamization



IATROGENIC FRACTURE

- Rare
- Often related to placement of pin
- Avoid unicortical pin and stress riser
- Pin size <1/3 diameter of diaphysis

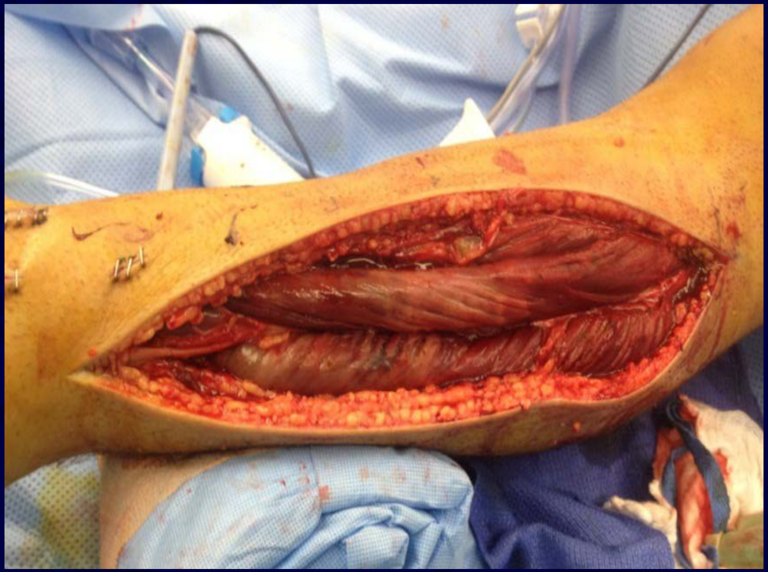
67 yo diabetic, charcot contralateral limb

SOFT TISSUE TETHERING

- Entrapment of soft tissues/muscle
  - Loss of motion
  - Scarring and adhesion
  - Neurovascular injury
- Prevention
  - Check ROM intra-operatively
  - Avoid piercing muscle or tendons
  - Position joint in NEUTRAL
  - Early stretching and ROM exercises
  - Convert to definitive fixation when possible

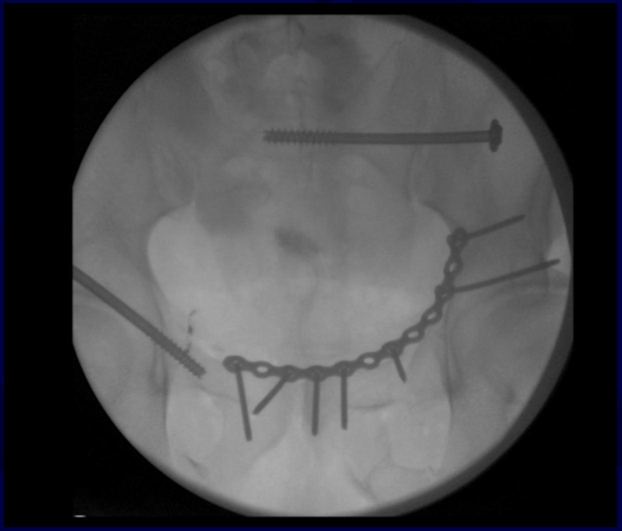
COMPARTMENT SYNDROME

- Pathophysiology
  - Rare
  - Initial trauma
  - Pin or wire causing additional bleeding
- Prevention
  - Understand anatomy
  - Good technique
  - Post-operative vigilance
    - Low threshold for fasciotomy



EXTERNAL FIXATION OF PELVIC RING

- See: http://ota.org/education/resident-resources/core-curriculum/pelvis-and-acetabulum



KEYS TO SUCCESS

- Chose optimal pin diameter
- Use good insertion technique
- Place clamps and frames close to skin
- Build frame in plane of deforming forces
- Double stack frame
- Consider use of ring fixator for definitive fixation
- Respect the soft tissues and think ahead about the next step. Don’t burn a bridge

Plan ahead!

SUMMARY

- Multiple applications and techniques
- Pair technique with clinical indication(s)
- Appropriate use can lead to excellent results
- Understand the biomechanics o each frame type
- Recognize and correct complications early

If you would like to volunteer as an author for the Resident Slide Project or recommend updates to any of the following slides, please send an e-mail to ota@ota.org

E-mail OTA about Questions/Comments

Return to General/Principles Index

OTA
Return to index

REFERENCES

1. Bhandari M, Zlowodski M, Tornetta P, Schmidt A, Templeman D. Intramedullary Nailing Following External Fixation in Femoral and Tibial Shaft Fractures. Evidence-Based Orthopaedic Trauma. JOT, 19(2): 40-144, 2005.
2. Cannada LK, Herzenberg JE, Hughes PM, Belkoff S. Safety and Image Artifact of External Fixators and Magnetic Resonance Imaging. CORR, 317, 206-214:1995.
3. Calhoun JH, Li F, Ledbetter BR, et al. Biomechanics of the Ilizarov Fixator for Fracture Fixation. Clin Orthop Relat Res. 280:15-22. 1992.
4. COTS. Open reduction and Internal Fixation Compared with Circular Fixator Application for Bicondylar Tibial Plateau Fractures. Results of a Multicenter, Prospective, Randomized Clinical Trial. JBJS-Am. 88(12):2613-23. 2006.
5. Davison BL, Cantu RV, Van Woerkom S. The Magnetic Attraction of Lower Extremity External Fixators in an MRI Suite. JOT, 18 (1): 24-27, 2004.
6. Egol KA, Tejwani NC, Capla EL, Wolinsky PL, Koval KJ., Staged management of high-energy proximal tibia fractures (OTA types 41): the results of a prospective, standardized protocol. JOT, 19(7):448-55. 2005.
7. Garcia-Cimbrelo E, Marti-Gonzalez JC., Circular External Fixation in Tibial Nonunion. Clin Orthop Relat Res.,419: 65-70. 2004.
8. Giotakis N, Panchani SK, Narayan B,. Segmental Fractures of the Tibia Treated by Circular External Fixation. JBJS-Br. 92B:687-92. 2010.
9. Hildebrand F.,Giannoudis P.,Krettek C.,Pape H.C., Damage Control: Extremiteis. Injury. 35:678-689. 2004
10. Foster PA, Barton SB, Jones SC, Morrison RJ, Britten S. The Treatment of Complex Tibial Shaft Fractures by the Ilizarov Method. JBJS- Br. 12:1678-1683. 2012.
11. Jones CP, Youngblood CS, Waldrop N, Davis WH, Pinaur MS, Tibial Stress Fracture Secondary to Half-Pins in Circular Ring External Fixation for Charcot Foot. Foot and Ankle Int, 35(6): 572-577. 2014
12. Keating J, Simpson A, Robinson C. The Management of Fracture with Bone Loss. JBJS Br. 87::142-50. 2005.
13. Kenwright J, Richardson JB, Cunningham, et al. Axial Movement and Tibial Fractures. A Controlled Randomized Trial of Treatment, JBJS-Br, 73 (4): 654-650, 1991.
14. Kenwright J , Gardner T. Mechanical Influences on Tibial Fracture Healing. CORR, 355: 179-190,1998.
15. Kowalski, M et al, Comparative Biomechanical Evaluation of Different External Fixator Sidebars: Stainless-Steel Tubes versus Carbon Fiber Bars, JOT 10(7): 470-475, 1996.
16. Kumar R, Lerski RA, Gandy S, Clift BA, Abboud RJ. Safety of Orthopedic Implants in Magnetic Resonance Imaging: an Experimental Verification. J Orthop Res, 24 (9): 1799-1802, 2006.
17. Larsson S, Kim W, Caja VL, Egger EL, Inoue N, Chao EY. Effect of Early Axial Dynamization on Tibial Bone Healing: A Study in Dogs. CORR, 388: 240-51, 2001.
18. Lowenberg DW, Nork S, Abruzzo FM. The Correlation of Shearing Force with Fracture Line Migration for Progressive Fracture Obliquities Stabilized by External Fixation in the Tibial Model. CORR, 466:2947–2954, 2008.

1. Lowenberg DW, Parrett BM, Bunti RF, Et al. Long Term Results and Costs of Muscle Flap Coverage with Ilizarov Bone Transport in Lower Limb Salvage. JOT. 27(10):576-81. 2013
2. Lowenberg DW, Principles of Tibial Fracture Management with Circular External Fixation. Orthop Clin North Am, 45(2):191-206.
3. Marsh JL. Nepola JV, Wuest TK, Osteen D, Cox K, Oppenheim W. Unilateral External Fixation Until Healing with the Dynamic Axial Fixator for Severe Open Tibial Fractures. Review of Two Consecutive Series , JOT, 5(3): 341-348, 1991.
4. Maurer DJ, Merkow RL, Gustilo RB. Infection After Intramedullary Nailing of Severe Open Tibial Fractures Initially Treated with External Fixation. JBJS-A, 71(6), 835-838, 1989.
5. Metcalfe AJ, Saleh M, Yang L. Techniques for Improving Stability in Oblique Fractures Treated by Circular Fixation with Particular Reference to the Sagittal Plane. JBJS-Br, 87 (6): 868-872, 2005.
6. Moroni A, Faldini C, Marchetti S, Manca M, Consoli V, Giannini S. Improvement of the Bone-Pin Interface Strength in Osteoporotic Bone with Use of Hydroxyapatite-Coated Tapered External-Fixation Pins: A Prospective, Randomized Clinical Study of Wrist Fractures . JBJS –A, 83:717-721, 2001.
7. Moroni A, Faldini C. Pegreffi F. Hoang-Kim A. Vannini F. Giannini S. Dynamic Hip Screw versus External Fixation for Treatment of Osteoporotic Pertrochanteric Fractures, J BJS-Am. 87:753-759, 2005.
8. Moroni A. Faldini C. Rocca M. Stea S. Giannini S. Improvement of the Bone-Screw Interface Strength with Hydroxyapatite-coated and Titanium-coated AO/ASIF Cortical Screws. J OT. 16(4): 257-63, 2002 .
9. Nowotarski PJ, Turen CH, Brumback RJ, Scarboro JM, Conversion of External Fixation to Intramedullary Nailing for Fractures of the Shaft of the Femur in Multiply Injured Patients, JBJS-A, 82:781-788, 2000.
10. Pape H.C.,Rixen D., Morley J., et al. Impact of the Method of Initial Stabilization for Femoral Shaft Fractures in Patients With Multiple Injuries at Risk for Complications (Borderline Patients). Ann Surg. 246 (3):491-501. 2007
11. Patterson MJ, Cole J. Two-Staged Delayed Open Reduction and Internal Fixation of Severe Pilon Fractures. JOT, 13(2): 85-91, 1999.
12. Pugh K.J, Wolinsky PR, Dawson JM, Stahlman GC. The Biomechanics of Hybrid External Fixation. JOT. 13(1):20-26, 1999.
13. Ring D.,Bruinsma E.,Jupiter.,Complications of Hinged External Fixation Compared With Cross-pinning of the Elbow for Acute and Subacute Instability. CORR, 472: 2044-2048, 2014.
14. Roberts C, Dodds JC, Perry K, Beck D, Seligson D, Voor M. Hybrid External Fixation of the Proximal Tibia: Strategies to Improve Frame Stability. JOT, 17(6):415-420, 2003.
15. Scalea TM, Boswell SA, Scott JD, Mitchell KA, Kramer ME, Pollak AN. External Fixation as a Bridge to Intramedullary Nailing for Patients with Multiple Injuries and with Femur Fractures: Damage Control Orthopedics. J Trauma, 48(4):613-623, 2000.
16. Sirkin M, Sanders R, DiPasquale T, Herscovici, A Staged Protocol for Soft Tissue Management in the Treatment of Complex Pilon Fractures. JOT, 13(2): 78-84, 1999.
17. Watson T, Coufal C. Treatment of complex lateral plateau fracture using Ilizarov techniques. Clin Orthop Relat Res. 353:97-106. 1998
18. Yilmaz E, Belhan O, Karakurt L, Arslan N, Serin E. Mechanical performance of hybrid Ilizarov External Fixator in Comparison with Ilizarov Circular External Fixator. Clin Biomech, 18 (6): 518, 2003.