Minimally Invasive Plating of Fractures:

Advantages, Techniques and Trade-offs

Matthew Garner, MD

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OUTLINE

- Principles of fracture management
- The importance of vascular supply
- Equipment and reduction techniques
- Examples of minimally invasive plating
- Advantages and outcomes of minimally invasive plating
- Disadvantages of minimally invasive plating

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PRINCIPLES OF FRACTURE MANAGEMENT

1. Restoration of anatomic relationships:
   - Malalignment leads to limited function of limb
   - Limp leads to increased physiologic demand
   - Either can lead to chronic disability and an unsatisfied patient

PRINCIPLES OF FRACTURE MANAGEMENT

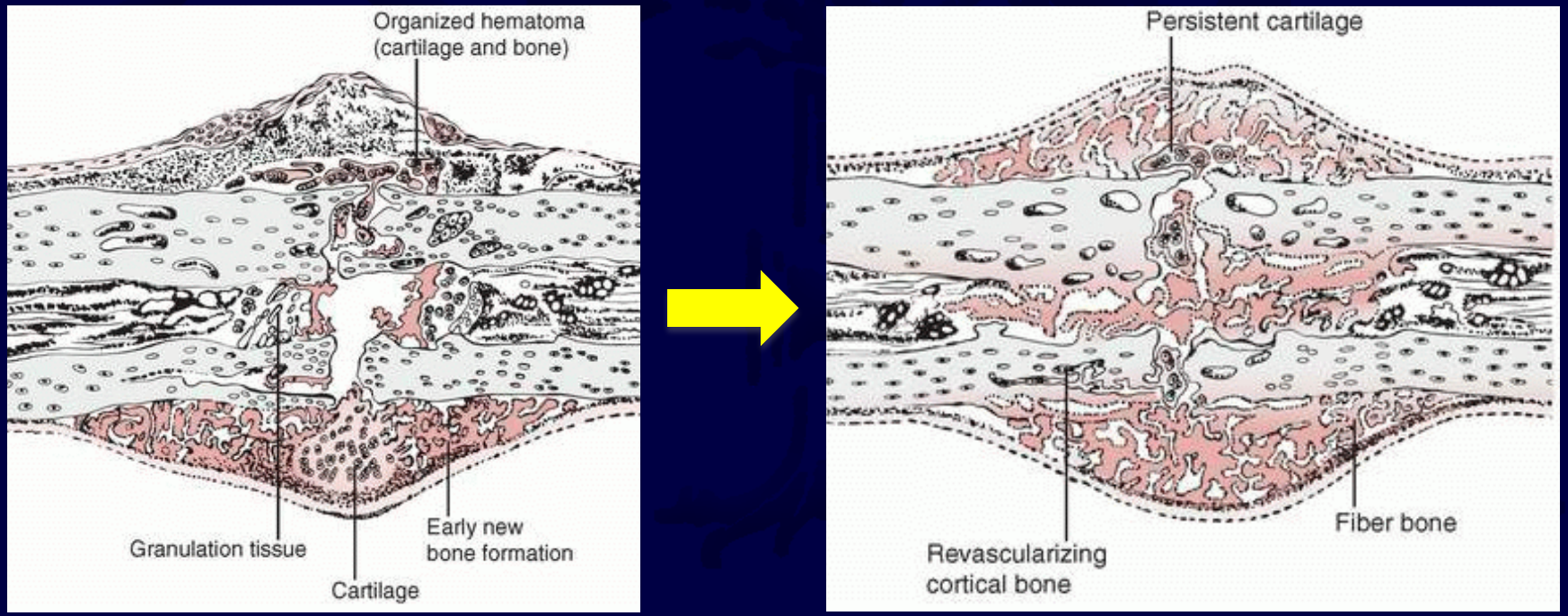
2. Preservation of osseous blood supply :

- Bone has two primary blood supplies:
  - Endosteal—high pressure, inner 2/3
  - Periosteal—low pressure, outer 1/3
- Loss of blood supply limits healing

PRINCIPLES OF FRACTURE MANAGEMENT

2. Preservation of osseous blood supply :

- An intact blood supply is necessary for fracture healing



PRINCIPLES OF FRACTURE MANAGEMENT

3. Stable fixation until union:
   - Surgical implants share or bear physiologic loads until healing:
     - Absolute stability for anatomic reduction and primary bone healing
     - Relative stability for bridging construct, callus formation and secondary bone healing

PRINCIPLES OF FRACTURE MANAGEMENT

4. Early and safe mobility:
   - Limits risk of morbidity that is associated with immobilization
     - Pneumonia
     - Venous thromboembolism
     - Bedsores/skin breakdown
   - Helps restore joint range of motion and prevent contractures

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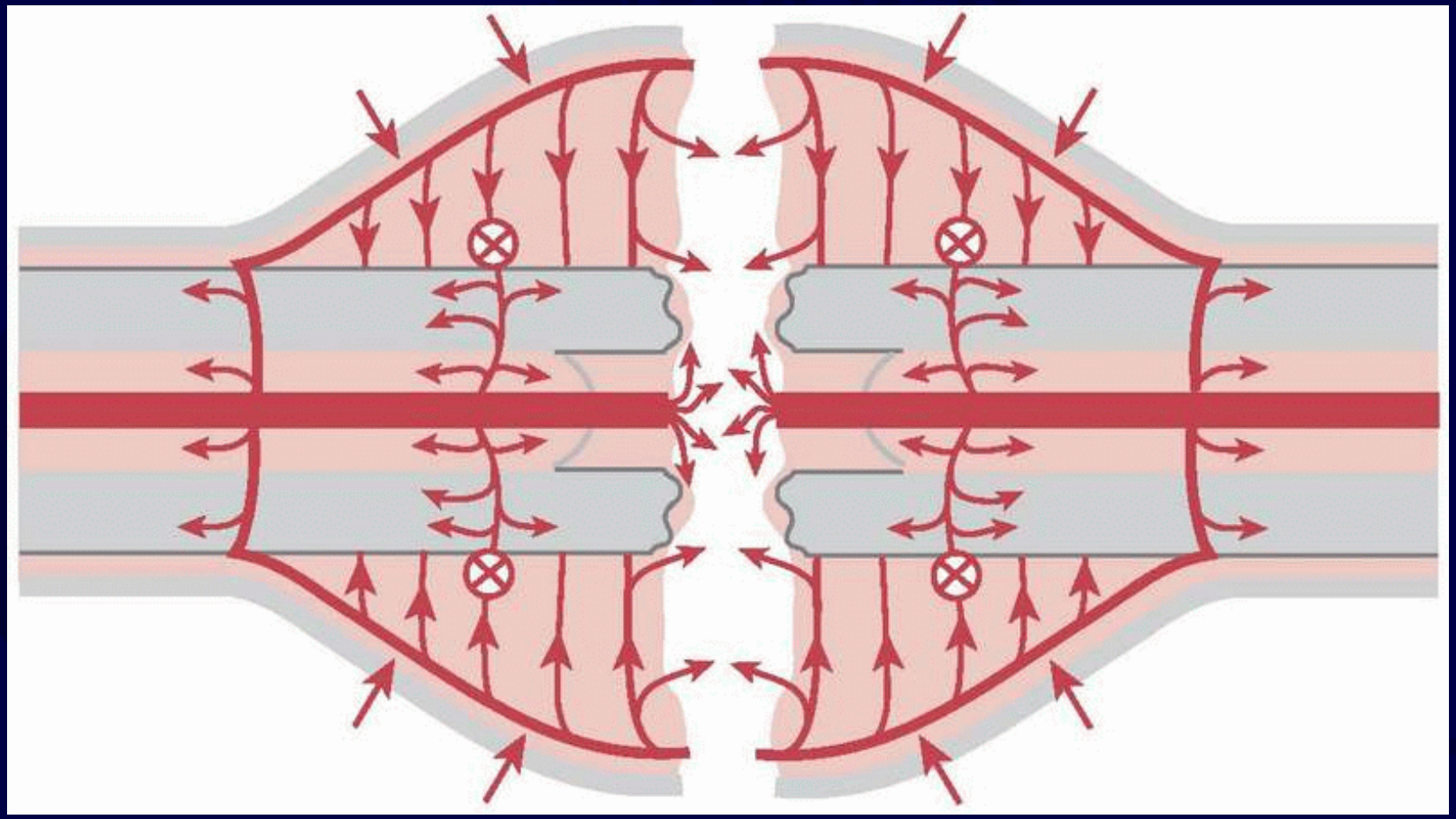
Importance of Vascular Supply



Importance of Vascular Supply

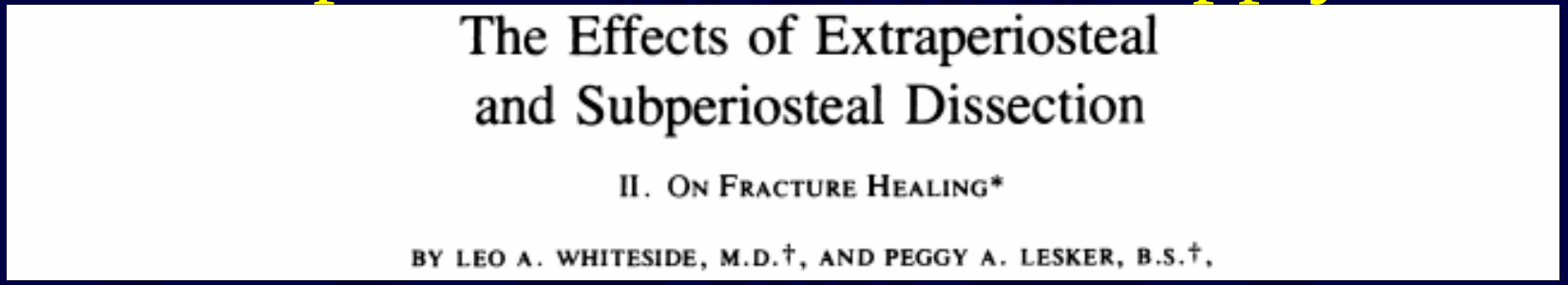
- All fractures are associated with soft tissue disruption of some extent:
  - Vascular tearing, laceration or occlusion
  - Periosteal stripping
- Soft tissue damage is typically related to mechanism of injury:
  - Rotation = low energy with limited soft tissue damage
  - Blunt trauma = high energy with potential for extensive stripping

Importance of Vascular Supply

- Early ORIF results were discouraging:
  - Over dissection of distal femur resulted in unacceptably high rates of non-union, malunion, infection and need for bone graft

Neer et al., Injury 1975
Schatzker and Lambert, Clin Orthop 1979
Siliski et al., J Bone Joint Surg-Am 1989

Importance of Vascular Supply



The Effects of Extraperiosteal and Subperiosteal Dissection

II. On Fracture Healing*

BY LEO A. WHITESIDE, M.D.†, AND PEGGY A. LESKER, B.S.†,

Whitesides and Lesker, JBJS 1978

- Rabbit Model:
  - Healing was significantly retarded with muscle and periosteal injury
  - Healing potential was inversely proportional to amount of soft tissue stripping

Importance of Vascular Supply

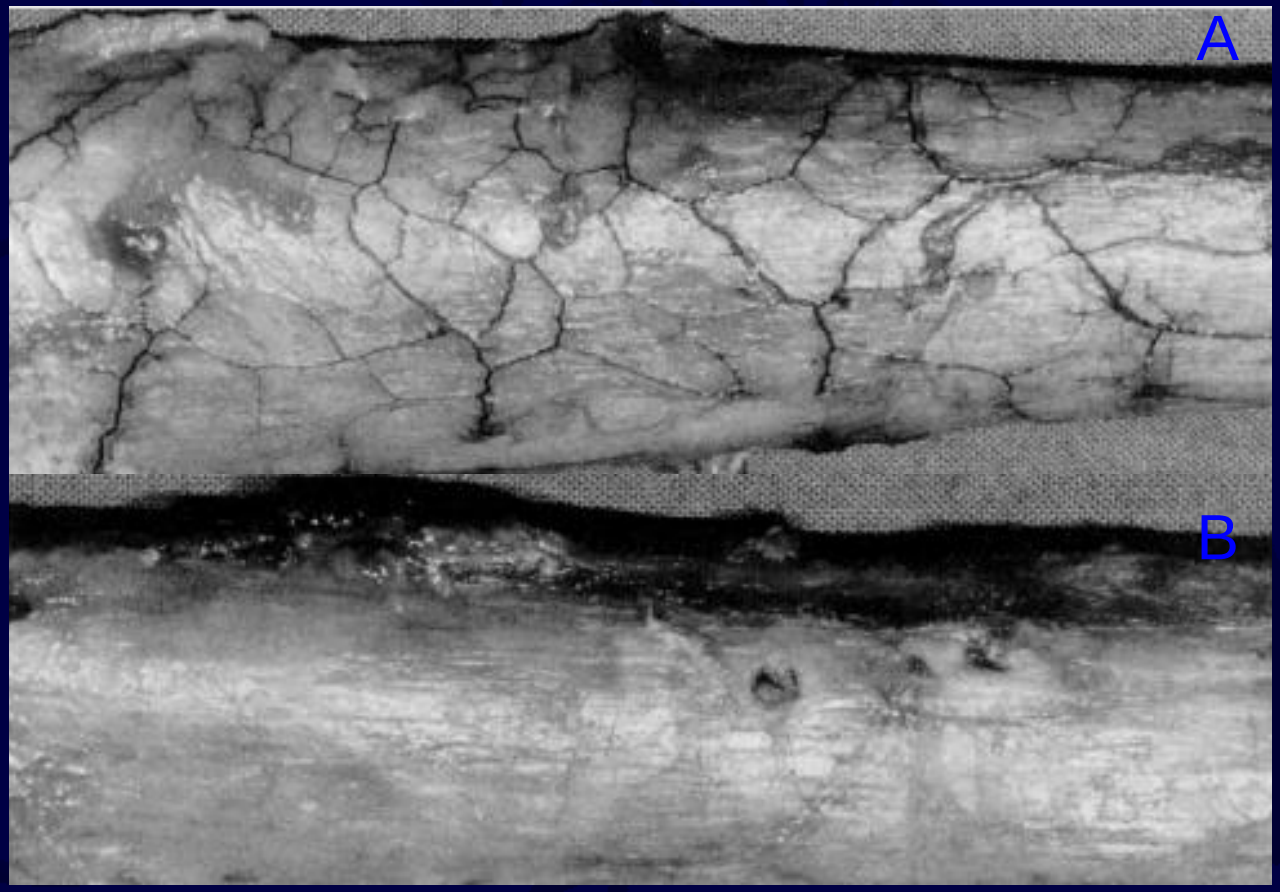
Minimally Invasive Plate Osteosynthesis: Does Percutaneous Plating Disrupt Femoral Blood Supply Less Than the Traditional Technique?

Farouk, Osama; Krettek, Christian*; Miclau, Theodore†; Schandelmaier, Peter; Guy, Pierre; Tscherne, Harald

– JOT, 1999

- 10 fresh cadaveric specimens underwent conventional open plating and minimally invasive plating.
- Each cadaver was injected with silicone dye and vascularity was assessed.
- Results:
  - MIPO demonstrated improved extramedullary and intramedullary perfusion

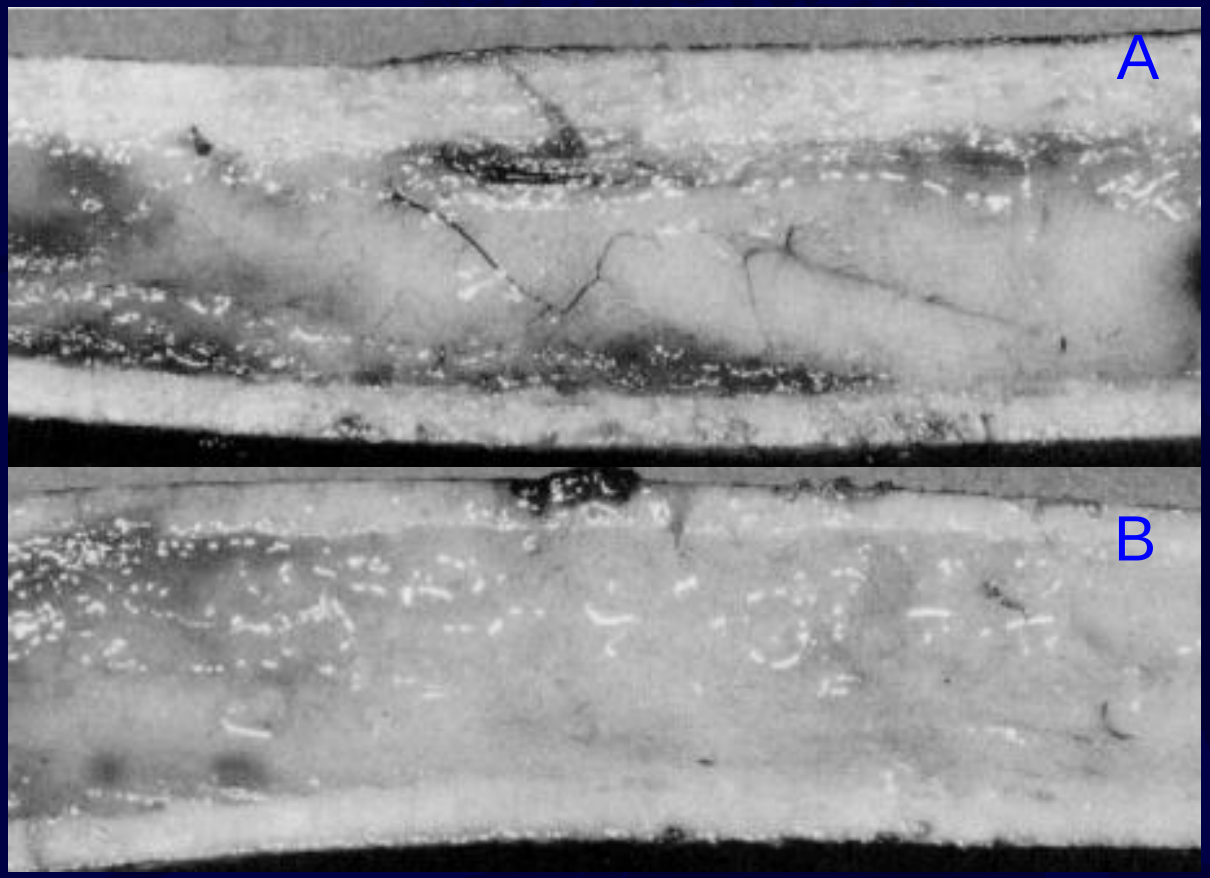
Importance of Vascular Supply



Periosteal perfusion after MIPO (A) and conventional plating (B)

Farouk et al., JOT 1999

Importance of Vascular Supply



Medullary perfusion after MIPO (A) and conventional plating (B)

Farouk et al., JOT 1999

Importance of Vascular Supply

- "…the extensive operative exposure require to achieve an anatomic reduction often results in devitalization of the bone and surrounding tissues as well as evacuation of the fracture hematoma, which has osteogenic potential."

Collinge et al., JAAOS 2000

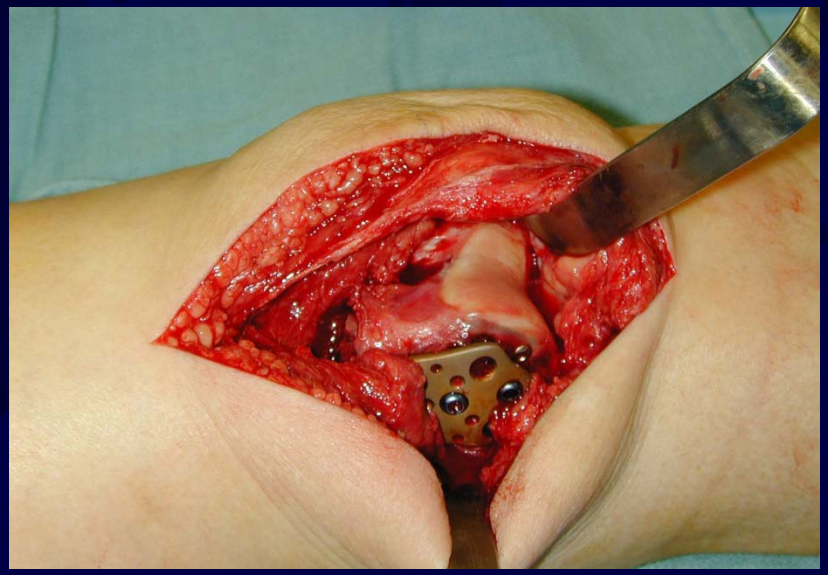
Importance of Vascular Supply

- "Biologic Fixation":
  - Surgical techniques designed to limit biological damage at the time of surgery.
    - Avoids the need for precise reduction by using bridging construct and indirect reduction techniques.
    - Minimizes soft tissue trauma and damage to the remaining vascular supply.
    - Can be achieved with plating or intramedullary rodding.

Moore et al., J Trauma 1987
Perran et al., JBJS (Br) 2002

Importance of Vascular Supply

- Surgeon's responsibility:
  - Limit iatrogenic soft tissue damage
  - Limit further damage to periosteal and/or endosteal blood supply



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MIPO Reduction Techniques

- Minimally invasive plating relies on indirect reduction techniques.

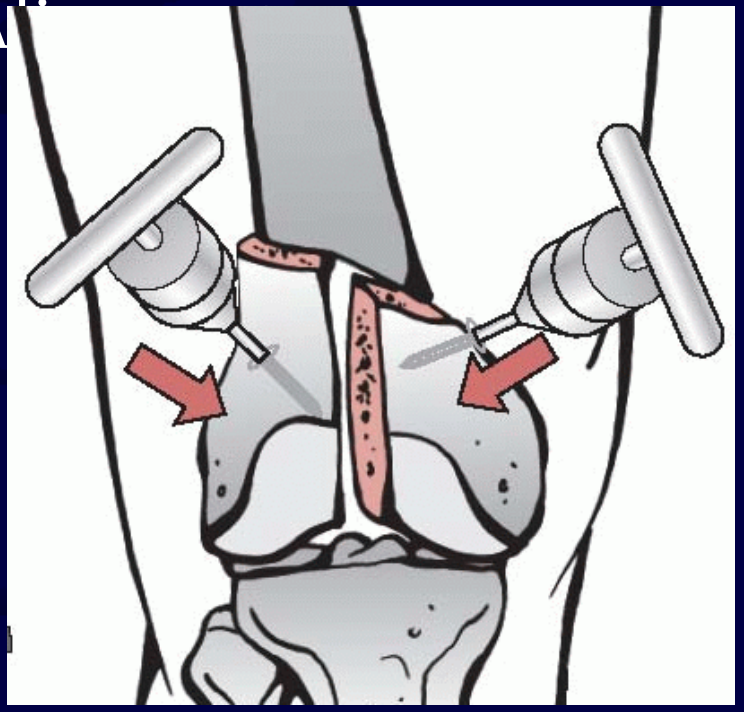
- Required Equipment:
  - Radiolucent Table
  - C-arm/Fluoroscopy
  - Total Paralysis

MIPO Reduction Techniques

- Required Equipment Continued:
  - Length and Coronal Plane Alignment:
    - Traction pin:
      - Can often help with pulling femur to length, especially for extra-articular fractures
        - » May actually be harmful if attempting joint reduction as it tensions surrounding soft tissues
      - May be placed within the distal femur or proximal tibia depending on fracture pattern and planned fixation

MIPO Reduction Techniques

- Required Equipment Continued:
  - Length and Coronal Plane Al
    - Schantz Pins/T-Handle:
      - Can be used to manipulate fracture fragments through small incisions
      - Place outside of footprint of plate

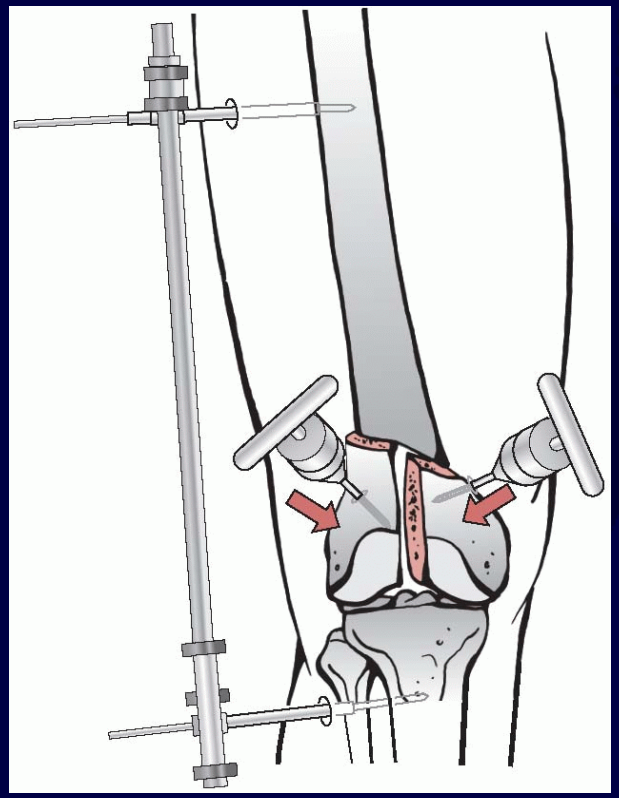


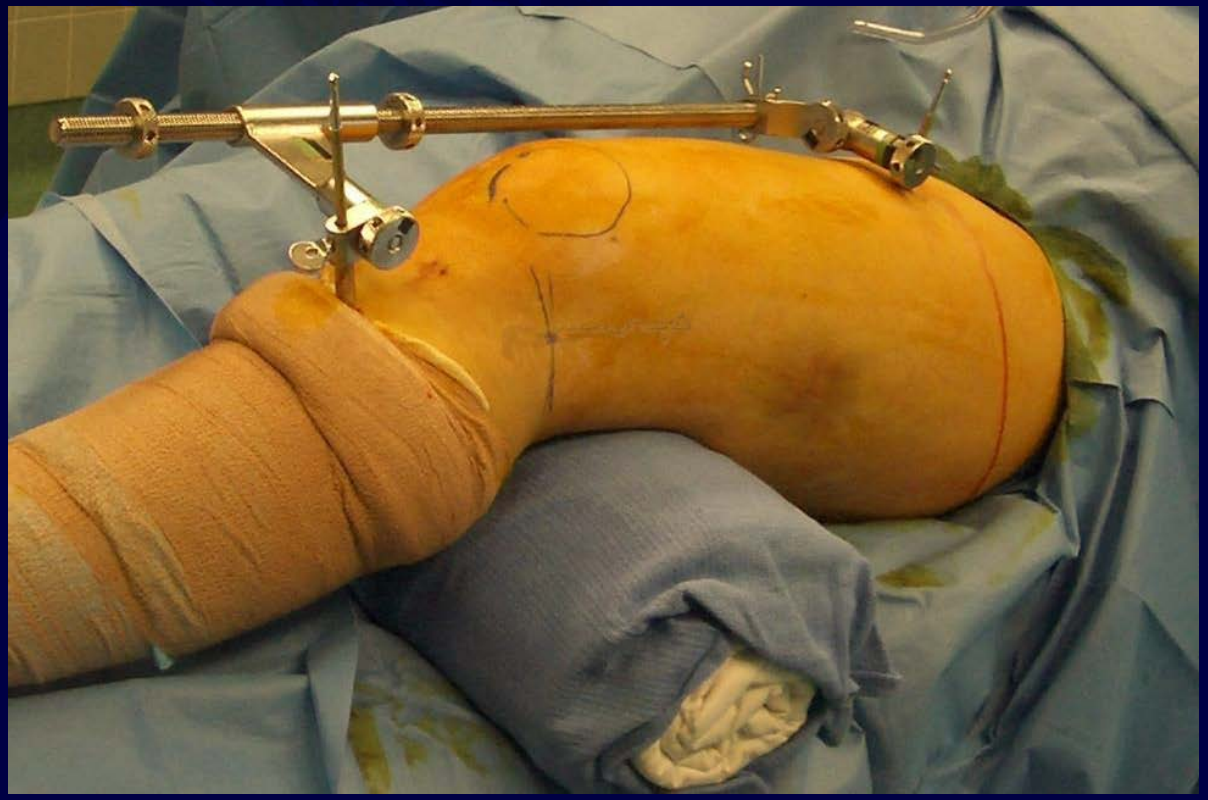
MIPO Reduction Techniques

- Required Equipment Continued:
  - Length and Coronal Plane Alignment:
    - Universal AO Distractor or External fixator:
      - Can be used for both length and coronal plane alignment
      - Hold preliminary reduction while assessing alignment/rotation and while placing definitive fixation
      - Multiplanar external fixation can assist with correction of deformity in multiple planes

MIPO Reduction Techniques

- Universal AO Distractor:



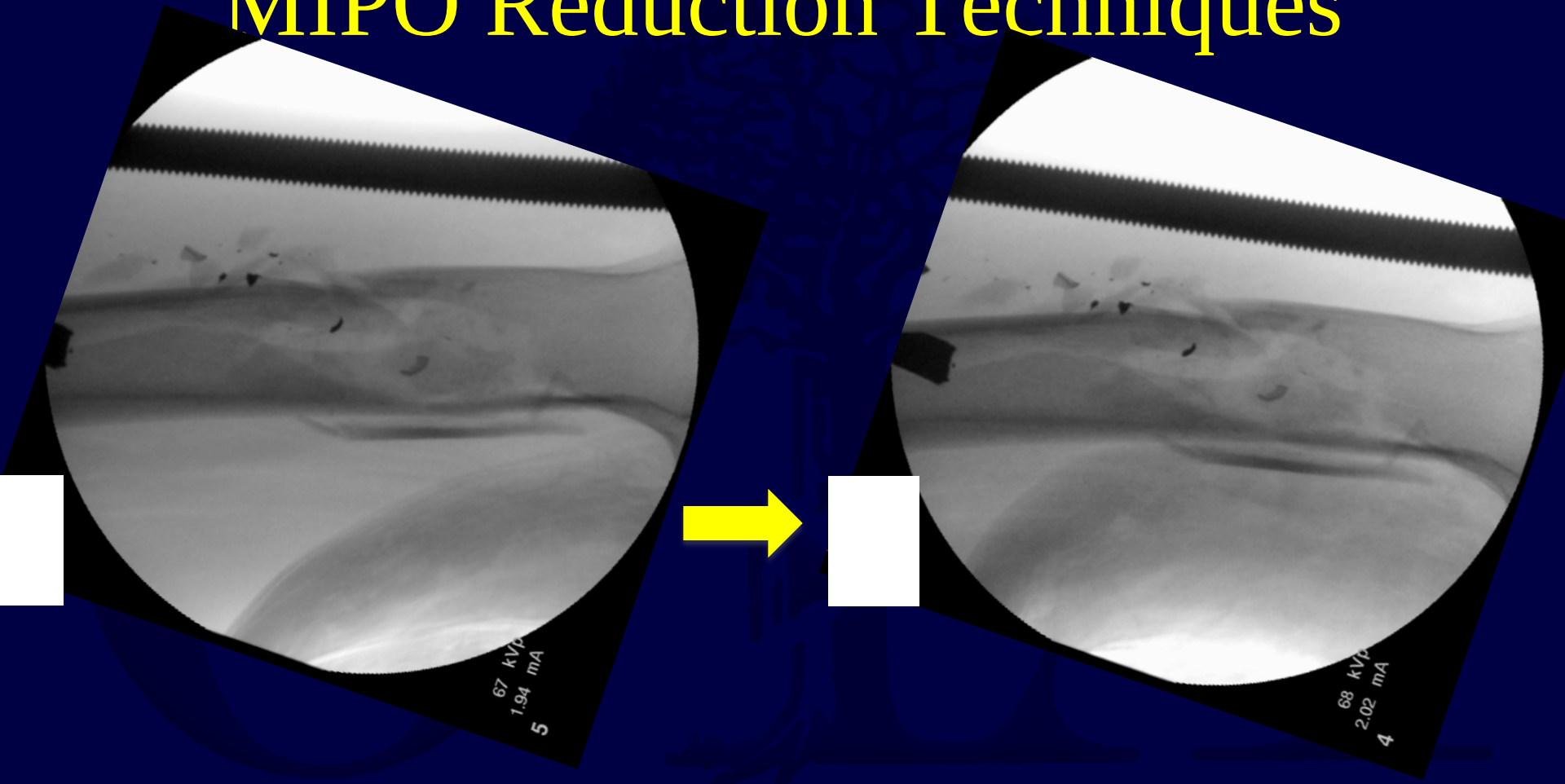


MIPO Reduction Techniques

MIPO Reduction Techniques

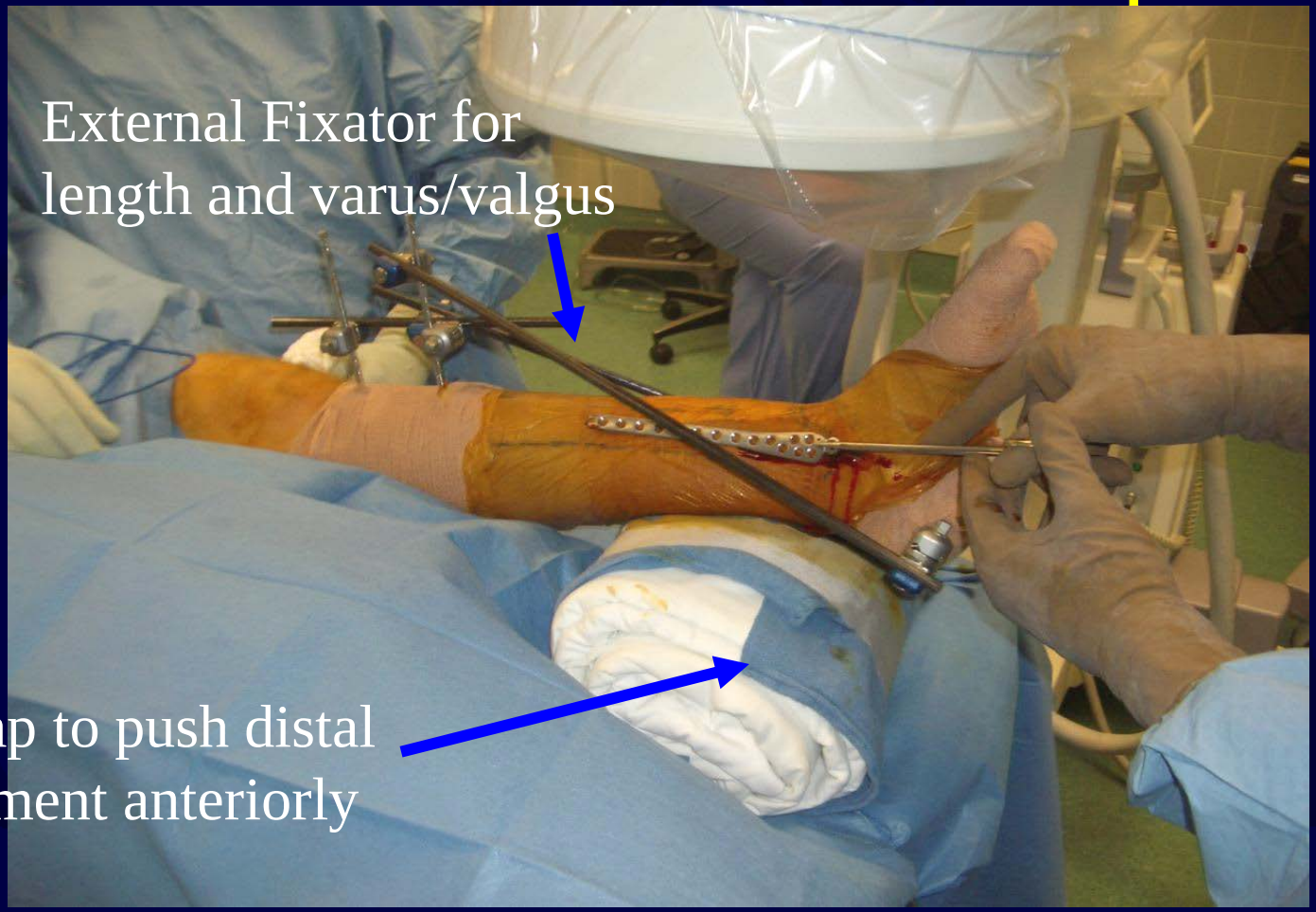
- Required Equipment Continued:
  - Sagittal Alignment:
    - Towel Bumps: for under the leg to correct apex anterior/posterior

MIPO Reduction Techniques



Bump adjustment to restore anterior bow

MIPO Reduction Techniques



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MIPO Examples

Pediatric Femoral Shaft Fracture
Submuscular Plating

MIPO Examples: Femoral Shaft

- Pediatric Femoral Shaft Fracture—Submuscular Plating
  - Patient positioning can help with reduction and ensure easy access to plate insertion site

MIPO Examples: Femoral Shaft

- Pediatric Femoral Shaft Fracture—Submuscular Plating
  - Marking osseous landmarks is essential to making accurate incisions.
  - Use fluoroscopy if necessary.

MIPO Examples: Femoral Shaft

- Pediatric Femoral Shaft Fracture—Submuscular Plating
  - The plate is used for submuscular dissection.
  - Insertion handles make insertion easier

MIPO Examples: Femoral Shaft

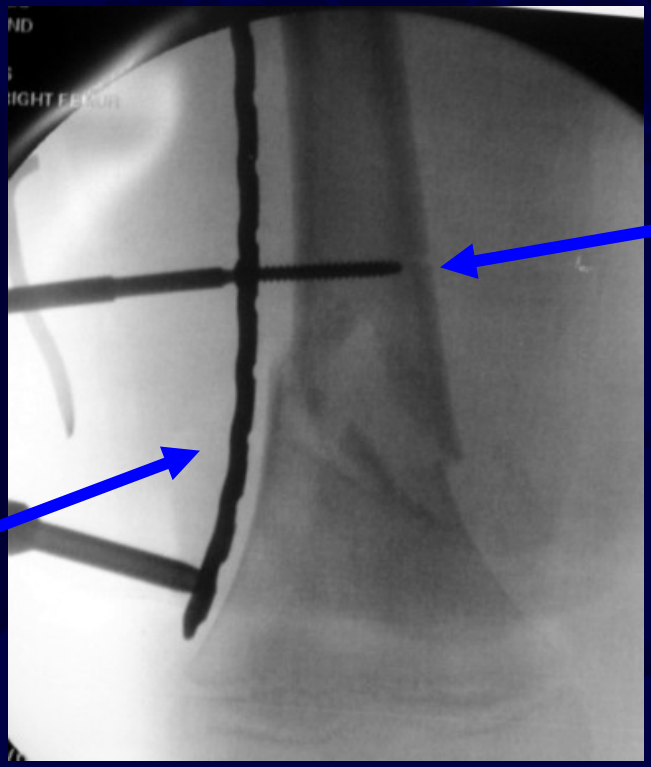
- Pediatric Femoral Shaft Fracture—Submuscular Plating
  - Suture tied to the screw head prevents the screw from being lost in a large soft tissue envelope

MIPO Examples: Femoral Shaft

- Pediatric Femoral Shaft Fracture—Submuscular Plating

MIPO Examples: Femoral Shaft

- Pediatric Femoral Shaft Fracture—Submuscular Plating



Antiglide Screw on Concavity of Fracture and Plate for reduction

Pre-bent Plate

MIPO Examples: Femoral Shaft

- Pediatric Femoral Shaft Fracture—Submuscular Plating

MIPO Examples

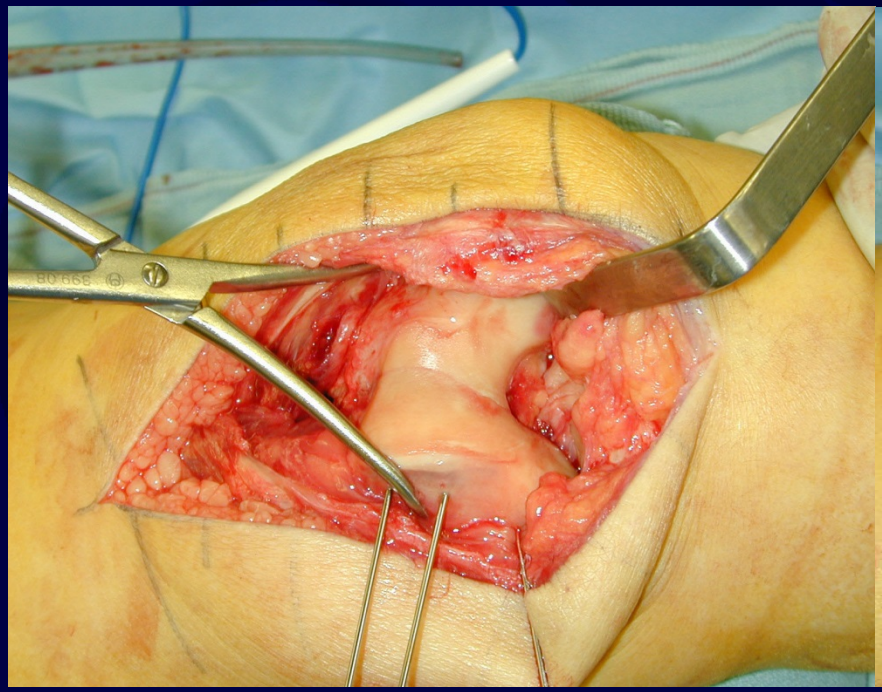
Intra-articular Distal Femur Fracture

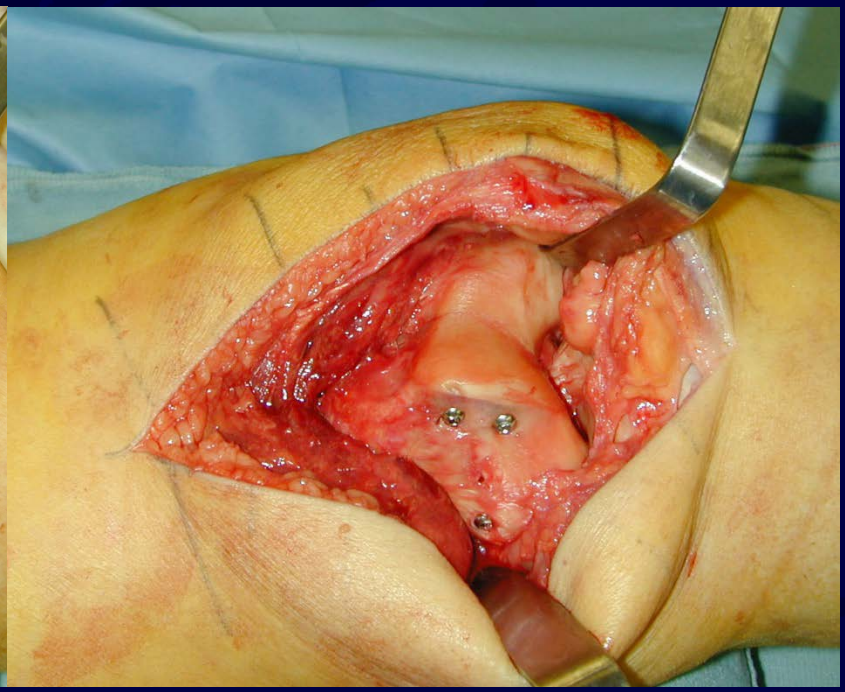
MIPO Examples: Distal Femur

- Intra-articular Distal Femur Fracture:
  - Lateral or lateral parapatellar incision permits access to articular surface

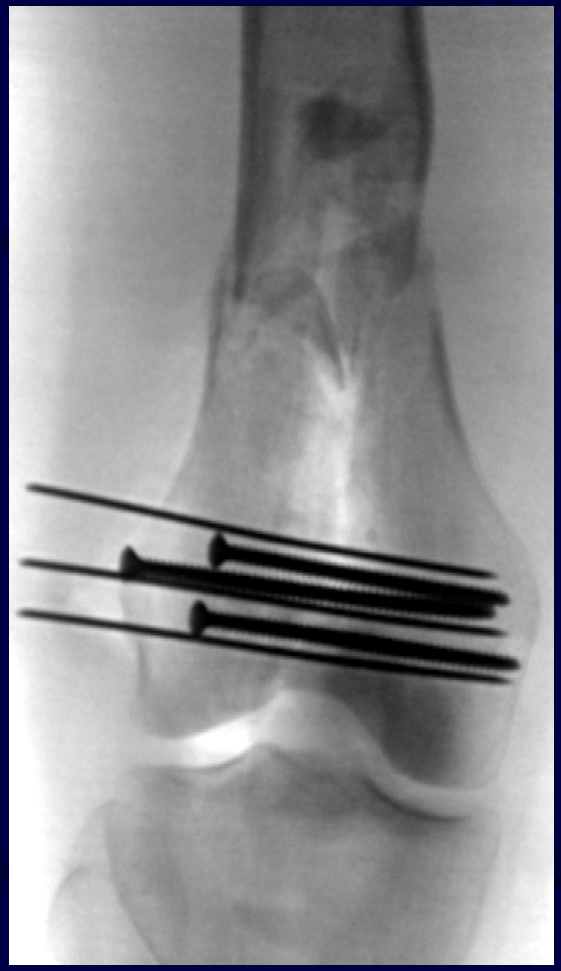
MIPO Examples: Distal Femur

- Intra-articular Distal Femur Fracture:
  - Lateral parapatellar incision



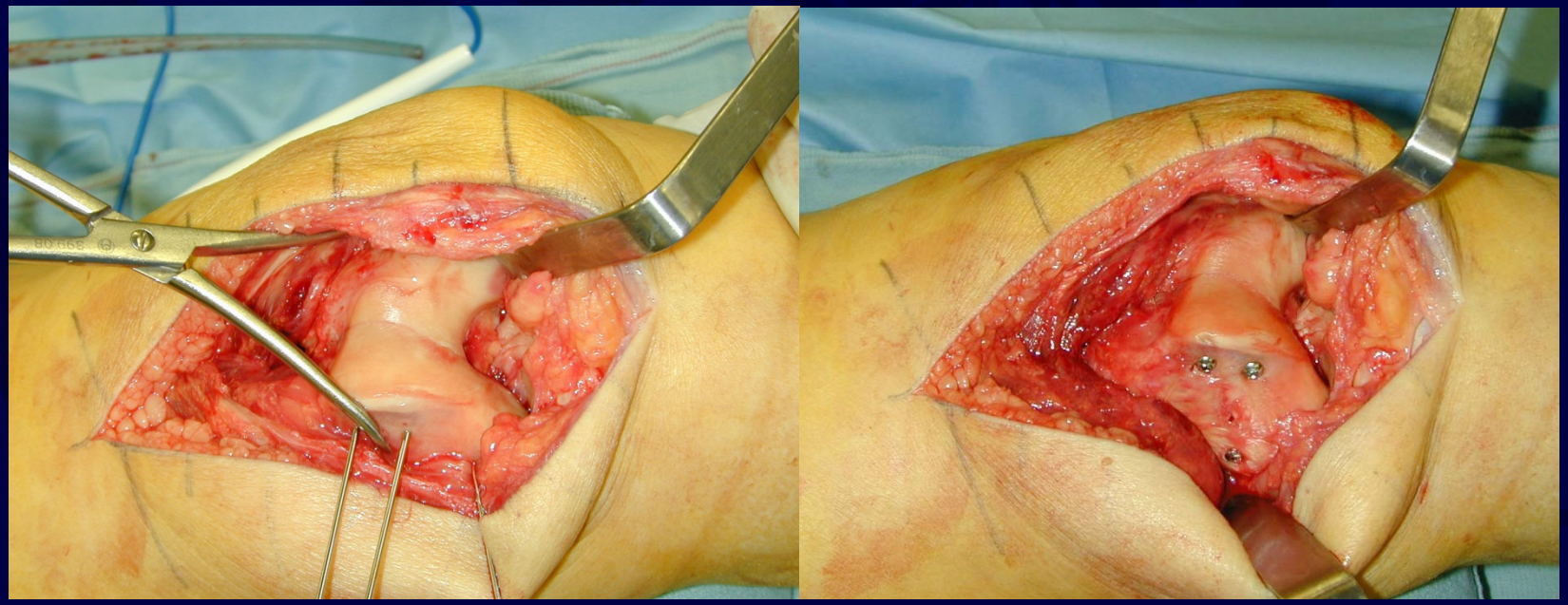


MIPO Examples: Distal Femur



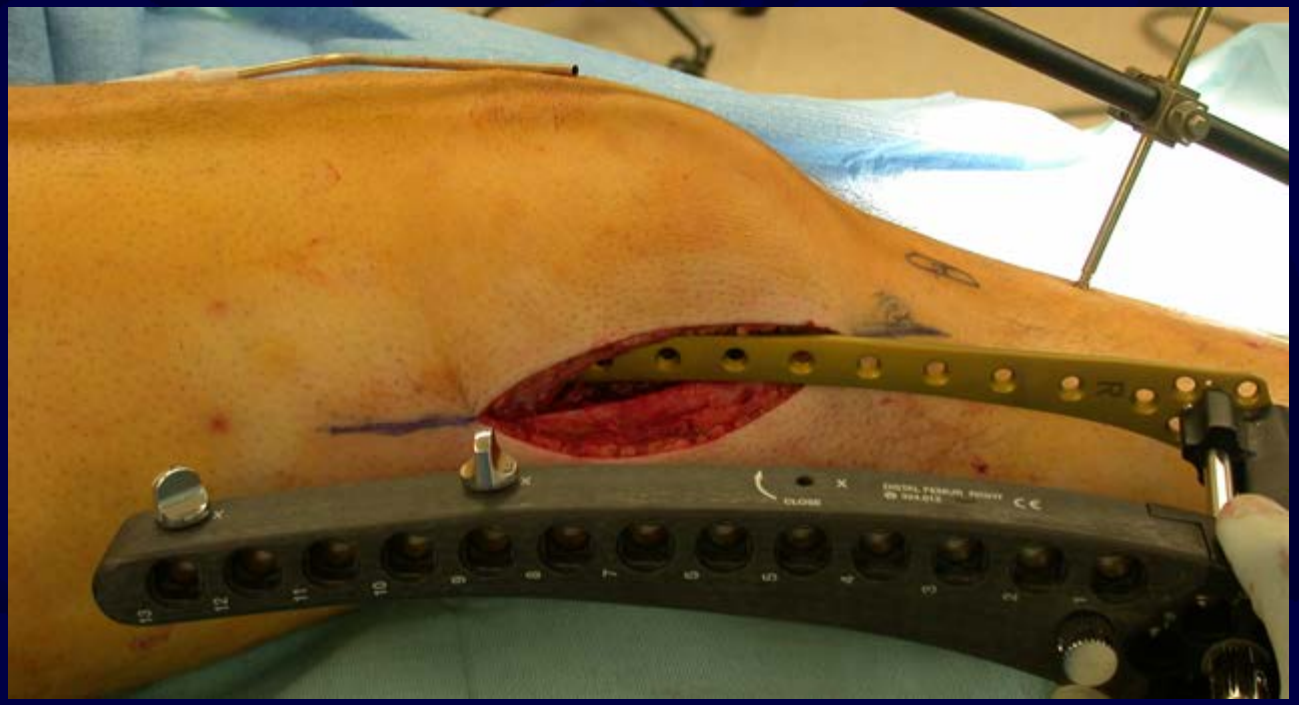
MIPO Examples: Distal Femur

- Intra-articular Distal Femur Fracture:
  - Absolute articular stability with lag screws



MIPO Examples: Distal Femur

- Intra-articular Distal Femur Fracture:
  - Submuscular plate insertion (Lateral Incision)



MIPO Examples: Distal Femur

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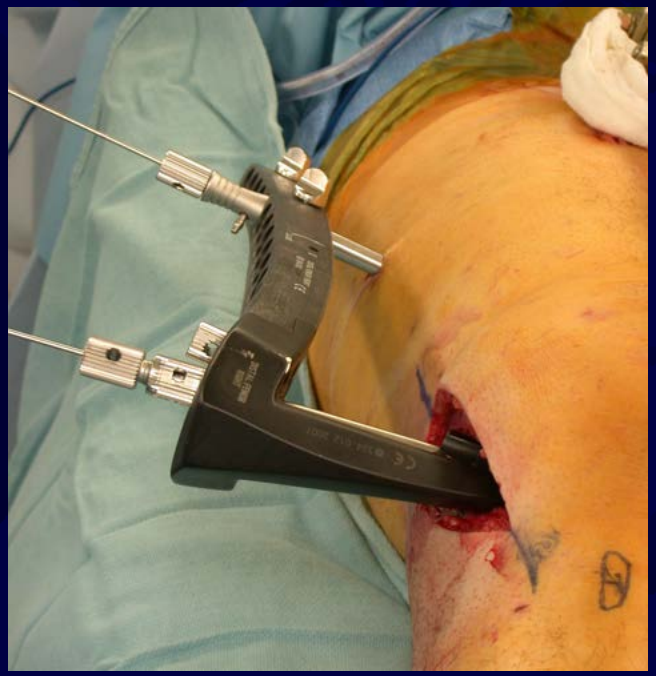


MIPO Examples: Distal Femur

- Intra-articular Distal Femur Fracture:
  - Lateral incision with plate in place

MIPO Examples: Distal Femur

- Intra-articular Distal Femur Fracture:
  - Lateral parapatellar closure

MIPO Examples

Extra-articular Distal Femur Fracture

MIPO Examples: Distal Femur

- Extra-articular Distal Femur Fracture:

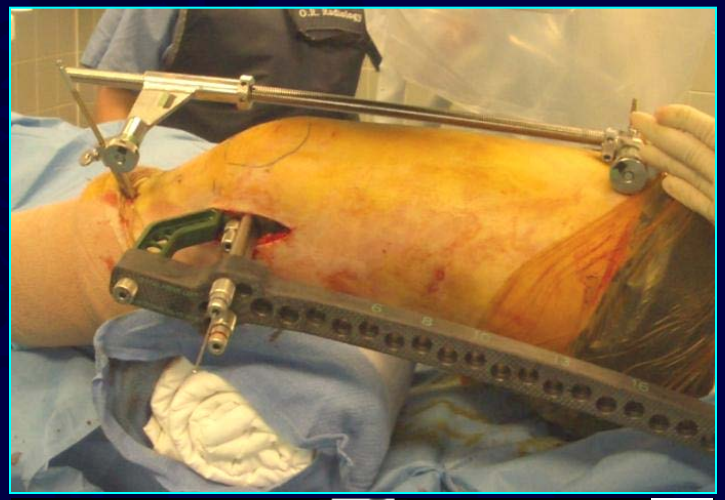
MIPO Examples: Distal Femur

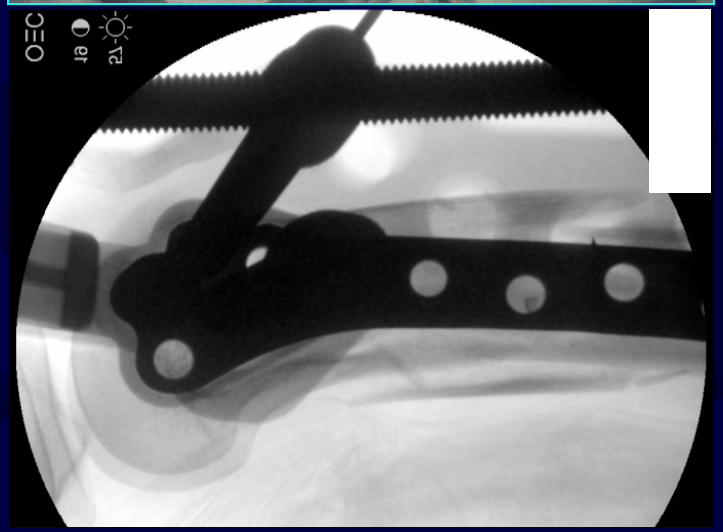
- Extra-articular Distal Femur Fracture:
  - Traction and bump improves alignment

MIPO Examples: Distal Femur

- Extra-articular Distal Femur Fracture:
  - Femoral distractor to hold reduction and length

MIPO Examples: Distal Femur



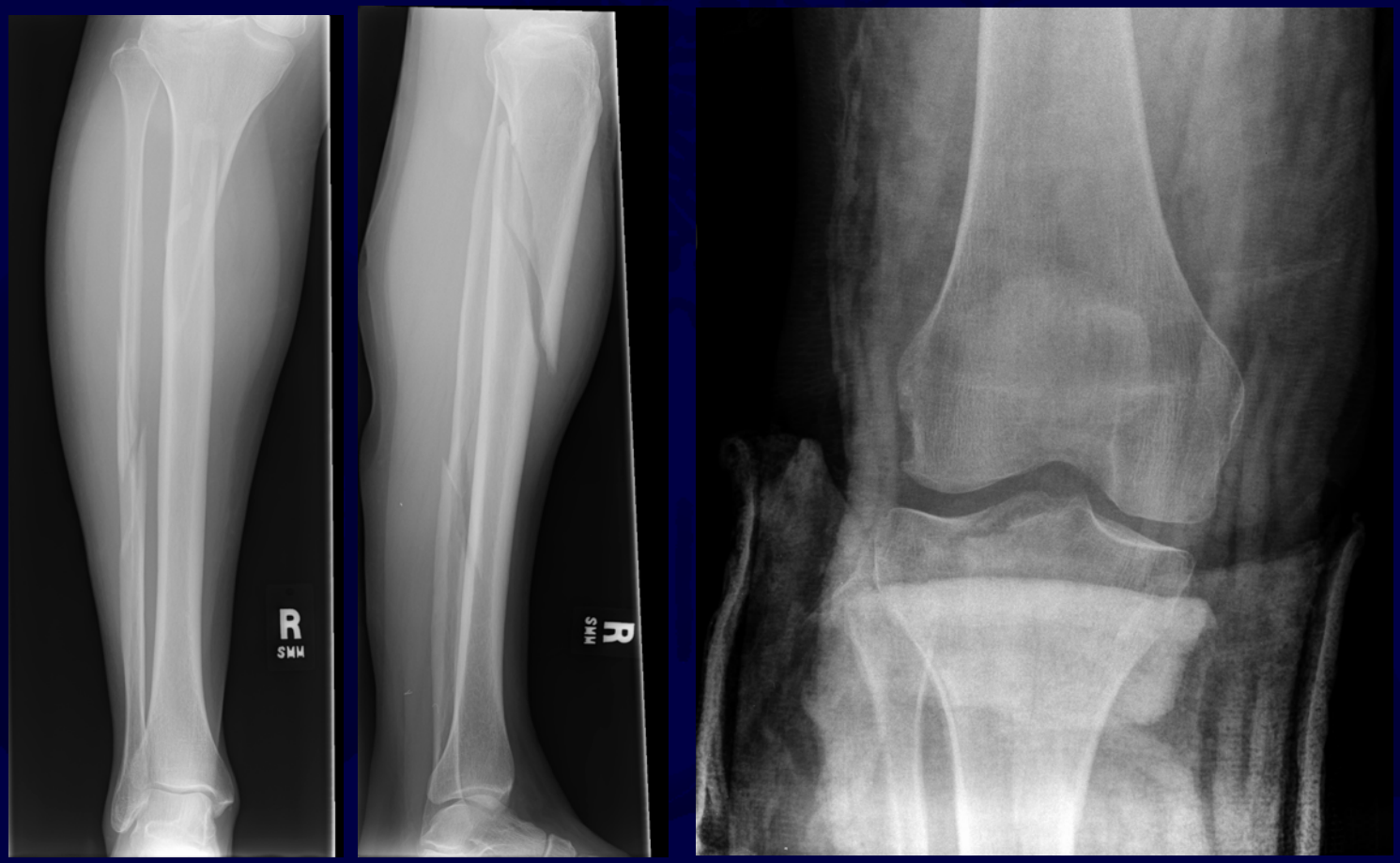


MIPO Examples: Distal Femur

MIPO Examples

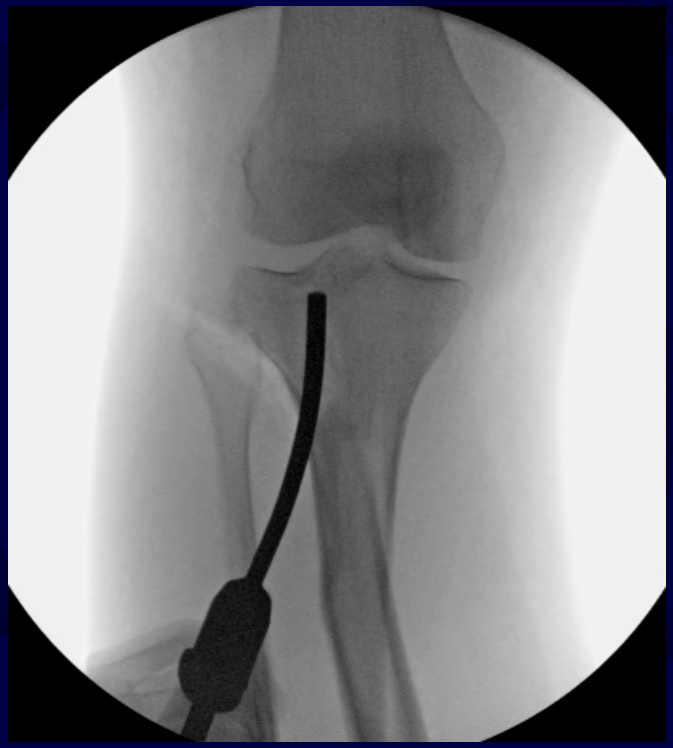
Intra-articular Proximal Tibial Shaft

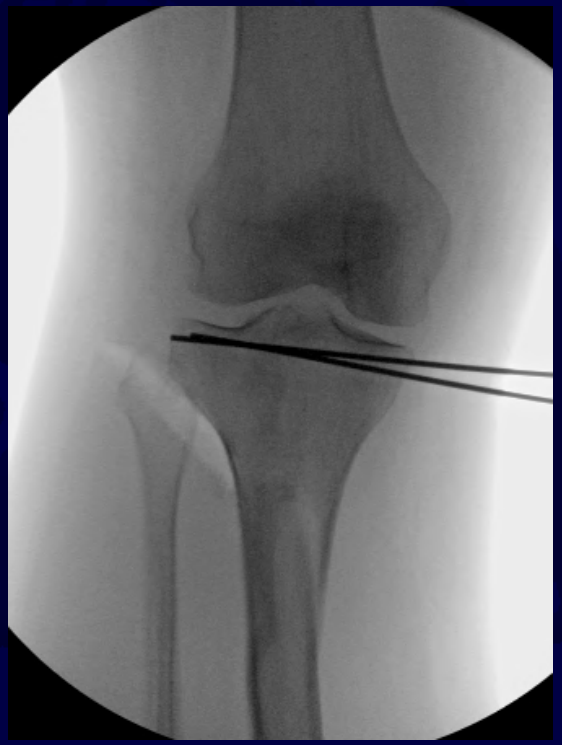
MIPO Examples: Proximal Tibia



MIPO Examples: Proximal Tibia

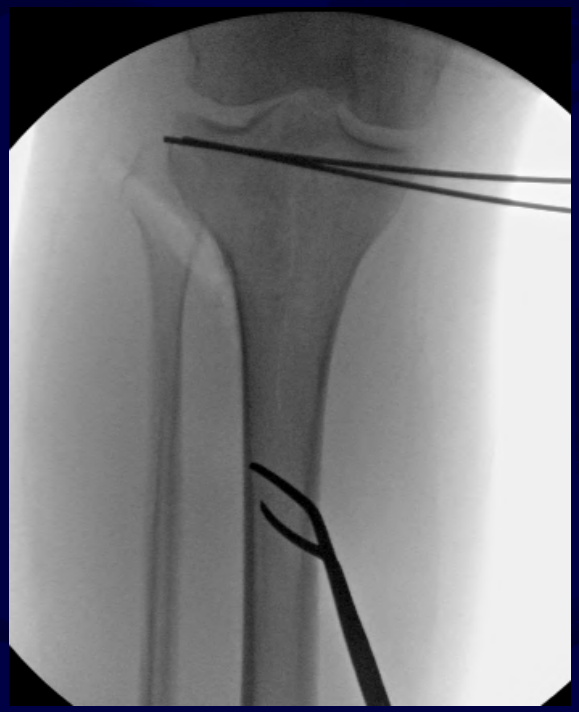
- Intra-articular Proximal Tibial Shaft Fracture:
  - Restore anatomic articular surface and hold reduction





MIPO Examples: Proximal Tibia

- Intra-articular Proximal Tibial Shaft Fracture:
  - Reduce shaft component percutaneously

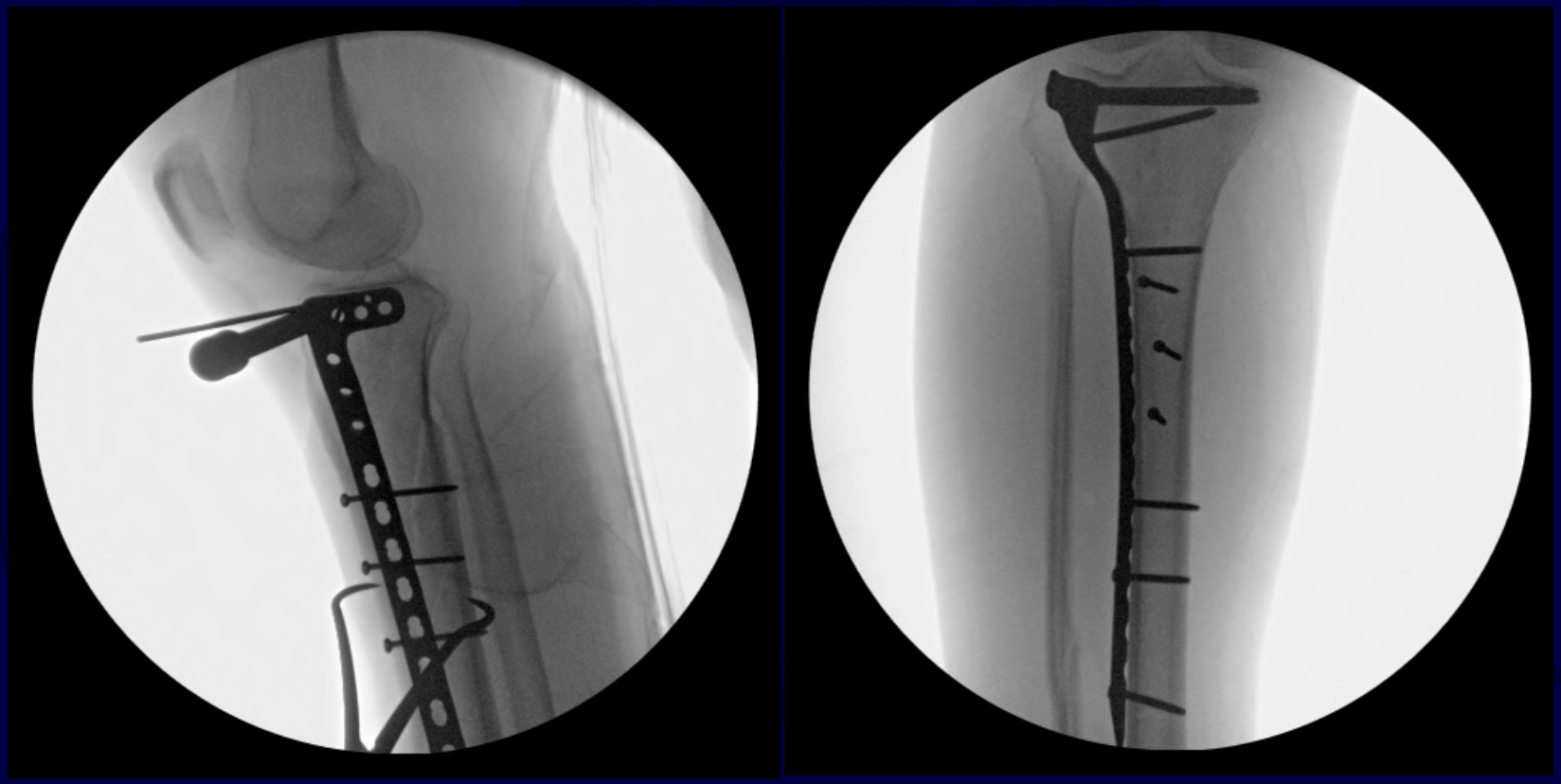


MIPO Examples: Proximal Tibia

- Intra-articular Proximal Tibial Shaft Fracture:
  - Lag screw fixation into shaft component

MIPO Examples: Proximal Tibia

- Intra-articular Proximal Tibial Shaft Fracture:



MIPO Examples: Proximal Tibia

- Intra-articular Proximal Tibial Shaft Fracture:

MIPO Examples: Proximal Tibia

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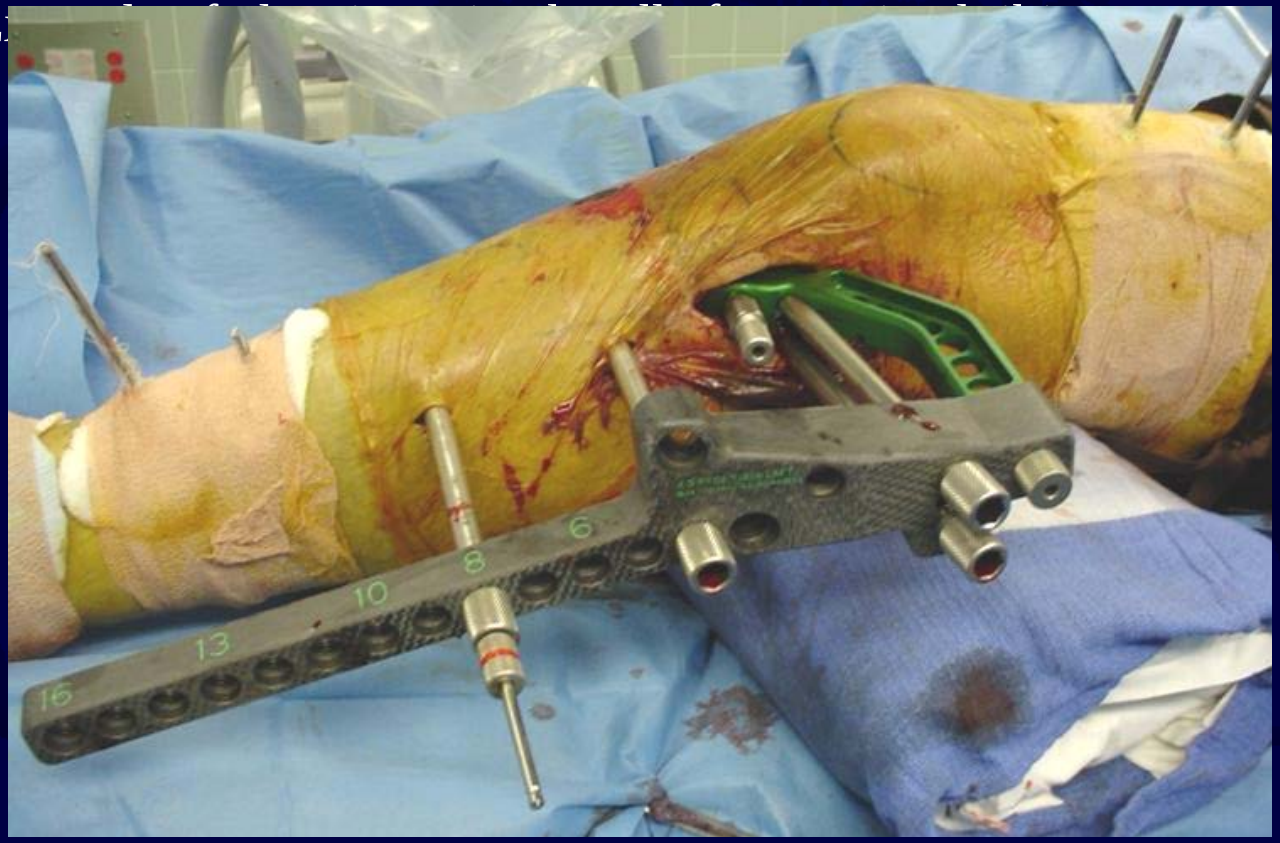

MIPO Examples

Tibial Shaft Fracture

MIPO Examples: Tibial Shaft

- Tibial Shaft Fracture below TKA with prior saphenous vein graft

MIPO Examples: Tibial Shaft

- Select appropriate plate length and incision location

MIPO Examples: Tibial Shaft

MIPO Examples: Tibial Shaft

MIPO Examples

Extra-Articular Distal Tibial Shaft Fracture

MIPO Examples: Distal Tibia

- Extra-articular Distal Tibial Shaft Fracture:

MIPO Examples: Distal Tibia

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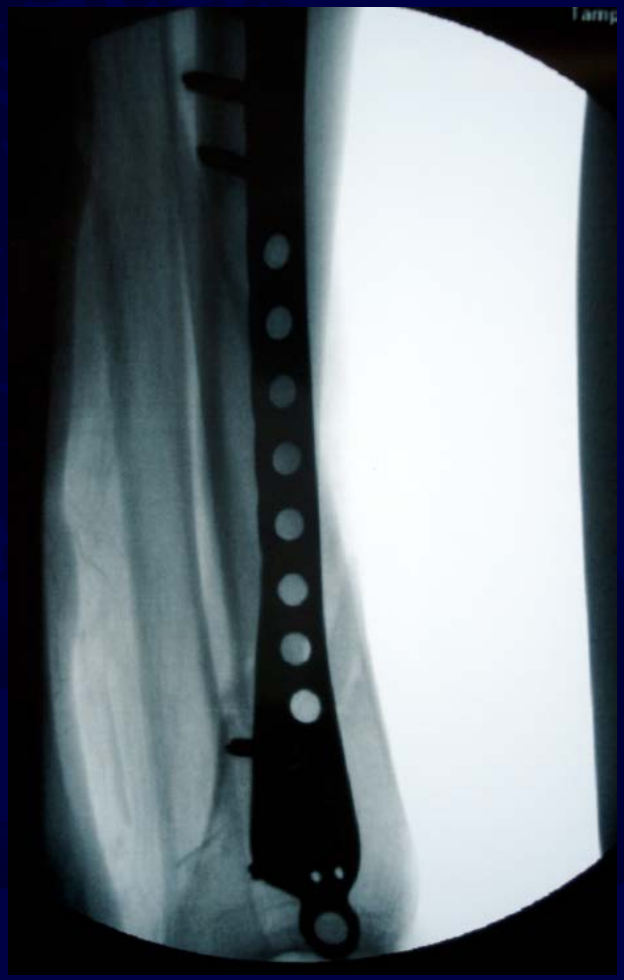
MIPO Examples: Distal Tibia

- Extra-articular Distal Tibial Shaft Fracture:

MIPO Examples: Distal Tibia

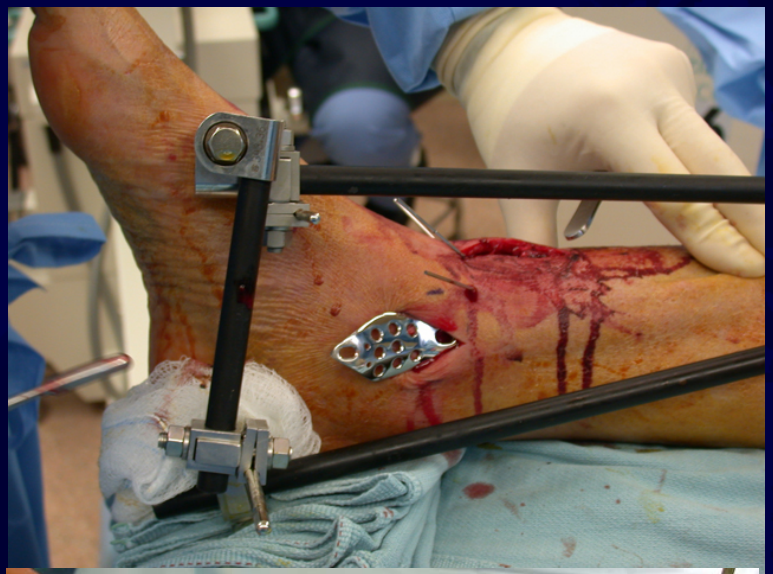


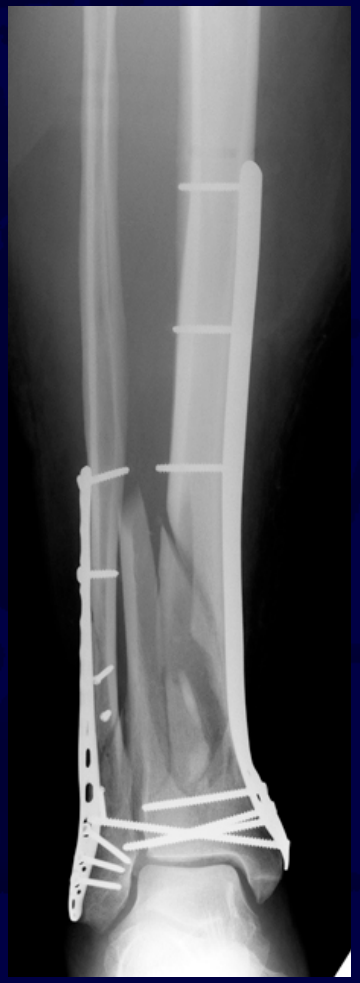
MIPO Examples

Extra-Articular Distal Tibia Fracture:

Anterior wounds prevent conventional appraoch

MIPO Examples: Distal Tibia





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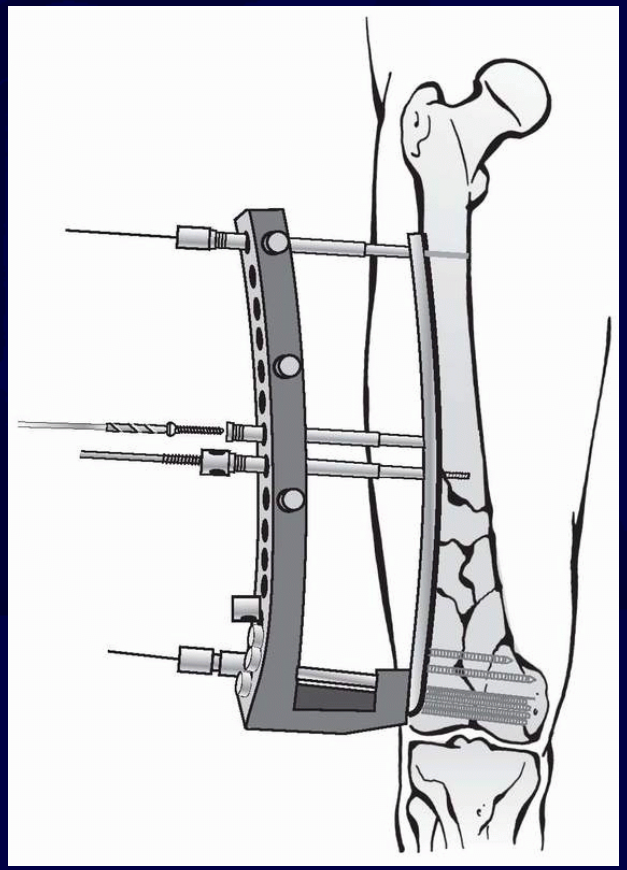
Minimally Invasive Plating Outcomes

- Indirect reduction and preservation of soft tissues resulted in improved outcomes:
  - Distal Femur:
    - 0-10% non-union
    - 2% infection
    - 2% malunion



Riemer et al, Orthopaedics 1992
Bolhofner et al, JOT 1996
Ostrum and Geel, JOT 1995
Schatzker et al., CORR 1998

Minimally Invasive Plating Outcomes

- Newer studies with larger cohorts better demonstrate risks, complications and clinical outcomes

Minimally Invasive Plating Outcomes

RESEARCH ARTICLE Open Access

Clinical outcomes of locked plating of distal femoral fractures in a retrospective cohort

Martin F Hoffmann[1,2], Clifford B Jones[3*], Debra L Sietsema[3], Paul Tornetta III[4] and Scott J Koenig[4]

J Orthop Surg Res, 2013

- 111 fracture treated with locked plating
  - 18% non-union rate:
    - Risks = Open fracture and severity of open injury (Type III > Type I or II)
  - 10 % implant failure
  - TKA = risk of implant failure and poor outcome

Minimally Invasive Plating Outcomes

Early Mechanical Failures of the Synthes Variable Angle Locking Distal Femur Plate

Jason C. Tank, MD, Prism S. Schneider, MD, PhD, Elizabeth Davis, BS, Matthew Galpin, Mark L. Prasarn, MD, Andrew M. Choo, MD, John W. Munz, MD, Timothy S. Achor, MD, James F. Kellam, MD, and Joshua L. Gary, MD

J Ortho Trauma, 2016

- Up to 22% implant failure rate with VA implant compared to 14% and 0% for LISS and LCP plating.
- New technology does not always result in improved fixation/outcomes

Minimally Invasive Plating Outcomes

- Tibial fractures, clinical results:
  - Proximal tibia:
    - 3-9% malalignment
    - 3% non-union
    - 0-4% infection

Cole et al., JOT 2004
Ricci et al., JOT 2004
Sitnik et al. CORR 2013

Minimally Invasive Plating Outcomes

- Tibial fractures, clinical results:
  - Distal Tibia:
    - 0-20% malunions
    - 0-4% nonunions
    - 0-5% infection

Helfet et al., Injury 1997
Oh et al. Clin Orthop 2002
Borg et al. Injury 2004
Redfern et al. Injury 2004
Maffuli et al. Int Orthop 2004
Khoury et al. Foot Ankle Int 2002
Sitnik et al. CORR 2013
Paluvadi et al. J Ortho Trauma, 2014

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Disadvantages of Minimally Invasive Plate Fixation

- Restoration of fracture alignment is critical to gaining acceptable clinical outcomes
- Intraoperative assessment of length, alignment and rotation may be difficult with fluoroscopy
- Several techniques can be used to help assess and maintain alignment

Disadvantages of Minimally Invasive Plate Fixation

Pitfalls in the Application of Distal Femur Plates for Fractures

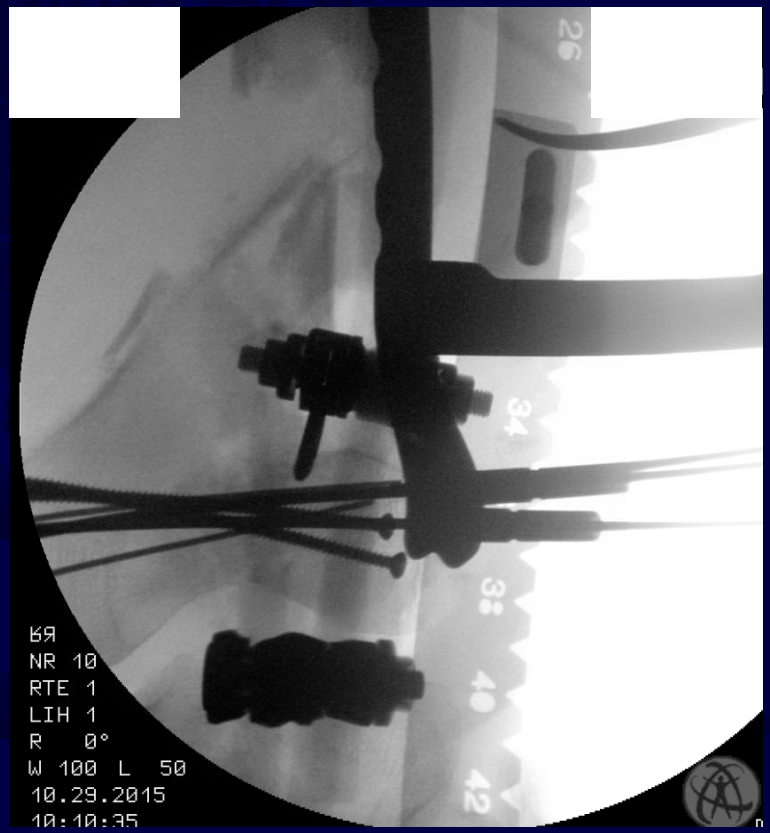
Cory A. Collinge, MD, Michael J. Gardner, MD,† and Brett D. Crist, MD‡*

J Ortho Trauma, 2011

- Accurate plate placement is essential:
  - Modern plates are designed to fit the femur anatomically, but not all patients are the same
  - A plate placed in the wrong location can lead to malalignment in the coronal or sagittal plane, malrotation, or translation
  - Avoid the “golf club deformity”—medialization and external rotation of the distal femoral articular surface.
    - Typically occurs when plate placed too posteriorly

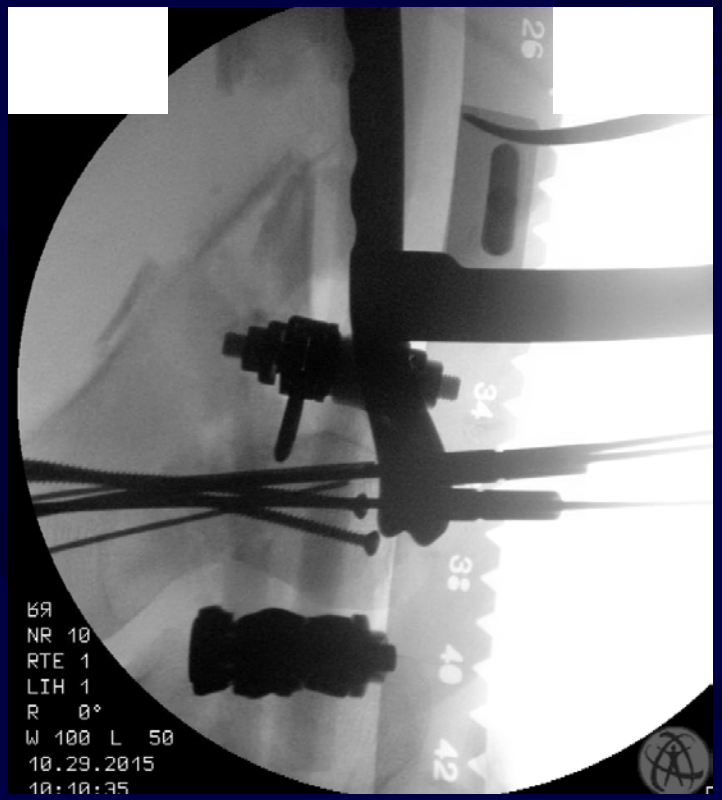
Disadvantages of Minimally Invasive Plate Fixation

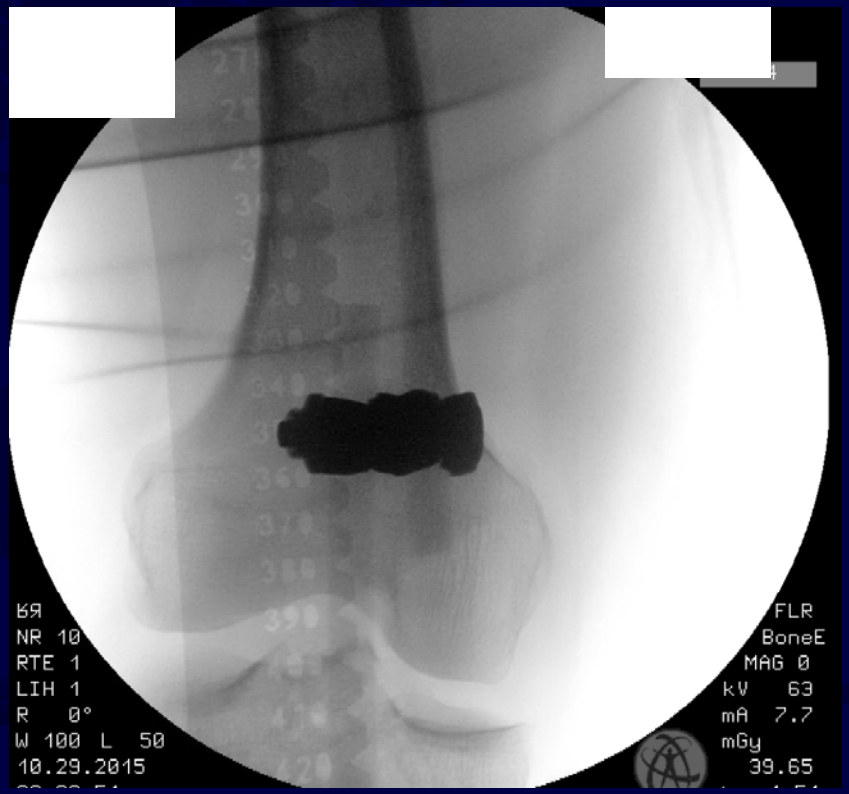
- Difficulty assessing length



Disadvantages of Minimally Invasive Plate Fixation

- Use intraoperative measurements from other leg





Disadvantages of Minimally Invasive Plate Fixation

- Unable to assess varus/valgus

Disadvantages of Minimally Invasive Plate Fixation

- Get intraoperative plain radiograph and measure on PACS

Disadvantages of Minimally Invasive Plate Fixation

- Other Disadvantages:
  - Indirect reduction can be technically difficult
  - Learning curve associated with use—may increase malreduction rate early on.

Minimally Invasive Plate Fixation

Future direction of MIPO:

Minimally Invasive Plate Fixation

Humeral Shaft Fractures?

Minimally Invasive Plate Fixation

Minimally Invasive Plating Osteosynthesis (MIPO) of Middle and Distal Third Humeral Shaft Fractures

An Zhiquan, MD, PhD, Zeng Bingfang, MD, Wang Yeming, MD, PhD, Zhang Chi, MD, and Huang Peiyan, MD

J Ortho Trauma, 2007

Minimally Invasive Plate Fixation

Minimally invasive percutaneous plating of proximal humeral shaft fractures with the Proximal Humerus Internal Locking System (PHILOS)

Alexander Brunner, MD, Sebastian Thormann, MD*, Reto Babst, MD

J Shoulder and Elbow, 2012

Minimally Invasive Plate Fixation

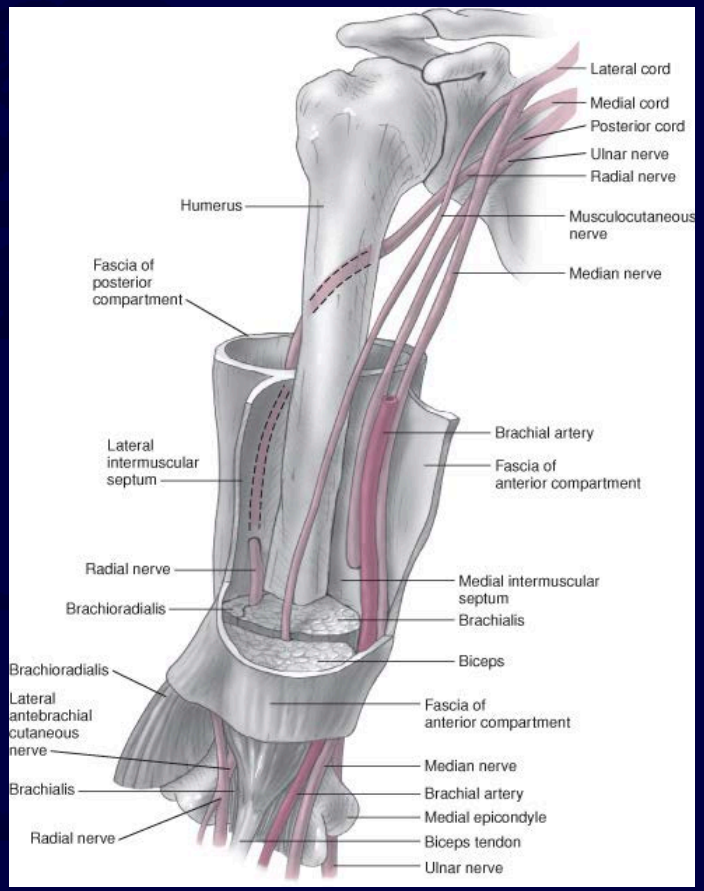
A Prospective Randomized Study of Operative Treatment for Noncomminuted Humeral Shaft Fractures: Conventional Open Plating Versus Minimal Invasive Plate Osteosynthesis

Ji Wan Kim, MD, Chang-Wug Oh, MD,† Young-Soo Byun, MD,‡ Jung Jae Kim, MD,§ and Ki Chul Park, MD‖*

J Orthop Trauma, 2015

Minimally Invasive Plate Fixation

- Humeral Shaft Fractures:
  - More data on surgical techniques, complications and clinical outcomes is required
  - Complex neurovascular anatomy may limit utility of minimally invasive plating in this area



SUMMARY

- Fracture healing requires an intact soft tissue envelope and blood supply.
- Minimally invasive plating of fractures allows for the preservation of surrounding vasculature.
  - Improves union rates
  - Limits infection risk
- Achievement and maintenance of reduction can be technically demanding
- Must be overly critical of fracture alignment as malreduction and malunion is more common with minimally invasive techniques.

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- Selected Images from: Court-Brown, C. et al. Rockwood & Greens Fractures in Adults. Philadelphia: Lippincott Williams & Wilkins, 2014