Distal Femur Fractures

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Top 5 Learning Objectives

1) **Osteology & deforming forces**
2) **Fracture classification**
3) **Treatment options and considerations**
4) **Surgical approaches**
5) **Fixation options**

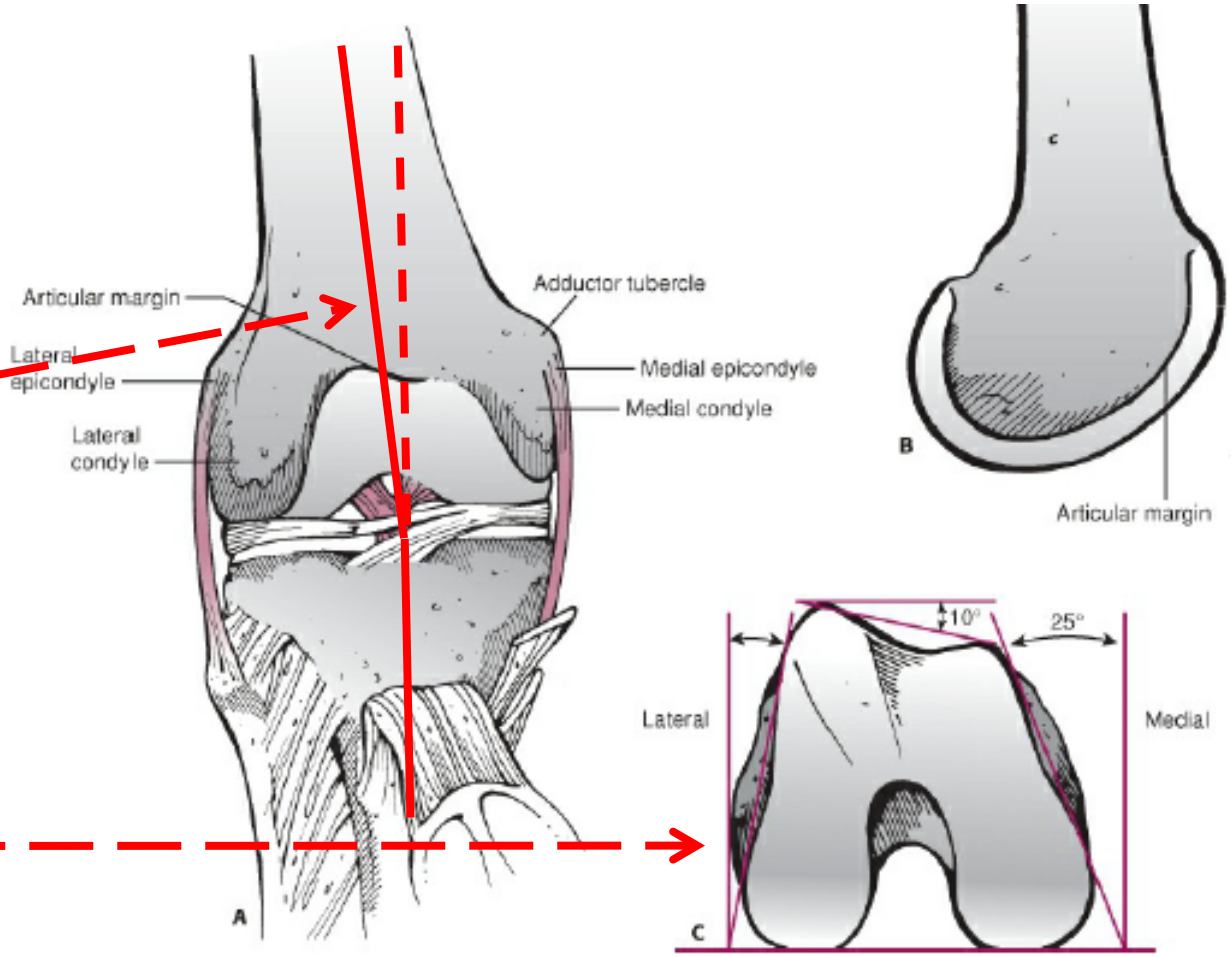
(Collinge CA, Wiss DA. Distal Femur Fractures. In: Tornetta P, Ricci WM, eds. *Rockwood and Green's Fractures in Adults, 9e.* Philadelphia, PA: Wolters Kluwer Health, Inc; 2019.)

Introduction

- **Account for 7% of all femur fractures**
  - **Bimodal distribution: High-energy injuries in the young, low-energy in the elderly**
- **Historical treatment**
  - **1960's and earlier: Skeletal traction favored**
    - **Neer et al. (JBJS 1967) advocated for closed, non-operative treatment based on poor results and high complications resulting from ORIF**
  - **1960's: Angled blade plate introduced and subsequently the dynamic condylar screw (DCS) plate improved fixation options**
  - **1990's: ORIF established as the standard of care (Butt et al., JBJS Br 1996)**
  - **2000's: Early iterations of the lateral locking plates improved outcomes (Weight & Collinge, JOT, 2004)**
  - **2010's: Improved plate design and ongoing experimentation with far cortical locking (FCL) and intramedullary (IM) nail design aim to improve non-union rates and allow for early weight-bearing**

Osteology

- **Shaft of femur aligned with anterior half of lateral condyle**
- **Anatomic axis 9° valgus (range 7-11°)**
  - **anatomic lateral distal femoral angle (aLDF) 81° (79°- 83°)**
  - **mechanical lateral distal femoral angle (mLDF) 87° (85° - 90°)**
- **Sectioned axially, distal femur is trapezoidal**
  - **Ramifications for:**
    - **Implant placement**
    - **Screw prominence**



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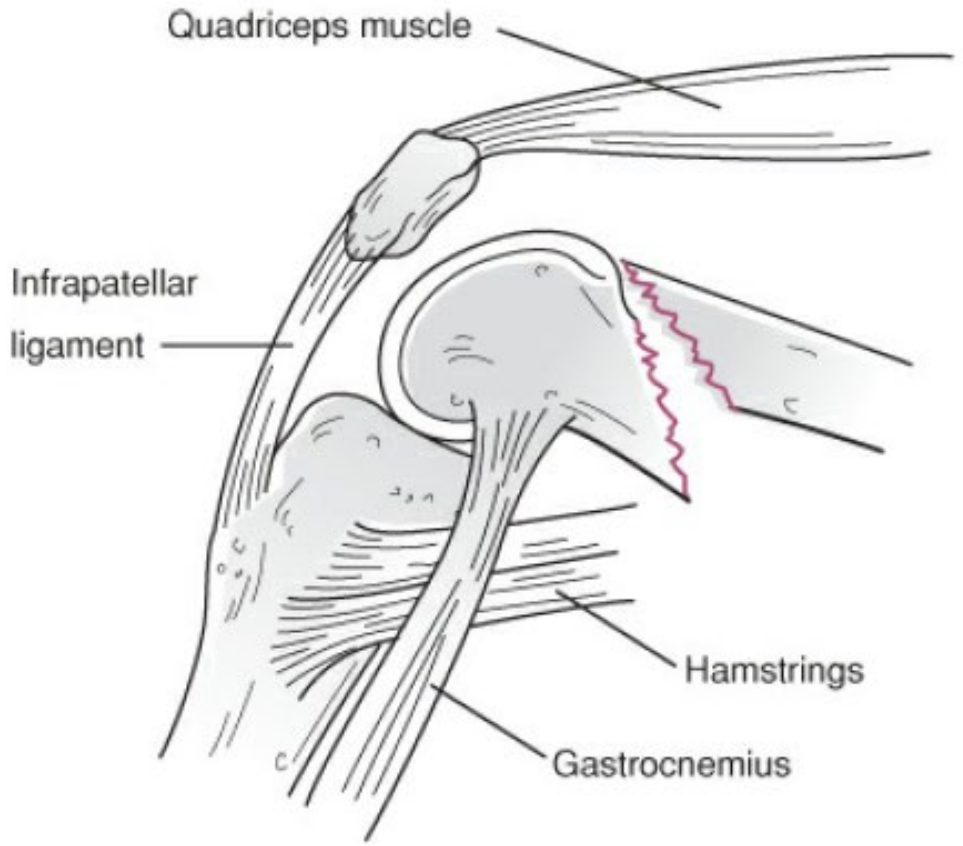
Injury Considerations

- **Mechanism of injury**
  - **Young patient: high energy (MVC, fall from height)**
  - **Elderly: low energy fall on flexed knee**
- **Deforming forces**
  - **Quadriceps → shortening**
  - **Hamstring → shortening**
  - **Gastrocnemius → apex posterior angulation, posterior displacement**
  - **Adductors → varus**



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Injury Considerations

- **Associated injuries**
  - **Open fracture (5-10%)**
  - **Knee ligament injury (up to 20% of cases)**
  - **Tibial plateau fracture**
  - **Patella fracture**
  - **Acetabulum fracture**
  - **Femoral neck fracture**
  - **Femoral shaft fracture**

Courtesy of Jeff Potter, MD

Injury Considerations

- **History**
  - **Mechanism of injury**
  - **Ambulatory status**
  - **Pre-existing knee arthritis**
- **Physical exam**
  - **If high energy injury: ATLS**
  - **Examine for other injuries**
  - **Neurovascular status of limb**
    - **Ankle-brachial index/ CT angiogram if any discrepancy in pulses**
  - **Inspect for soft tissue injury**

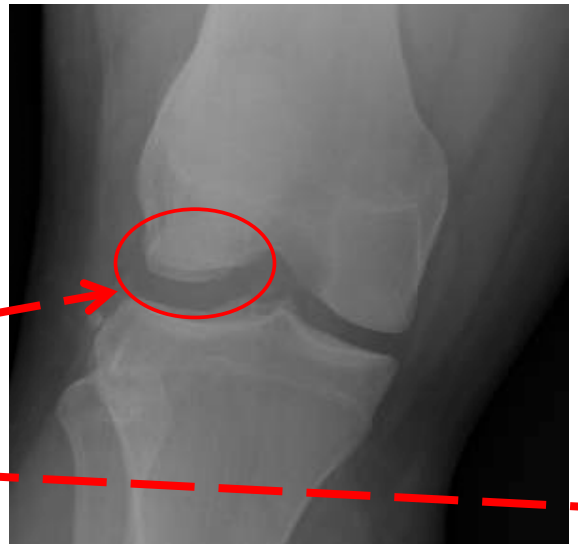
Indications for CT angiogram:

1) Diminished/ absent pulse
2) Expanding hematoma
3) ABI <0.9
4) Persistent arterial bleeding
5) Damage to associated nervous structures

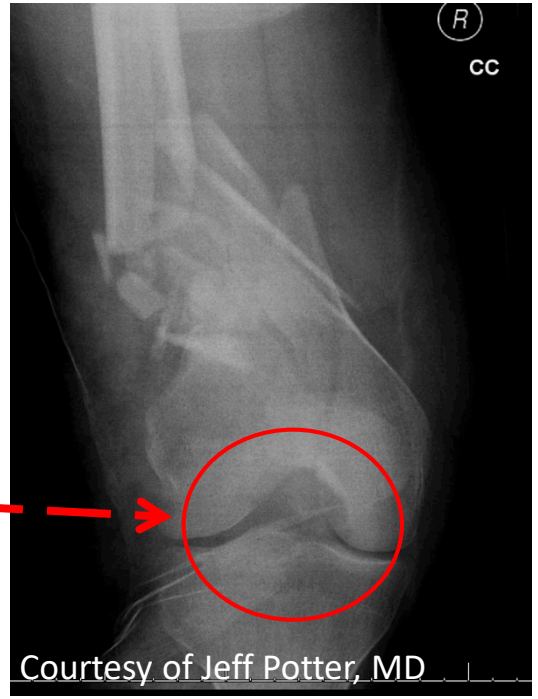
Injury Considerations

- **Workup**
  - **Orthogonal X-Rays**
    - **Double-density on AP X-Ray: Hoffa fragment**
    - **'Paradoxical notch view' on AP X-Ray: articular fragment in recurvatum**
  - **Image joint above and below**
  - **Low threshold for CT scan**
    - **Demonstrates intra-articular involvement**
    - **Reveals coronally oriented Hoffa fracture**
      - **38% incidence (Nork et al., JBJS 2005)**
      - **Lateral > medial condyle**
      - **Missed ~31% of the time**

Double density sign



Paradoxical notch view



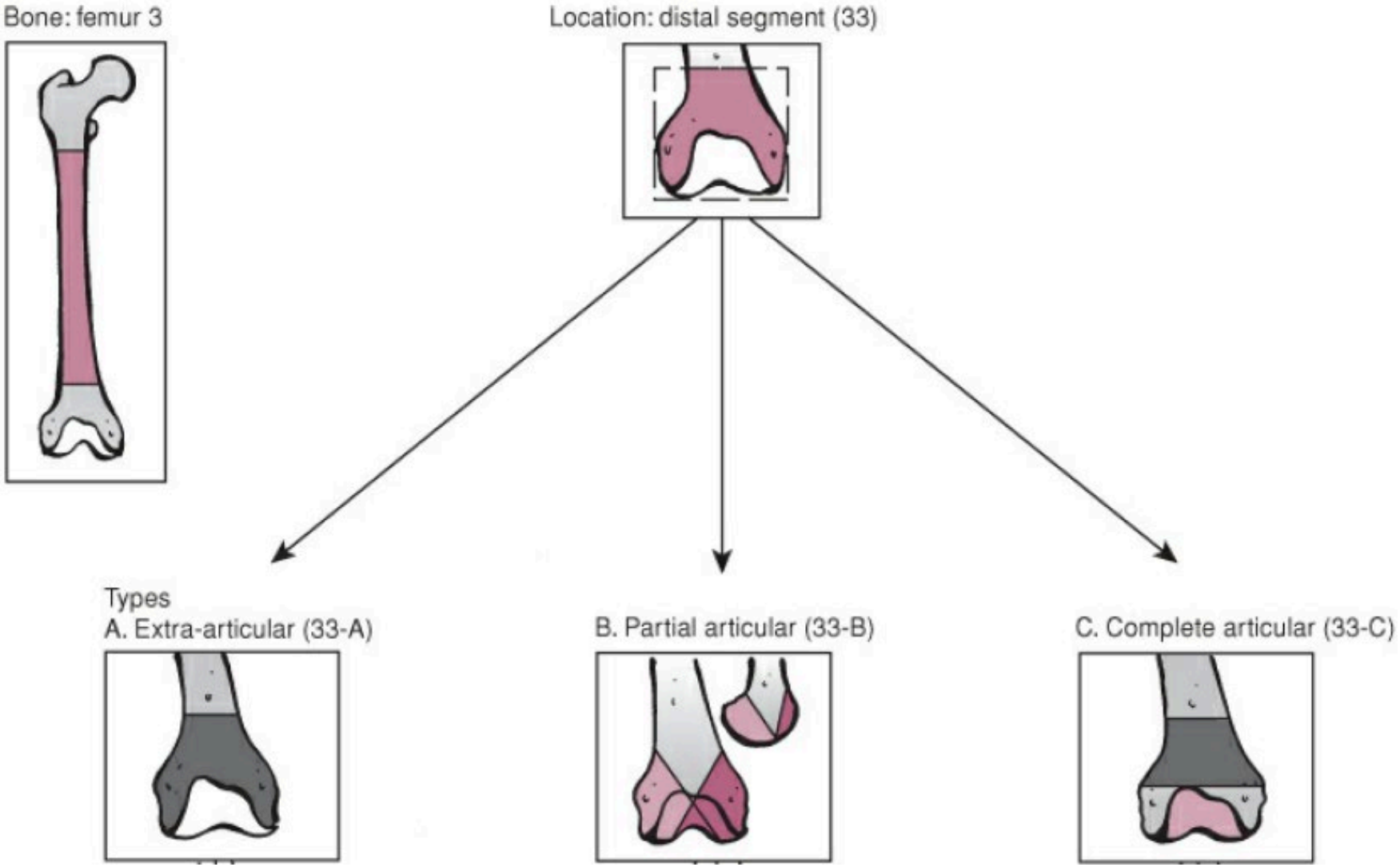
Courtesy of Jeff Potter, MD

Hoffa fracture

Injury Considerations

- **Prior to classifying the fracture, consider:**
  - **Amount of displacement**
  - **Degree of comminution**
  - **Extent of soft tissue injury**
  - **Damage to the articular surface**
  - **Bone quality**
  - **Associated fracture of patella or tibial plateau**
  - **Associated neurovascular injury**
  - **Presence of coronal fracture line**

Fracture Classification: AO/OTA



(Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. AO/ OTA fracture and dislocation classification compendium 2018. *J Orthop Trauma.* 2018;32 Suppl 1:S1-S170.)

Fracture Classification: AO/ OTA

33

Location: Femur, **distal end segment** 33

Types:

Femur, distal end segment,
extraarticular fracture
33A

Femur, distal end segment,
partial articular fracture
33B

Femur, distal end segment,
complete articular fracture
33C

(Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. AO/ OTA fracture and dislocation classification compendium 2018. *J Orthop Trauma.* 2018;32 Suppl 1:S1-S170.)

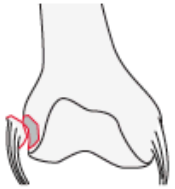
33A: Extra-articular

33A

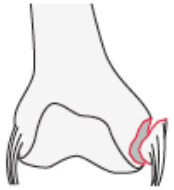
Type: Femur, distal end segment, **extraarticular fracture** 33A

Group: Femur, distal end segment, extraarticular, **avulsion fracture** 33A1

Subgroups:
Lateral epicondyle fracture
33A1.1

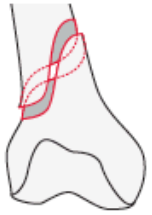


Medial epicondyle fracture
33A1.2



Group: Femur, distal end segment, extraarticular, **simple fracture** 33A2

Subgroups:
Spiral fracture
33A2.1



Oblique fracture
33A2.2

Transverse fracture
33A2.3

Group: Femur, distal end segment, extraarticular, **wedge or multifragmentary fracture** 33A3

Subgroups:
Intact wedge fracture
33A3.1*

Fragmentary wedge fracture
33A3.2*

Multifragmentary fracture
33A3.3

*Qualifications:
f Lateral
h **Medial**

(Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. AO/ OTA fracture and dislocation classification compendium 2018. *J Orthop Trauma*. 2018;32 Suppl 1:S1-S170.)

33B:
Partial articular

33B

Type: Femur, distal end segment, **partial articular fracture** 33B

Group: Femur, distal end segment, partial articular, **lateral condyle, sagittal fracture** 33B1

Subgroups:

Simple through the notch
33B1.1

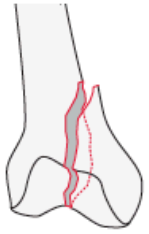
Simple through the load bearing surface
33B1.2

Fragmentary fracture
33B1.3

Group: Femur, distal end segment, partial articular, **medial condyle, sagittal fracture** 33B2

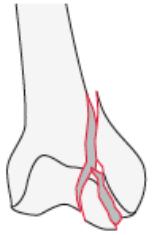
Subgroups:

Simple through the notch
33B2.1



Simple through the load bearing surface
33B2.2

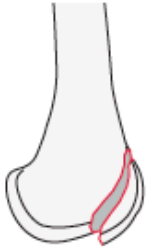
Fragmentary fracture
33B2.3



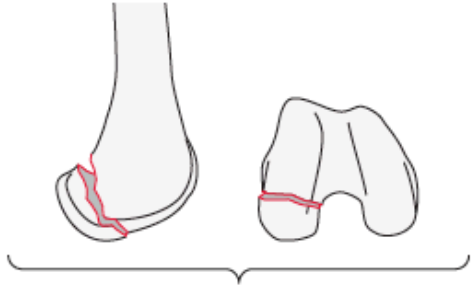
Group: Femur, distal end segment, partial articular, **frontal/coronal fracture** 33B3

Subgroups:

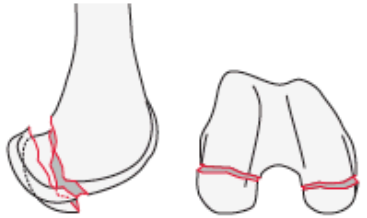
Anterior and lateral flake fracture
33B3.1



Posterior unicondylar fracture (Hoffa)
33B3.2*



Posterior bicondylar fracture (bilateral Hoffa)
33B3.3



*Qualifications:
f **Lateral**
h Medial

(Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. AO/ OTA fracture and dislocation classification compendium 2018. *J Orthop Trauma*. 2018;32 Suppl 1:S1-S170.)

33C:
Complete articular

33C

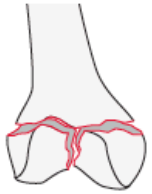
Type: Femur, distal end segment, **complete articular fracture** 33C

Group: Femur, distal end segment, complete, **simple articular, simple metaphyseal fracture** 33C1

Subgroups:

Above transcondylar axis
33C1.1

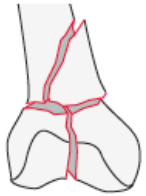
Through or below transcondylar axis
33C1.3



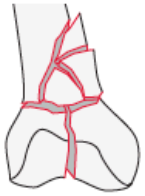
Group: Femur, distal end segment, complete, **simple articular, wedge or multifragmentary metaphyseal fracture** 33C2

Subgroups:

Intact wedge metaphyseal fracture
33C2.1*



Fragmentary wedge metaphyseal fracture
33C2.2*



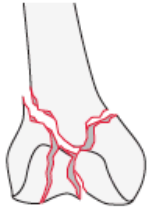
Multifragmentary metaphyseal fracture
33C2.3

*Qualifications:
f Lateral
h **Medial**

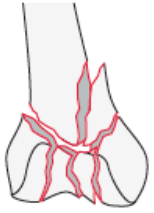
Group: Femur, distal end segment, complete, **multifragmentary articular fracture, simple, wedge or multifragmentary metaphyseal fracture** 33C3

Subgroups:

Simple metaphyseal fracture
33C3.1



Wedge metaphyseal fracture
33C3.2*



Multifragmentary metaphyseal fracture
33C3.3

*Qualifications:
f Lateral
h **Medial**
s **Intact**
l Fragmentary

(Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. AO/ OTA fracture and dislocation classification compendium 2018. *J Orthop Trauma.* 2018;32 Suppl 1:S1-S170.)

Treatment options

- **Relative indications for non-operative management**
  - **Patient factors**
    - **Medical contraindication to surgery**
    - **Non-ambulatory**
  - **Fracture factors**
    - **Non-displaced fracture**
    - **Impacted, stable fracture**
    - **Non-reconstructable fracture**
    - **Severe osteopenia**
  - **Surgeon factors**
    - **Lack of experience with operative treatment**
    - **Lack of appropriate instrumentation or facilities available**

Though non-operative treatment is rare, outcomes may be superior to poorly conceived and executed operative treatment

Treatment options

- **Non-operative treatment**
  - **Long-leg cast followed by hinged knee brace**
  - **Early range of motion is key to avoid stiffness**

Evidence

- Butt et al., JBJS Br 1996
  - RCT of 42 patients >60yrs old with displaced fractures to treatment with a Dynamic Condylar Screw versus skeletal traction with knee flexion exercises at 3-4 weeks
  - 53% of patients in operative group had excellent or good results, versus 32% in non-op group
  - Significantly more complications in the non-op group, many related to extended period of immobility (UTI, pressure sores, DVT, and pressure sores)

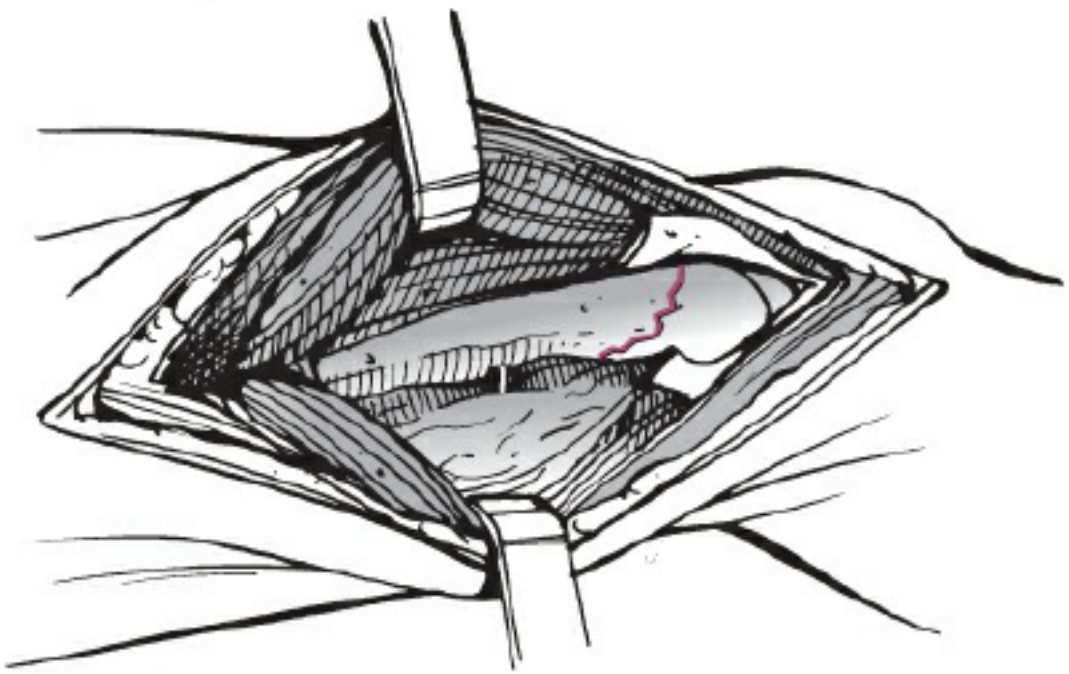
Treatment options

- **Operative indications:**
  - **Majority of distal femur fractures do not meet non-operative indications**

- **Operative Goals:**
  1) **Anatomic reduction of articular surface**
  2) **Functional reduction of the metaphysis restoring length, alignment, and rotation**
  3) **Restoration of anatomic and mechanical axis of the limb**
  4) **Stable fixation**
  5) **Early range of motion**

Surgical Approaches

- **Lateral**
  - **Most common approach**
  - **Skin incision in mid-lateral line of femoral shaft, curving slightly anteriorly over lateral femoral condyle towards tibial tubercle**
  - **Distal extent determined by need for joint arthrotomy if intra-articular reduction needs to be performed**
  - **Proximal extent determined by whether fracture will be directly or indirectly reduced**
  - **Divide IT band in line with its fibers**
  - **Incise vastus lateralis fascia and elevate fibers off septum, from distal to proximal, ligating femoral artery perforating vessels**

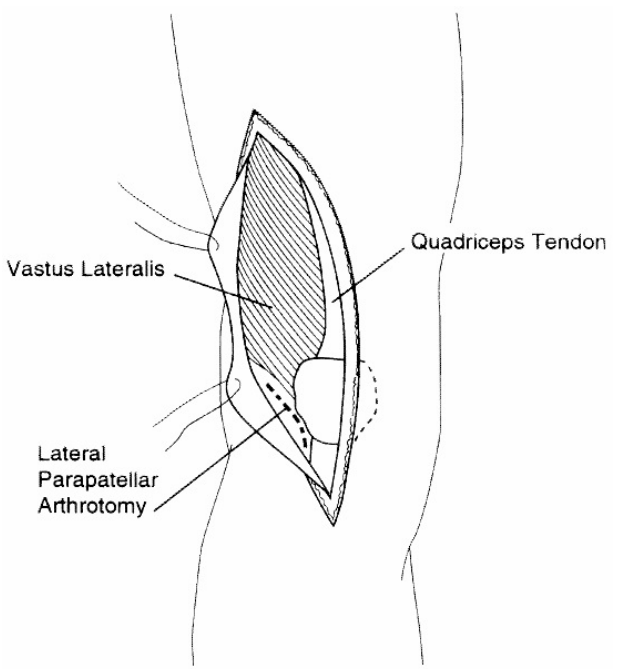


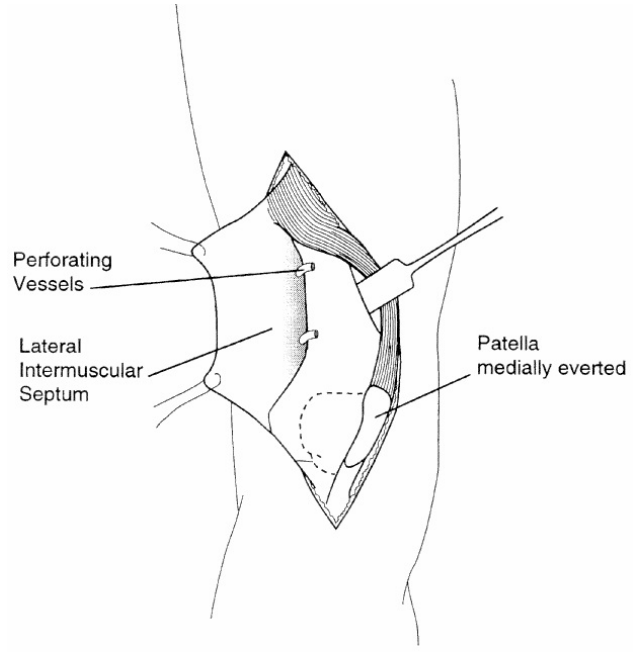
(Collinge CA, Wiss DA. Distal Femur Fractures. In: Tornetta P, Ricci WM, eds. *Rockwood and Green's Fractures in Adults, 9e.* Philadelphia, PA: Wolters Kluwer Health, Inc; 2019.)

Video demonstration: https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16731389/lateral-distal-femur-plate-for-periprosthetic

Surgical Approaches

- **Swashbuckler**
  - **Indicated when more articular reduction and fixation is needed**
  - **No tourniquet (prevents medial retraction of quads)**
  - **Midline anterior incision, curving laterally proximally**
  - **Quadriceps fascia incised in line with skin incision, connecting distally with a lateral parapatellar arthrotomy**
  - **Fascia & IT band elevated off vastus lateralis; IT band retracted laterally and quadriceps retracted medially**



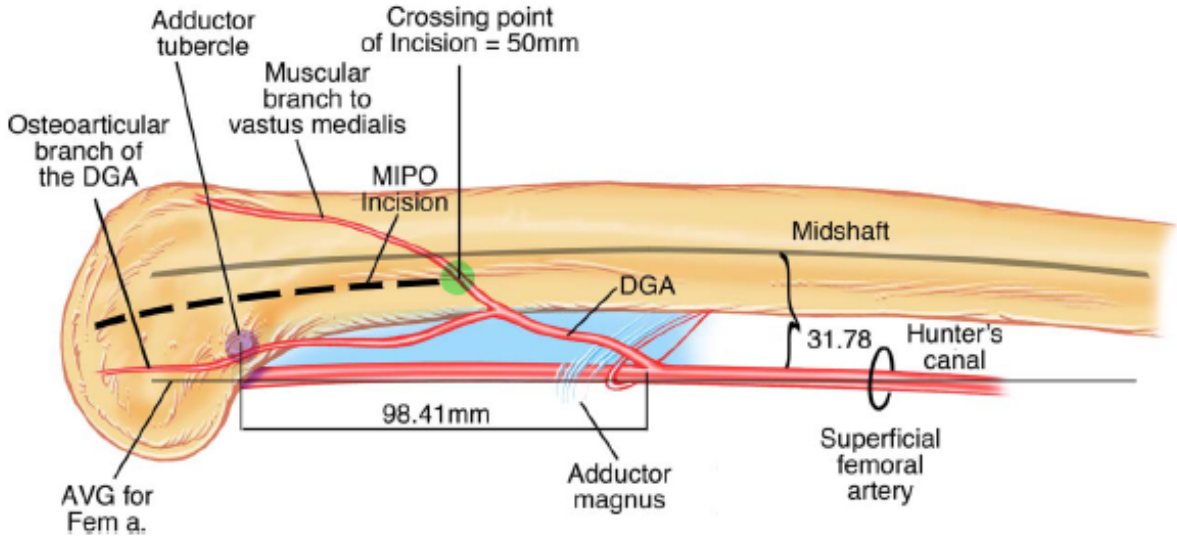


(Starr AJ, Jones AL, Reinert CM. The "swashbuckler": a modified anterior approach for fractures of the distal femur. *J Orthop Trauma.* 1999;13(2):138-140)

Video demonstration: https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16776605/distal-femur-swashbuckler-exposure

Surgical Approaches

- **Medial**
  - **Useful for isolated medial condyle fractures or severely comminuted fractures in which medial fixation is required**
  - **Straight medial incision extending distally to a point just anterior to adductor tubercle**
  - **Fascia divided in line with skin incision, anterior to sartorius**
  - **Vastus medialis elevated, care taken to avoid articular branch of descending geniculate artery (DGA) and muscular branch to vastus medialis**
  - **Muscular branch of DGA ~5cm and adductor hiatus ~16cm proximal to adductor tubercle**

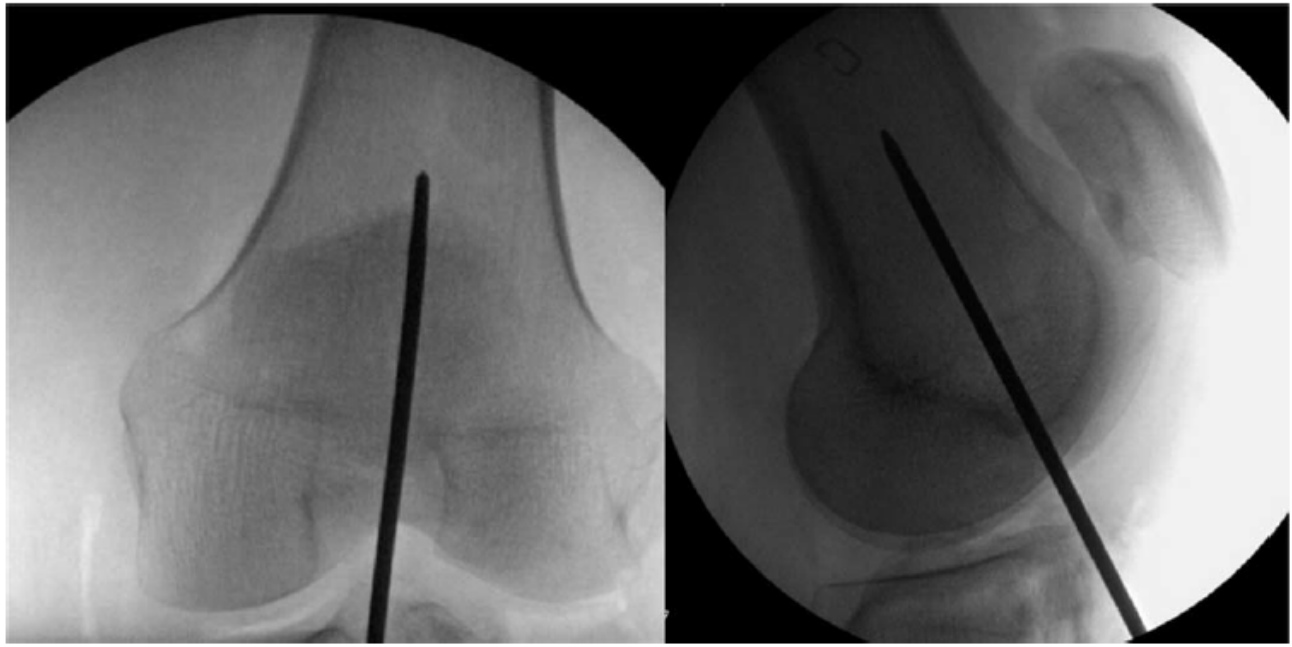


(Sirisreetreerux N, Shafiq B, Osgood GM, Hasenboehler EA. Medial knee approach: An anatomical study of minimally invasive plate osteosynthesis in medial femoral condylar fracture. *J Orthop Trauma.* 2016;30(11):e357-e361)

Video demonstration: https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16731423/medial-femur-dissection

Surgical Approaches

- **Limited anterior approach for IM nailing**
  - **Trans-patellar tendon incision or medial to tendon**
  - **Start point just anterior to femoral origin of PCL**
  - **Centered in shaft on AP Xray**
  - **Anterior edge of Blumensaat's line on perfect lateral Xray**



(Beltran MJ, Gary JL, Collinge CA. Management of distal femur fractures with modern plates and nails: state of the art. *J Orthop Trauma.* 2015;29(4):165-172)

Video demonstration: https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16731387/percutaneous-retrograde-supracondylar-femoral

Reduction Tools

- **Chemical paralysis**
- **Bump placed under knee corrects apex posterior deformity by relaxing gastrocnemius muscle**
- **Adequate exposure**
- **Femoral distractor**
  - **‘Pre-load’ Shanz pins (angle them slightly away from fracture) to account for angular deformity induced by distraction**
- **K-wires**
- **Reduction clamps**
  - **Large Weber clamps**
  - **Large peri-articular reduction clamp**

Courtesy of Claude Sagi, MD

Types of Fixation

- **Lateral pre-contoured plates**
  - **May be used for most fracture patterns**
- **Retrograde intramedullary nail**
  - **Most common for AO/OTA type A fractures**
  - **Some simple intra-articular patterns (AO/OTA type C1 & C2)**
- **Dynamic condylar screw/ Angled blade plate**
- **Distal femoral replacement**
  - **Elderly, pre-existing osteoarthritis, severely comminuted, with a need to immediately mobilize**
- **Augmented fixation**
  - **Bilateral plates, plate/ nail combo**
- **Buried screw fixation for Hoffa fractures**

Fixation Options

- **Lateral pre-contoured plates**
  - **Modes of fixation:**
    - **Simple fractures: neutralization plate for an anatomically reduced fracture with lag screw fixation**
    - **Comminuted fractures: bridge plate**
    - **Vertical shear fracture fixation: buttress plate**
  - **Available with variable-angle locking, fixed-angle locking, and non-locking options**
  - **Have largely replaced the dynamic condylar screw and blade plate**

Bridge plate fixation

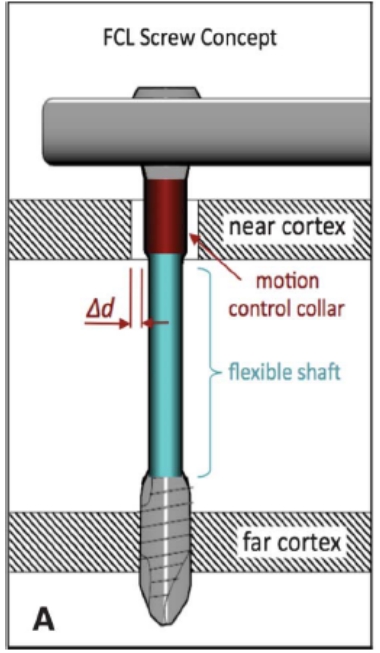
Buttress plate fixation

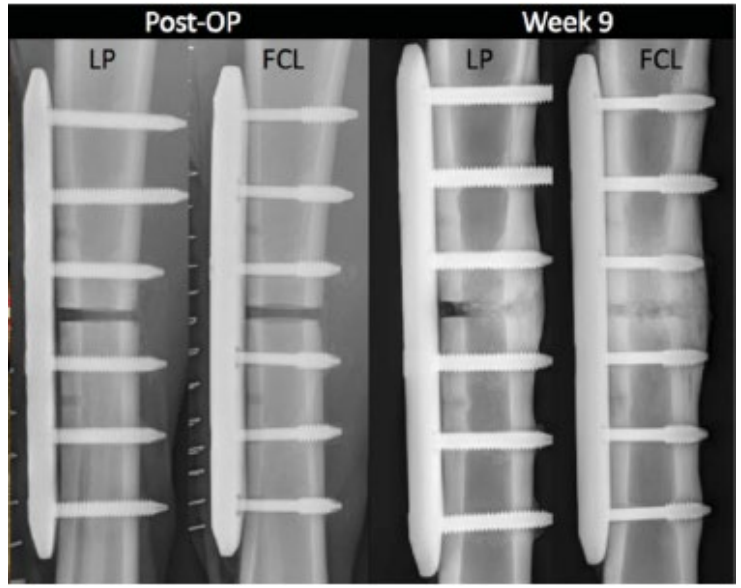
Fixation Options

- **Pre-contoured lateral plates**
  - **Stress modulation: the concept of manipulating bridge plating variables to optimize the flexibility of the construct to allow callus formation (Beltran et al. JOT 2015)**
    - **Titanium vs. stainless steel**
    - **Locking vs. non-locking**
    - **Unicortical vs. bicortical screws**
    - **Plate length**
    - **Screw hole fill**
    - **Working length**

Fixation Options

- **Far-cortical locking plates**
  - **Biomechanical and animal studies show increased and more evenly distributed callus**
  - **Plumarom et al., JOT 2019**
    - **Retrospective cohort of AO/OTA type A, C, and periprosthetic fractures**
    - **42 treated with far-cortical locking plates and 15 with lateral locked plates**
    - **mRUST scores from blinded radiographs statistically higher in FCL group at 6, 12, and 24**
    - **91% union for FCL group vs. 82% for LLP group at one year**





(Bottlang M, Feist F. Biomechanics of far cortical locking. *J Orthop Trauma.* 2011;25 Suppl 1:S21-28)

Case Example

- **59 year old male, workplace injury where a 250lb marble slab fell on his leg**
- **Pre-existing severe knee osteoarthritis**

Courtesy of Jeff Potter, MD

2 week post-op X-Ray

Final 1 year follow-up X-Ray

Courtesy of Jeff Potter, MD

Fixation Options

- **Dynamic Condylar Screw (DCS) plate**
- **Less Invasive Stabilization System (LISS)**
- **Evidence:**
  - **COTS group, JOT 2016**
    - **RCT comparing LISS (28 patients) vs the DCS (24 patients)**
    - **52% of LISS group healed at 12 months vs. 91% in the DCS group**
- **Both have largely been replaced by modern implants that have variable angle/ fixed angle, and non-locking options**

Dynamic Condylar Screw (DCS) plate

Less Invasive Stabilization System (LISS)

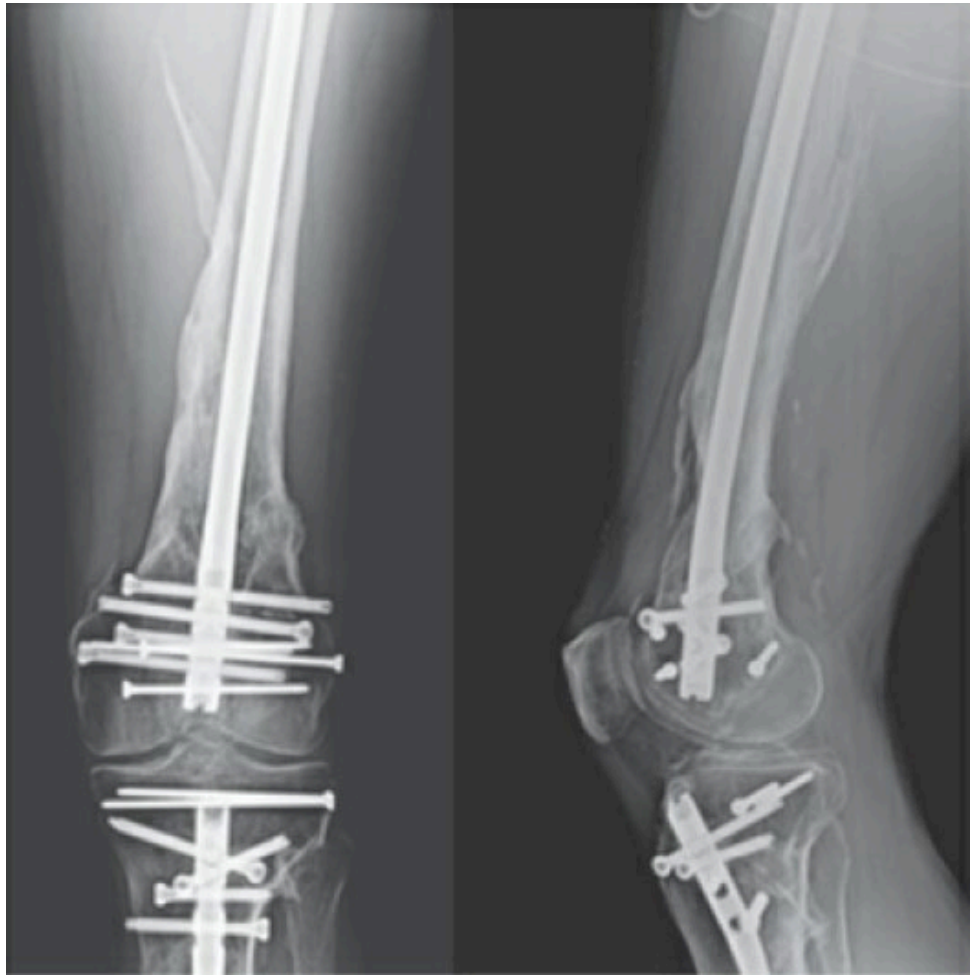
(Collinge CA, Wiss DA. Distal Femur Fractures. In: Tornetta P, Ricci WM, eds. *Rockwood and Green's Fractures in Adults, 9e.* Philadelphia, PA: Wolters Kluwer Health, Inc; 2019.)

Fixation Options

- **Limitations of lateral locked distal femur plates: non-union**
  - **Up to 31%**
  - **Rodriguez et al., JOT 2016**
    - **Retrospective study including 271 supracondylar femur fractures**
    - **Nonunion rate 13%**
    - **Plate material (stainless steel) and those with high rigidity scores were associated with nonunion**
    - **Rigidity score included: plate material, presence of screws across main fracture, and proximal screw density**
  - **Ricci et al., JOT 2014**
    - **Retrospective study including 335 AO/OTA Type A or C fractures**
    - **Nonunion rate 19%**
    - **Risk factors for reoperation to promote union include open fracture, diabetes, smoking, increased BMI, and shorter plate length**

Fixation Options

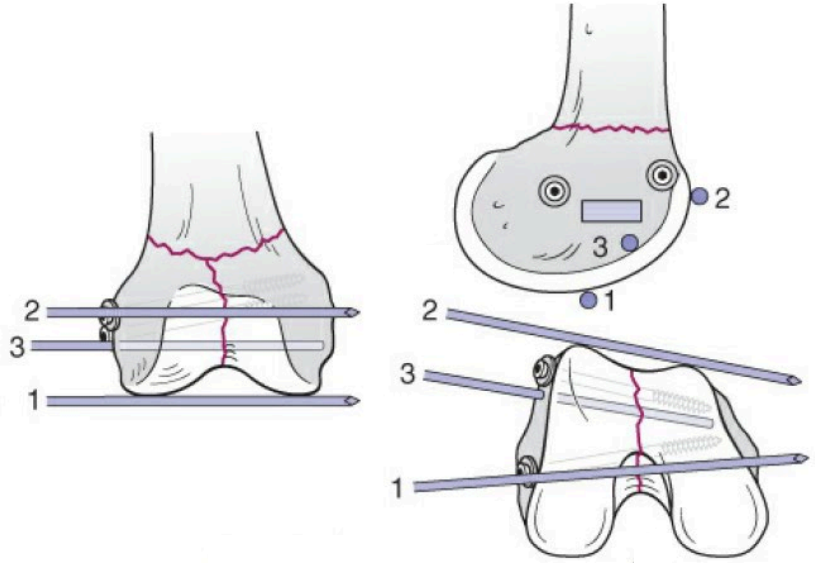
- **Intramedullary nail**
  - **Minimizes disruption of soft tissues**
  - **Improved designs (multiple distal screw options and ability to lock distal screws to the nail) have expanded their indications**
  - **Retrograde nail should extend to the level of the lesser trochanter, or at least allow two proximal interlocking screws**
  - **Antegrade nails may be an option for high supracondylar fractures or segmental fractures**
  - **Reduce fracture prior to reaming**



(Collinge CA, Wiss DA. Distal Femur Fractures. In: Tornetta P, Ricci WM, eds. *Rockwood and Green's Fractures in Adults, 9e.* Philadelphia, PA: Wolters Kluwer Health, Inc; 2019.)

Fixation Options

- **Dynamic condylar screw/ angled blade plate**
  - **Currently, used at times for nonunion/ revision scenarios**
  - **Stiff constructs (stainless steel)**
  - **Condylar screw & blade must be inserted parallel to joint**
  - **Position in the articular fragment is critical to avoid malreduction**

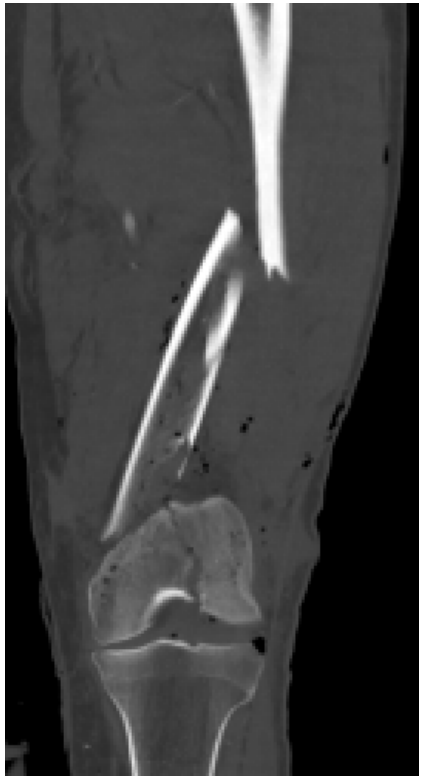


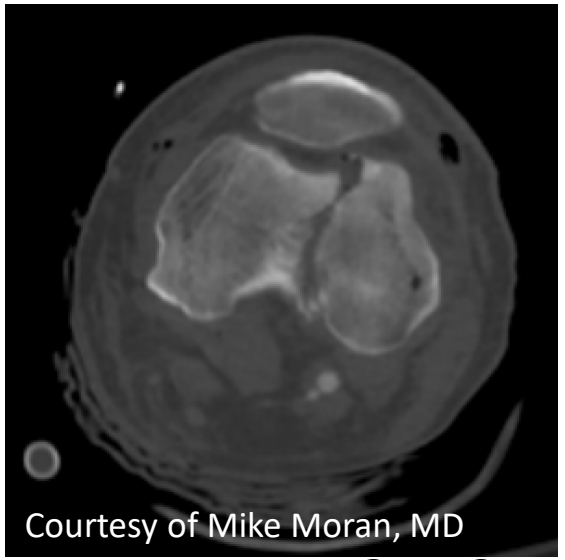
Blade positioning

(Collinge CA, Wiss DA. Distal Femur Fractures. In: Tornetta P, Ricci WM, eds. *Rockwood and Green's Fractures in Adults, 9e.* Philadelphia, PA: Wolters Kluwer Health, Inc; 2019.)

Case Example

- **68 year old man, left leg crushed when trailer fell off a jack and onto his leg**
- **Open left segmental, comminuted distal femur fracture**





2 week follow-up X-Rays

Courtesy of Mike Moran, MD

- **Distal femur & shaft fracture nonunion established at one year**
- **Persistent pain, no infectious symptoms, skin healed with no draining sinus, CRP normal**

Courtesy of Mike Moran, MD

V5

Intra-op image confirming DCS placement

Courtesy of Mike Moran, MD

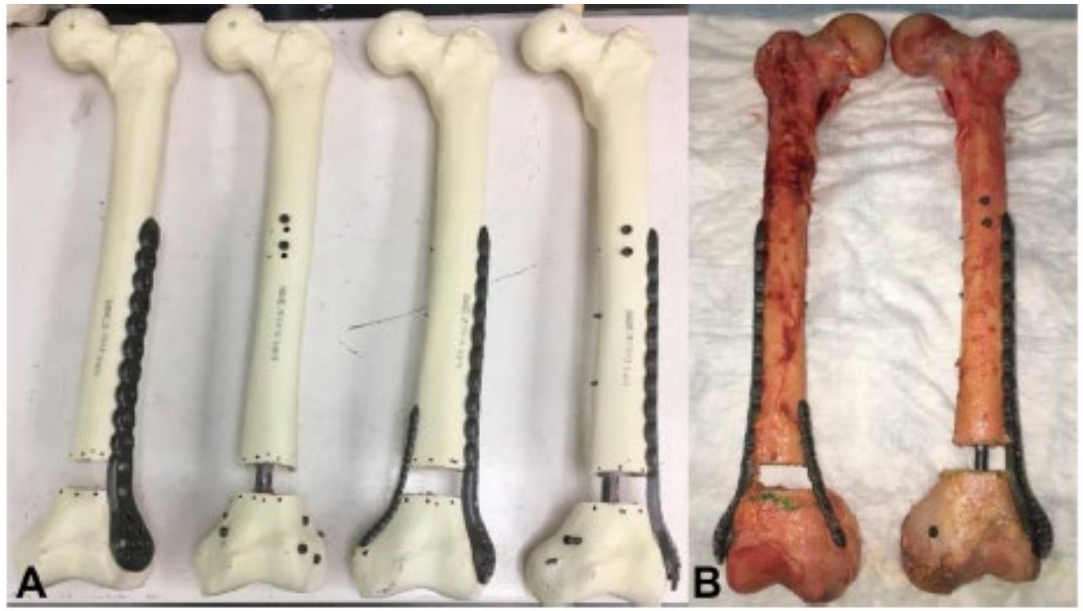
Union by 6 months post-op

Fixation Options

- **Distal femur replacement**
  - **Advantages**
    - **Immediate weight-bearing, eliminates risks of nonunion, malunion, fixation failure, and post-traumatic OA (Meluzio et al. Injury 2020)**
  - **Disadvantages**
    - **Limited salvage options in cases of osteolysis, loosening, peri-prosthetic fracture, or infection**

Fixation Options

- **Lateral plate augmented fixation with**
  - **Medial pre-contoured distal tibia plate**
  - **Medial 3.5mm recon plate**
  - **Retrograde IM nail**
- **May be useful to avoid varus failure and permit early weight-bearing**
- **Fontenot et al. J Orthop Trauma 2019**
  - **Biomechanical study using 28 synthetic femora**
  - **Both Lateral plate plus medial recon plate & lateral plate plus nail exhibited higher stiffness and load to failure**
- **Wright et al. J Orthop Trauma 2020**
  - **Dual plate fixation had slightly higher torsional and axial stiffness**



(Wright DJ, DeSanto DJ, McGarry MH, Lee TQ, Scolaro JA. Supplemental fixation of supracondylar distal femur fractures: A biomechanical comparison of dual-plate and plate-nail constructs. *J Orthop Trauma.* 2020;34(8):434-440)

Fixation Options

- **Hoffa fracture fixation**
  - **Caused by shear moment through posterior condyle**
  - **Do not miss these fractures**
  - **Require independent screw fixation-prior to plate- in the sagittal plane**
  - **Flexion of knee helps to reduce fragment**
  - **Fixation outside articular margin when possible; buried/ headless screw when not**
  - **Very small posterior fragment may require posterior to anterior screw**

(Holmes SM, Bomback D, Baumgaertner MR. Coronal fractures of the femoral condyle: A brief report of five cases. *J Orthop Trauma.* 2004;18(5):316-319)

Post-surgery Rehabilitation

- **Traditional had been NWB for up to 12 weeks**
- **New evidence suggests immediate or early weight-bearing does not increase fixation failure rate**
  - **Poole et al., BJJ 2017**
    - **Case series of 127 fractures in patients with mean age 73 years old fixed with lateral distal femur locking plate**
    - **84% were allowed to weight-bear immediately. At minimum 1 year follow-up, 95% united and only 3% required re-operation for failure of fixation**
  - **Lieder et al., JOT 2020**
    - **Retrospective cohort of 135 patients with AO/OTA Type A and periprosthetic femur fractures allowed to either weight bear immediately or touch-down weight bear**
    - **No difference in adverse events (11% WBAT vs. 19% TDWB) including early fixation failure, nonunion, or infection**
- **Range of motion initiated immediately post-op**
- **Involve primary care physician and/or endocrinologist if osteoporosis is a concern**

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