Joint Preservation with High Tibial and Distal Femoral Osteotomies: Indications, Techniques, and Outcomes

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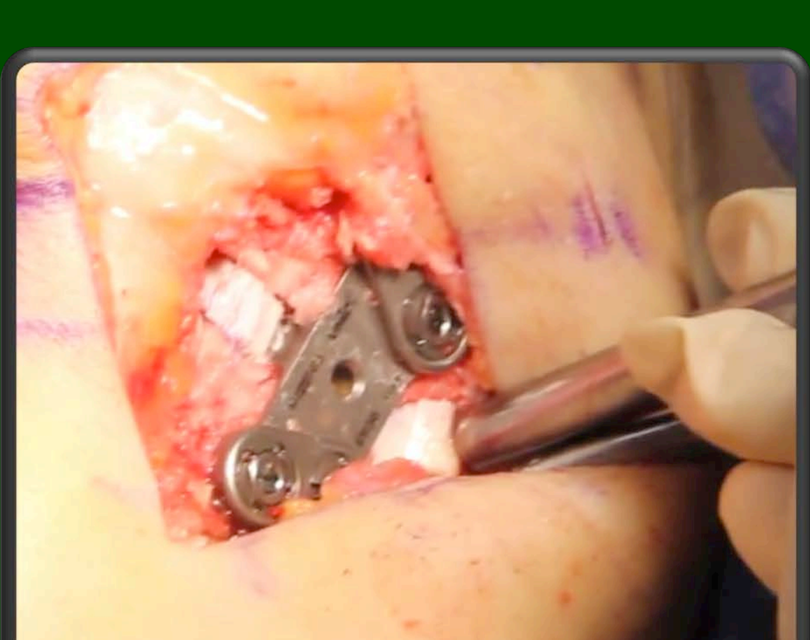
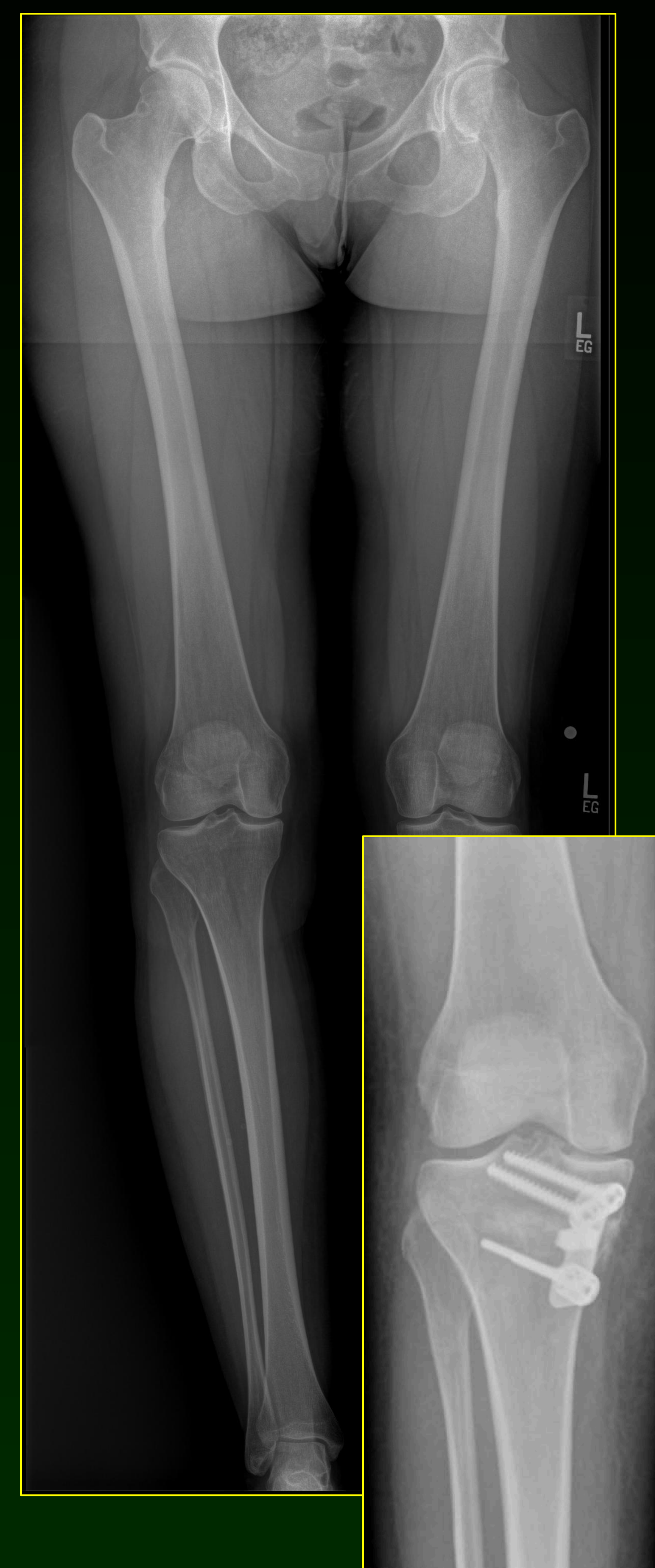
Abstract

Summary: Joint preservation strategies incorporating high tibial osteotomy (HTO) or distal femoral osteotomy (DFO) allow for successful outcomes in physiologically young, active patients that may otherwise require arthroplasty.

Introduction: The management of symptomatic malalignment in young, active patients is extremely challenging. With a demanding patient population that desires to remain active at older ages, non-arthroplasty strategies aimed at joint preservation are necessary. Historically, procedures intended for correction of the malaligned knee, including HTO and DFO, have been utilized in young laborers with painful knees. As techniques and implants improve, the indications for osteotomy are evolving to be utilized either as an adjunct to cartilage/ ligament reconstructive procedures, or as an isolated joint preservation strategy.

Methods: The purposes of this exhibit are to describe the history, physical examination, and surgical management of real patient examples of symptomatic malalignment treated effectively with either HTO or DFO. In addition, a video presentation will illustrate pertinent intraoperative findings that help to guide surgical decision-making for a successful and reproducible reconstructive, joint-preserving construct.





Results: Several patient-specific factors can be delineated by obtaining a proper history, performing a thorough physical examination, and obtaining reproducible imaging studies including long-leg alignment films. The non-arthroplasty surgical options for joint preservation in young patients include HTO (for varus malalignment) or DFO (for valgus malalignment) as appropriate, as well as management of concomitant symptomatic pathologies including ligamentous instability, articular cartilage lesions, and/or meniscal damage

Conclusions: Non-arthroplasty alternatives for young patients with advanced unicompartmental degenerative joint disease are evolving. This exhibit provides orthopaedic surgeons with a comprehensive framework based on the best-available evidence to assist in making treatment decisions for these patients to optimize outcomes.

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Diagnostic Work-Up

Patients with unicompartmental joint pathology should undergo a thorough history and physical examination. Care must be taken to evaluate malalignment, ligament insufficiency, and cartilage/meniscal deficiencies. Imaging studies should augment the work-up → especially for evaluation of malalignment.

Understanding Patient Expectations is Critical

History & Physical

MUST assess for:

- Ligamentous instability
- Degree of malalignment
- Bone loss
- Patellofemoral symptoms
- Range of motion → contractures
- Gait abnormalities

Inspection:

- Overall alignment
- Joint-line tenderness
- Patellofemoral joint pain
- Lower limb deformity
- Leg length discrepancy
- Q angle → in flexion and extension

Special Consideration: "triple varus knee"

- Tibiofemoral varus
- Varus recurvatum
- Lateral compartment opening due to ligamentous laxity

Imaging

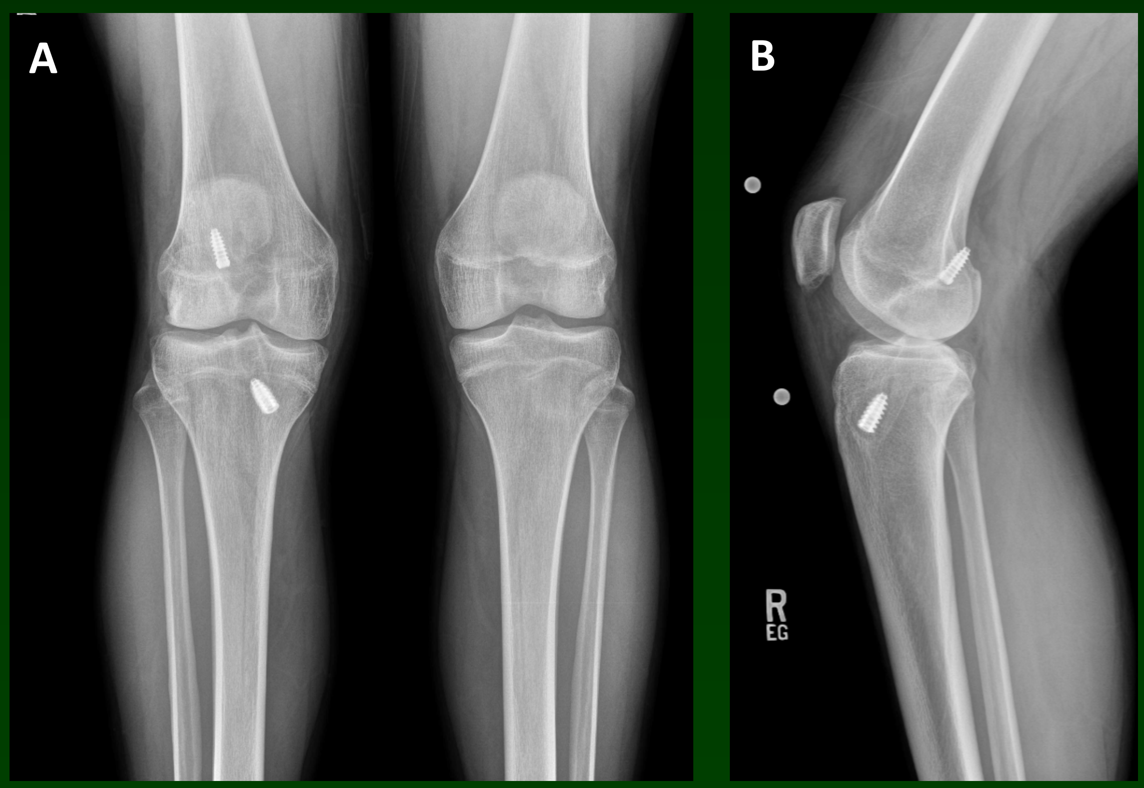
Radiographs:

- Anterior-Posterior (AP)
- Lateral
- Sunrise view
- 45 degree flexion PA
- Standing AP long-leg alignment view

Advanced Imaging:

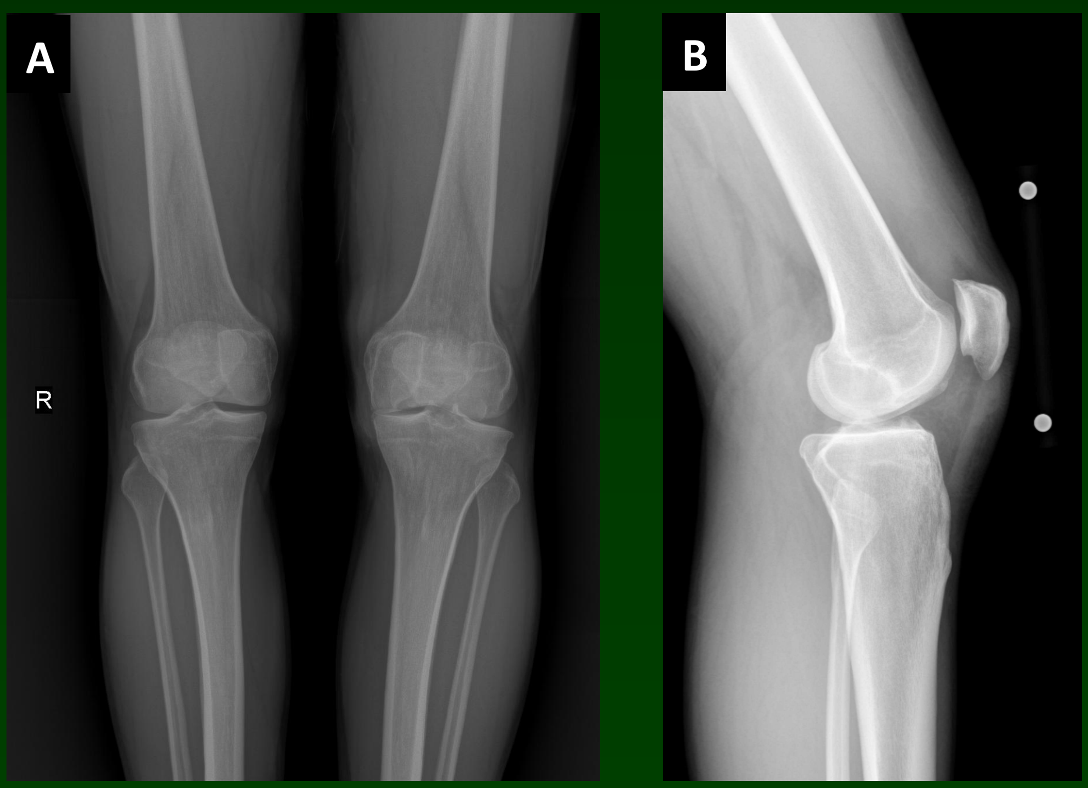
- **MRI:** Necessary only if ligamentous or cartilage pathology is suspected
- **CT:** Necessary only if concerned about bone loss
- **Diagnostic arthroscopy:** Typically performed at the time of surgery to verify the status of the articular cartilage and menisci

Example → Right knee valgus



AP (A), Lateral (B), and standing long-leg alignment (C) radiographs, demonstrating a right knee valgus deformity in a 17 year old male patient with a prior ACL reconstruction

Example → Left knee varus



AP (A), Lateral (B), and standing long-leg alignment (C) radiographs, demonstrating a left knee varus deformity in a 40 year old male patient with a history of multiple prior partial medial menisectomies

Indications (relative)

- **Age less than 65 years old**
- **Symptomatic unicompartmental arthritis**
- **Malalignment with or without cartilage deficiency**
- **Malalignment with or without meniscal deficiency**
- **Normal, or correctable, ligamentous status**
  - **Changing sagittal slope to address cruciate ligament insufficiency**
- **Willing to comply with rehabilitation**

Contraindications

- **Patellofemoral or tricompartmental arthritis**
- **Opposite compartment articular surface pathology**
- **Coronal deformity > 15 degrees**
- **Flexion contracture > 10 degrees**
- **Baseline knee flexion < 90 degrees**
- **Medial/lateral tibial subluxation > 1 cm**
- **Inflammatory arthritis**
- **Body Mass Index > 35 kg/m²**

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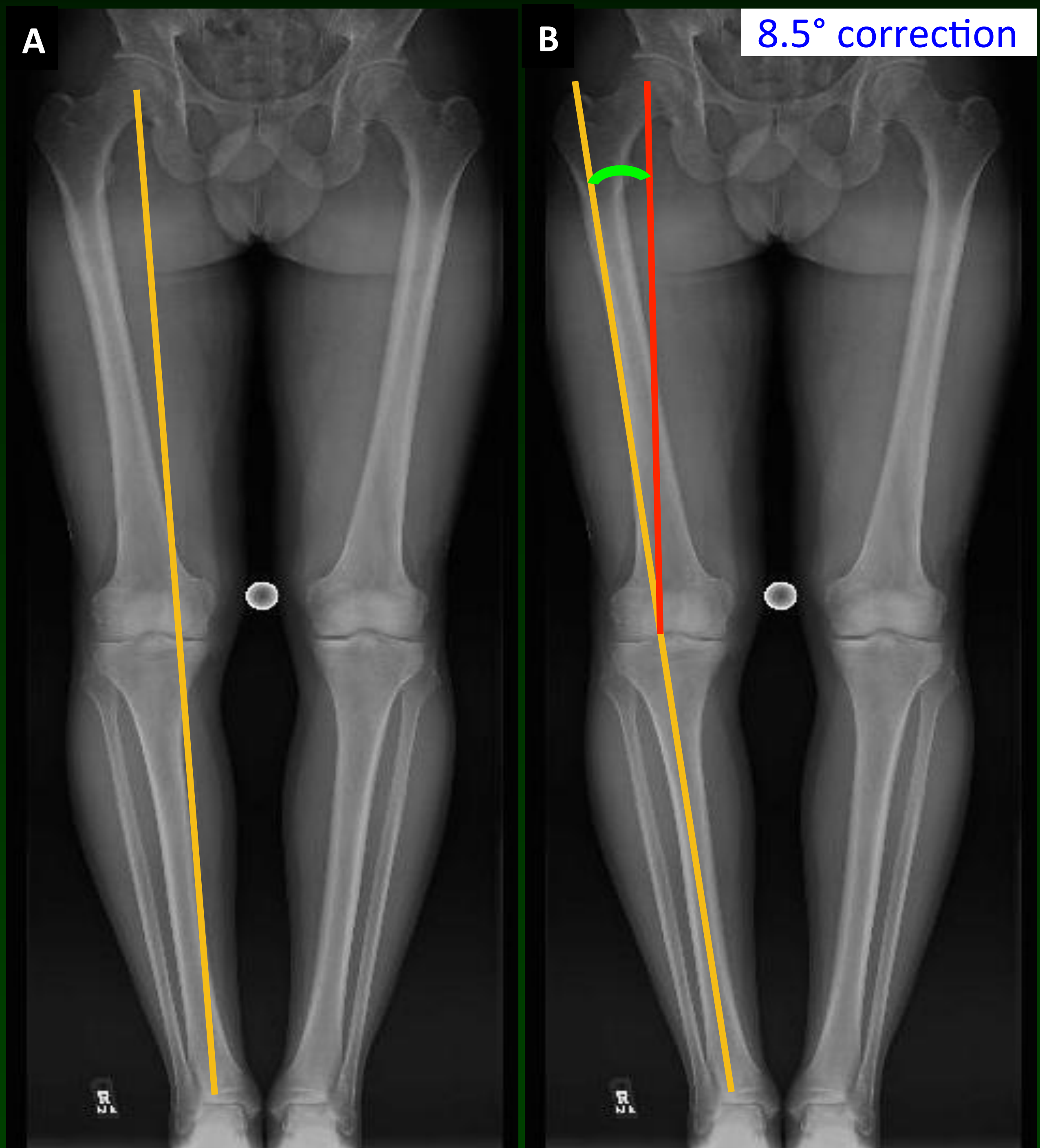
Preoperative Planning

Planning

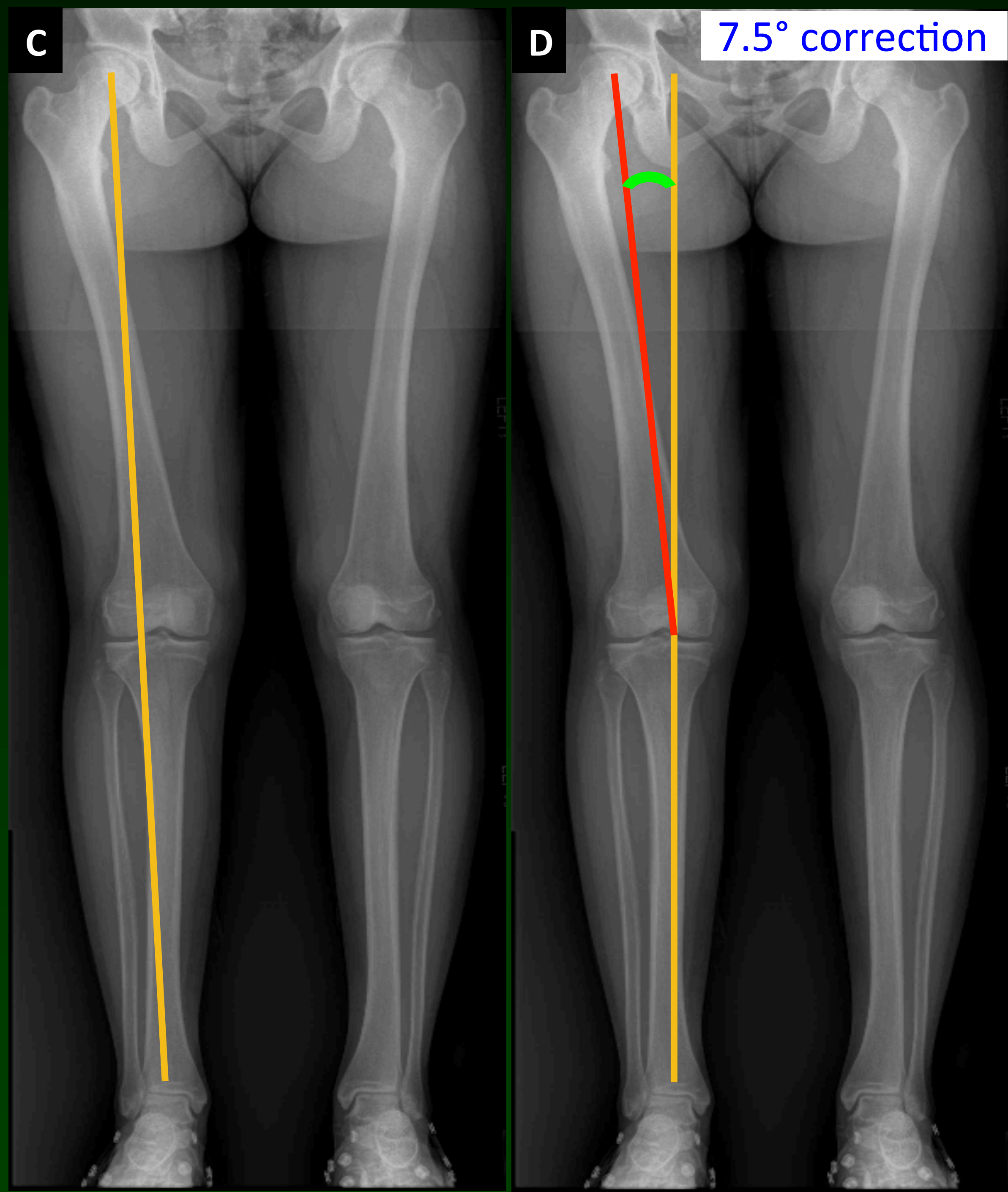
Coronal Corrections: Long-leg Weight-Bearing Films
- Mark desired correction point on tibial plateau
- Draw line from center of femoral head to point
- Draw line from point to center of tibial plafond
- Angle formed by these 2 lines → degree of correction needed

Sagittal Corrections:
- Increasing tibial slope will worsen ACL and improve PCL stability
- Decreasing tibial slope will improve ACL and worsen PCL stability

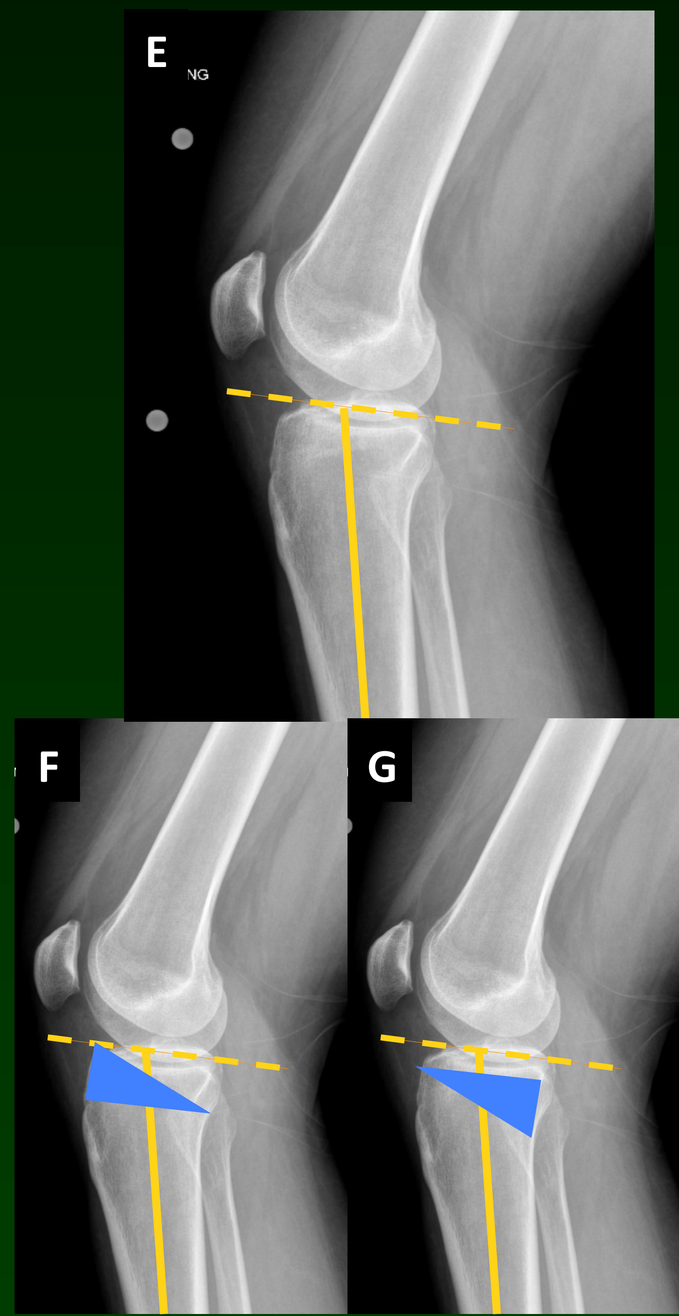
Key Concepts:
- **Mechanical axis:** center of femoral head to medial tibial spine (femur), medial tibial spine to center of ankle (tibia)
  - *Normal = 0°*
- **Anatomical axis:** defined by mid-diaphyseal axis of femur/tibia
  - *Normal = 5-7° valgus (femur)*
- **Weight-bearing axis:** center of femoral head to center of ankle joint



Standing long-leg alignment radiographs of a 30yo male with a right knee varus deformity: A) weight-bearing axis (yellow line) passing medial to medial tibial spine, B) anticipated 8.5°correction with an HTO

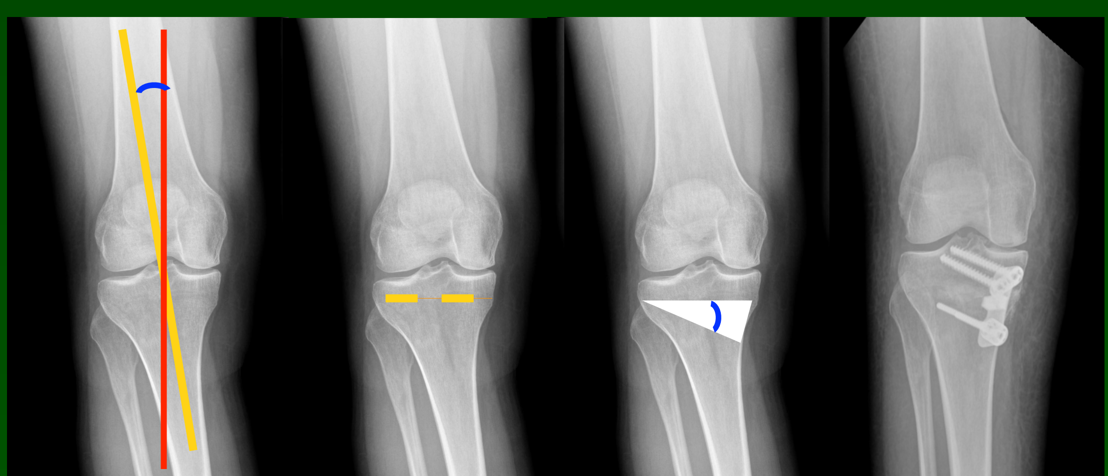


Standing long-leg alignment radiographs of a 36yo female with a right knee valgus deformity: A) weight-bearing axis (yellow line) passing lateral to medial tibial spine, B) anticipated 7.5°correction with a DFO

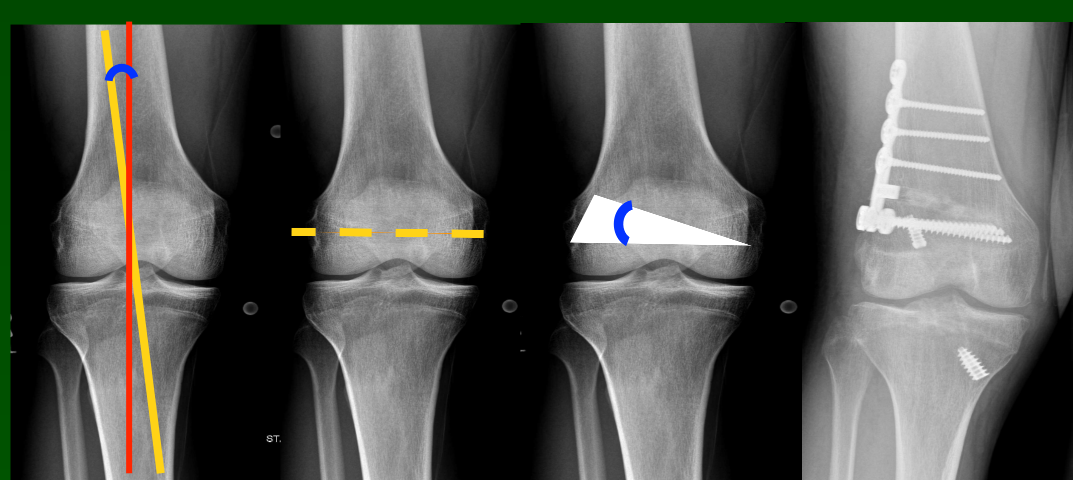


Lateral radiograph demonstrating ability of osteotomy to F) increase tibial slope with spacer wedge placed anteriorly and G) decrease tibial slope with spacer wedge placed posteriorly

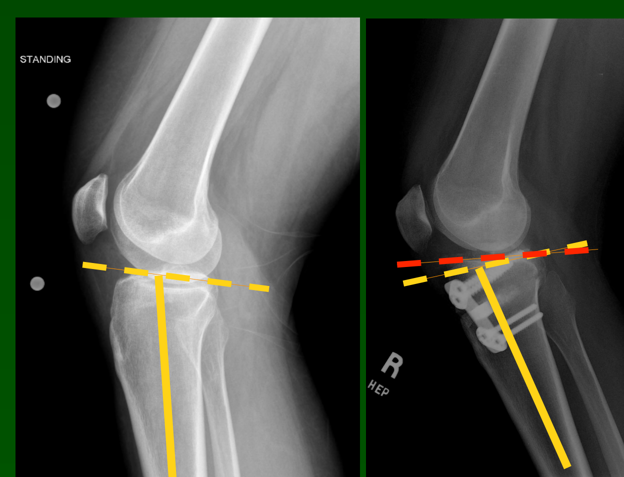
Example of Anticipated Correction



Demonstration of correction of varus deformity utilizing a medial opening wedge HTO, shifting the weight-bearing axis laterally



Demonstration of correction of valgus deformity utilizing a lateral opening wedge DFO, shifting the weight-bearing axis medially



Demonstration of a slight increase in tibial slope (red line) after HTO

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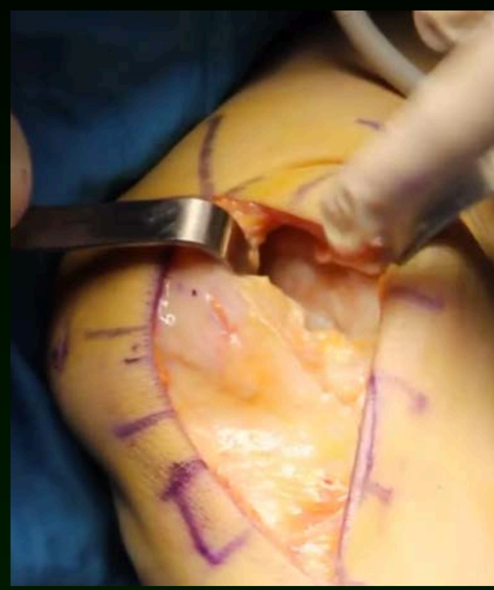
Varus Malalignment: *High Tibial Osteotomy*

Medial Opening Wedge HTO:

- **Approach →** 5cm longitudinal incision starting 1cm below joint line, between medial border of tibial tubercle and posteromedial border of tibia
- **Guide pin insertion →**
  - Inserted along anteromedial aspect of tibia from level of superior aspect of tibial tubercle, from inferomedial to superolateral, aiming guide pin toward tip of the fibular head
  - A second pin is inserted parallel to the first, taking into account the proximal slope of the tibia
- **Osteotomy cut and wedge insertion →**
  - With a cutting guide placed over the 2 pins, use an oscillating saw to cut the tibia to within 1 cm of the lateral cortex
  - Remove guide pins
  - Insert the calibrated wedge into the osteotomy site from the medial side of the tibia
  - Advance the wedge gently and slowly
    - Rapid insertion can cause a lateral wall fracture
- **Plate fixation →**
  - An angled plate is placed posteromedially and is secured with screws:
  - Proximal → 2 cancellous unicortical 6.5mm screws
  - Distal → 2 bicortical 4.5mm screws
  - Use fluoroscopy to assess hardware placement
- **Bone graft →**
  - Insert bone graft on both sides of the plate
  - If using allograft, make sure to continuously irrigate the bone while using the saw

Pearls and Pitfalls:

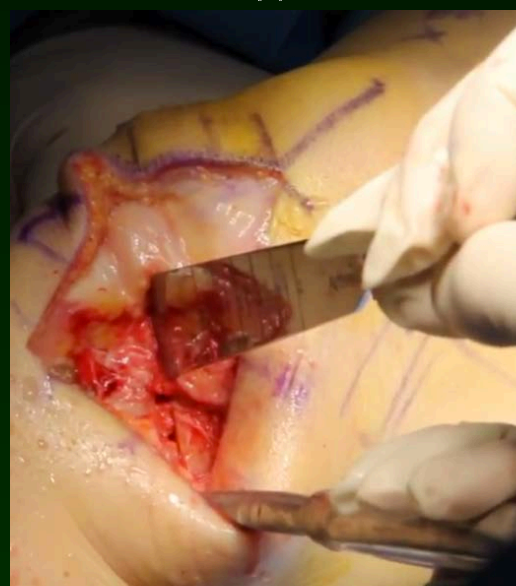
- Elevate entire insertion of superficial MCL from tibia to avoid over-tensioning ligament during correction
- Ensure proper placement of the guide pins → superior aspect of the trochlea can be marked using xray to assure that pin is not placed too distally
- Avoid violating the lateral tibial cortex
  - Use osteotome (instead of saw) to finish the cut
  - Use fluoroscopy to guide the bone cuts
- If lateral tibia cortex is fractured →
  - Fix with lateral sided plate and/or staples
  - Cut on inferior side of cutting guide and pins to avoid propagating the fracture into tibial plateau
- To maintain native sagittal slope → cortical hinge must be directly lateral
- An oblique metaphyseal osteotomy→ leads to more normalized sagittal tibial slope and patellar height
- Opening wedge HTO → increases tibial slope (~0.6°)
- Closing wedge HTO → decreases tibial slope (~0.7°)
  - Ducat *et al* 2012

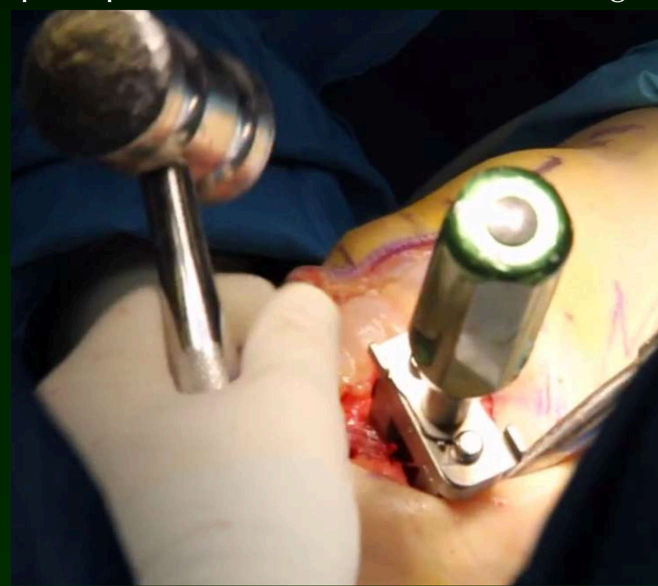

Incision and approach

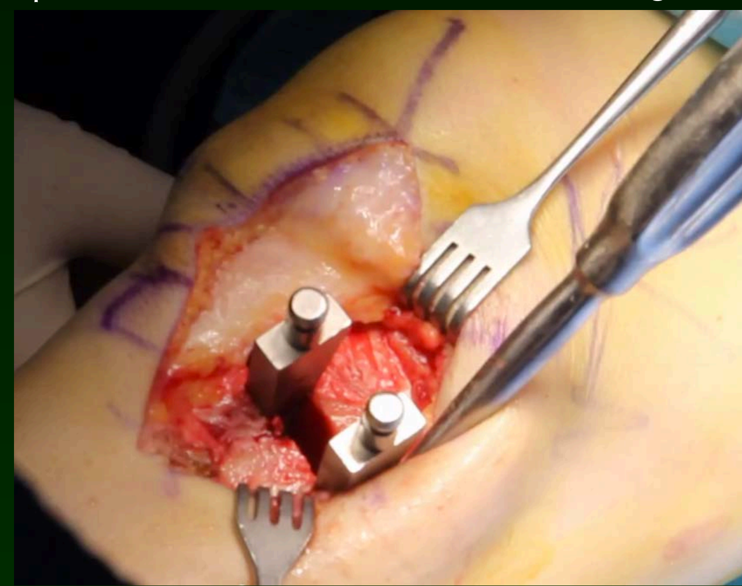

Expose proximal medial tibia


Drill guide pins x2

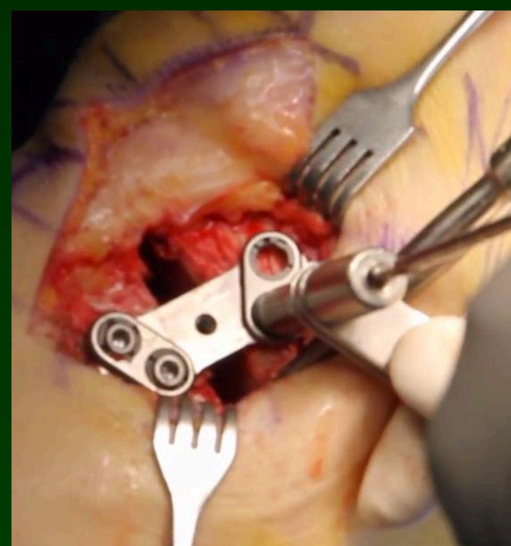

Cut with oscillating saw

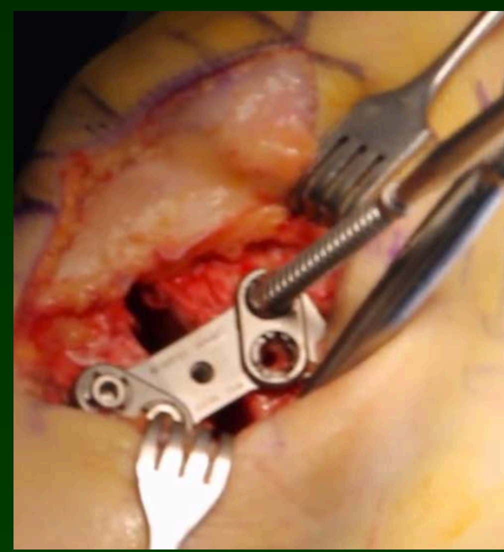
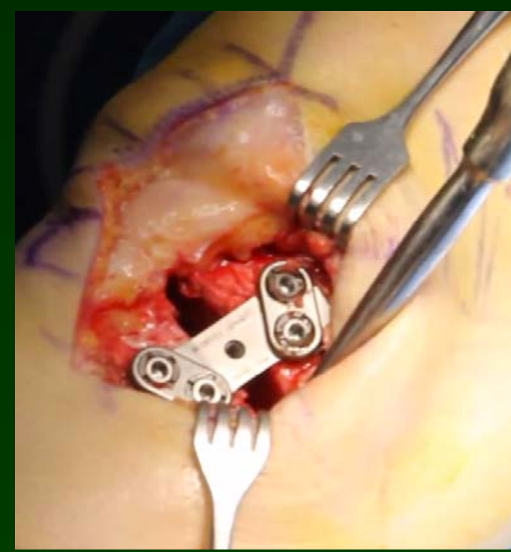

Finish cut with osteotome


Insert calibrated wedge into osteotomy site


Assess calibrated wedge position


Place angled plate


Drill for each screw



Insert screws (unicortical cancellous proximally; bicortical distally)

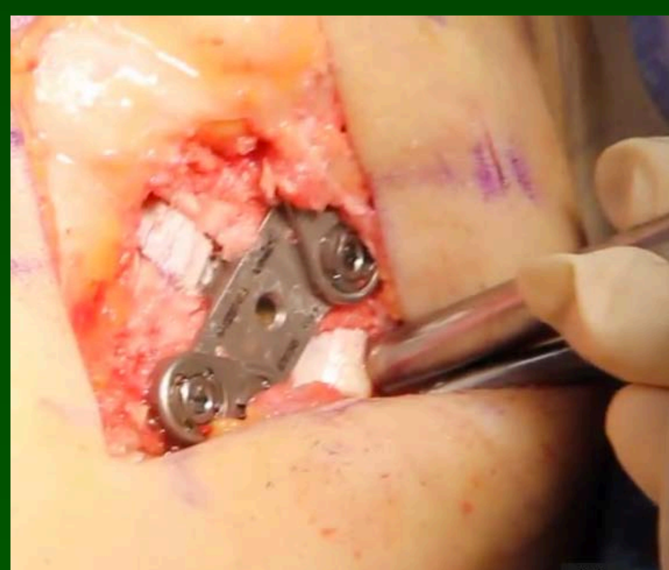

Fashion bone graft


Irrigate while using the saw


Assess graft cuts


Morselize graft and pack around plate


Assess plate position on XRay


Pack bone graft around plate


Final medial opening wedge HTO

Valgus Malalignment: *Distal Femoral Osteotomy*

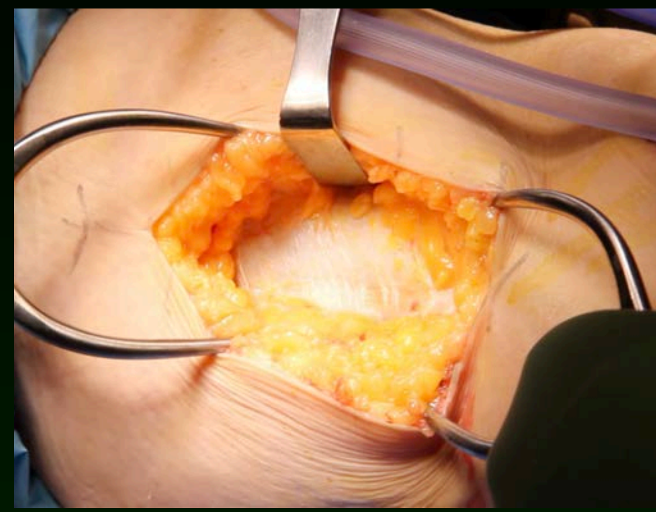
Lateral Opening-Wedge DFO:

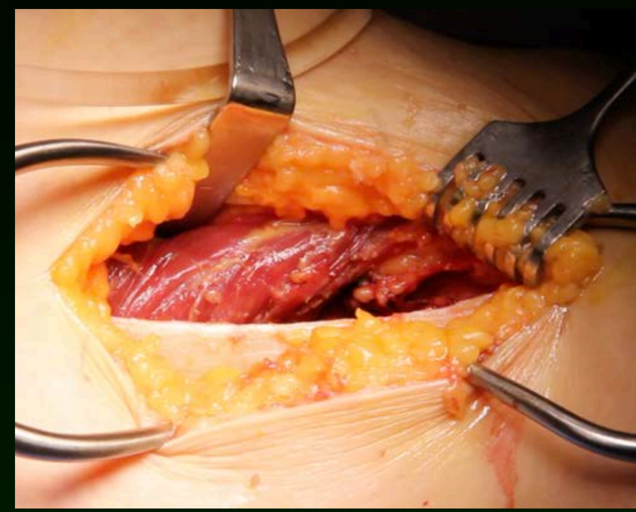
- **Approach →** 10cm longitudinal incision starting 2cm distal to lateral epicondyle, extending proximally in line with the femur
  - Cut IT band in line with its fibers
  - Retract Vastus Lateralis anterior
- **Guide pin insertion →**
  - Insert Hohmann retractor posterior to protect neurovascular structures
  - Starting at level of epiphysis, insert first pin parallel to the joint line from lateral to medial
  - Insert 2nd pin 3cm above lateral epicondyle, above trochlear groove, from proximal-lateral to distal-medial
- **Osteotomy cut and wedge insertion →**
  - With a cutting guide placed over the 2 pins, use an oscillating saw to cut the femur to within 1 cm of the medial cortex
  - Remove guide pins
  - Insert the calibrated wedge into the osteotomy site from the lateral side of the femur
  - Advance the wedge gently and slowly
    - Rapid insertion can cause a medial wall fracture
- **Plate fixation →**
  - Once correction is achieved, fix plate to femur
  - Proximal → bicortical 4.5mm screws (at least 3)
  - Distal → unicortical cancellous 6.5mm screws
  - Use fluroscopy to assess hardware placement
- **Bone graft →**
  - Insert bone graft on both sides of the plate
  - If using allograft, make sure to continuously irrigate the bone while using the saw

Pearls and Pitfalls:

- Goal is correct the angle between the anatomic axis of the femur and the mechanical axis of the tibia to 0-2° of valgus
- Ensure proper placement of the guide pins → superior aspect of the trochlea can be marked under fluoroscopy to avoid pin placement into the patellofemoral joint
- Avoid violating the medial femoral cortex
  - Use osteotome (instead of saw) to finish the cut
  - Avoid using thick osteotomes
  - Use fluoroscopy to guide the bone cuts
- If medial femoral cortex is fractured →
  - Fix with medial sided plate and/or staples
  - Cut on superiorside of cutting guide and pins to avoid propagating the fracture into patellofemoral joint
- Medial closing wedge DFO has reduced risk of nonunion, but requires 2 separate cuts for osteotomy

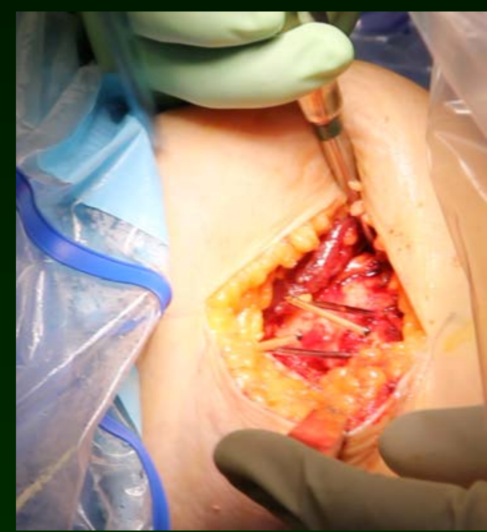

Incision and approach

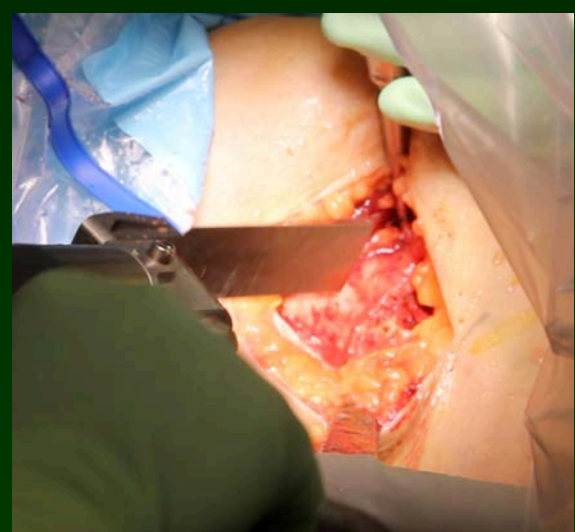

Split IT band in line with its fibers


Retract vastus lateralis anteriorly


Drill guide pins x2


Insert pins under xray from lateral to medial

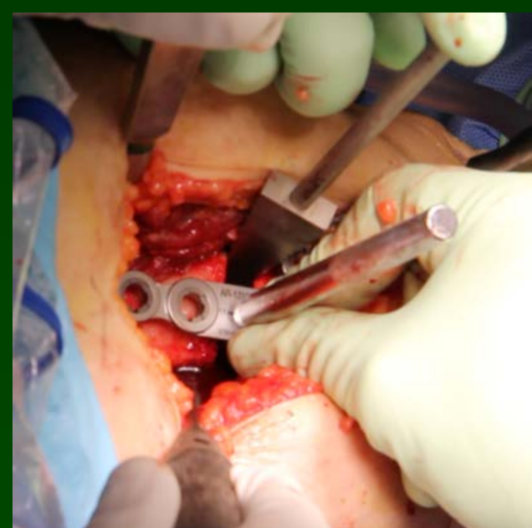

Expose lateral femur for cut

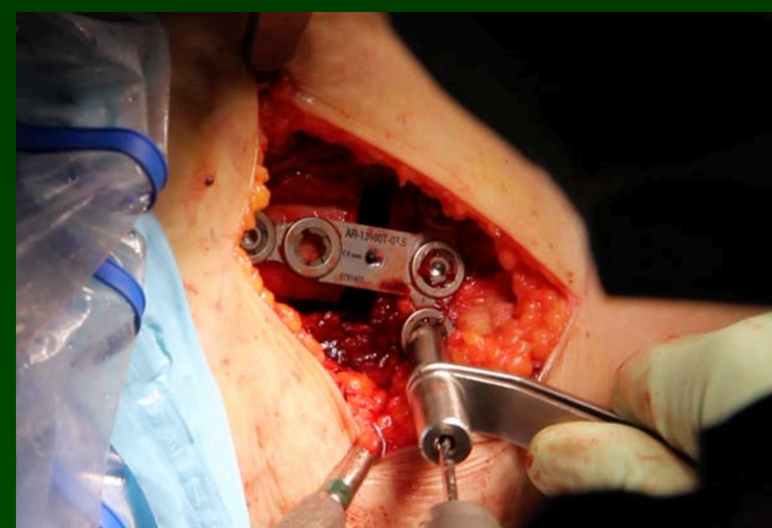

Cut with oscillating saw

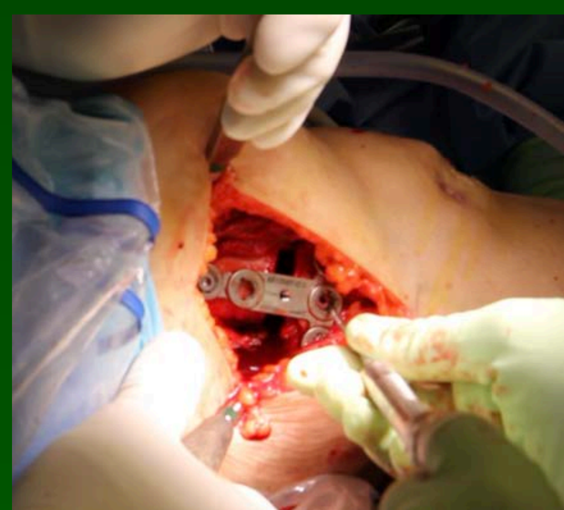

Finish cut with osteotome


Insert calibrated wedge into osteotomy site


Assess calibrated wedge position

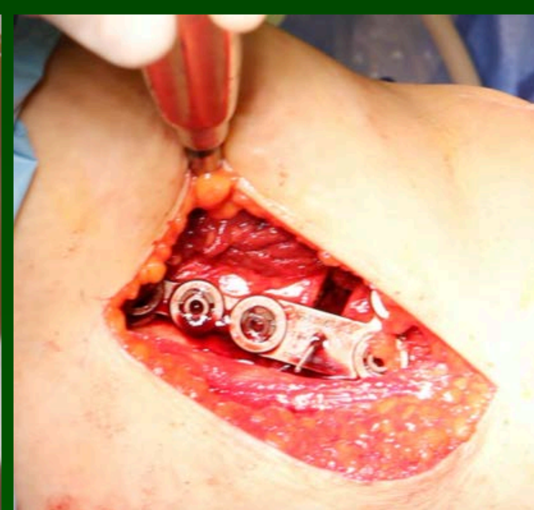

Place angled plate


Drill for each screw




Measure depth, then insert screws and place graft around plate


Assess position


Final lateral opening wedge HTO

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Concomitant Pathology Management

Osteochondral Allograft Transplantation

- Malalignment → risk factor for failure in patients undergoing isolated articular cartilage restoration procedure
- Unicompartmental articular disease may benefit from realigning osteotomy in addition to cartilage restoration to unload the involved compartment
- **KEY** → extend incision from allograft portion of procedure for the osteotomy portion

ACL Reconstruction (ACLR)

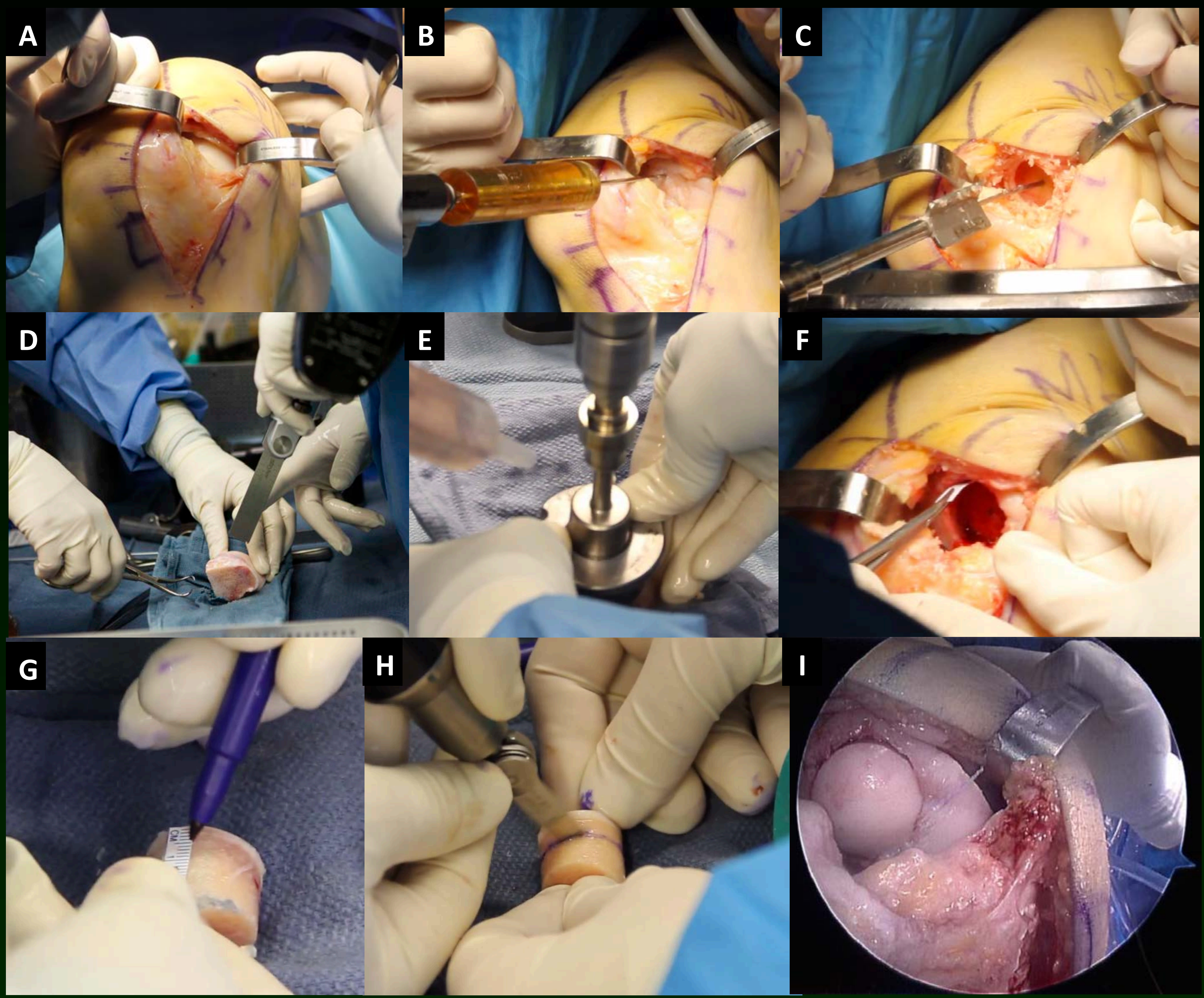
- Medial compartment overload may be implicated in certain cases of ACLR failure (Noyes *et al,* van de Pol *et al*)
- Patients undergoing revision ACLR may have more frequent varus malalignment and medial compartment articular disease (Won et *al,* Zaffagnini et *al)*
- ACLR with concomitant HTO may improve outcomes in select patients
- **KEY** → can use either bone plus or bridge-in-slot MAT construct, but bridge-in-slot more challenging in medial compartment due to intersection of bone bridge with tibia tunnel
- **KEY → must avoid unintentionally increasing posterior tibial slope** when performing concomitant opening wedge HTO, which increases strain within the ACL and may predispose to failure (Brandon *et al,* Ducat et *al,* Feucht *et al, McLean* et al)

Meniscus Allograft Transplantation (MAT)

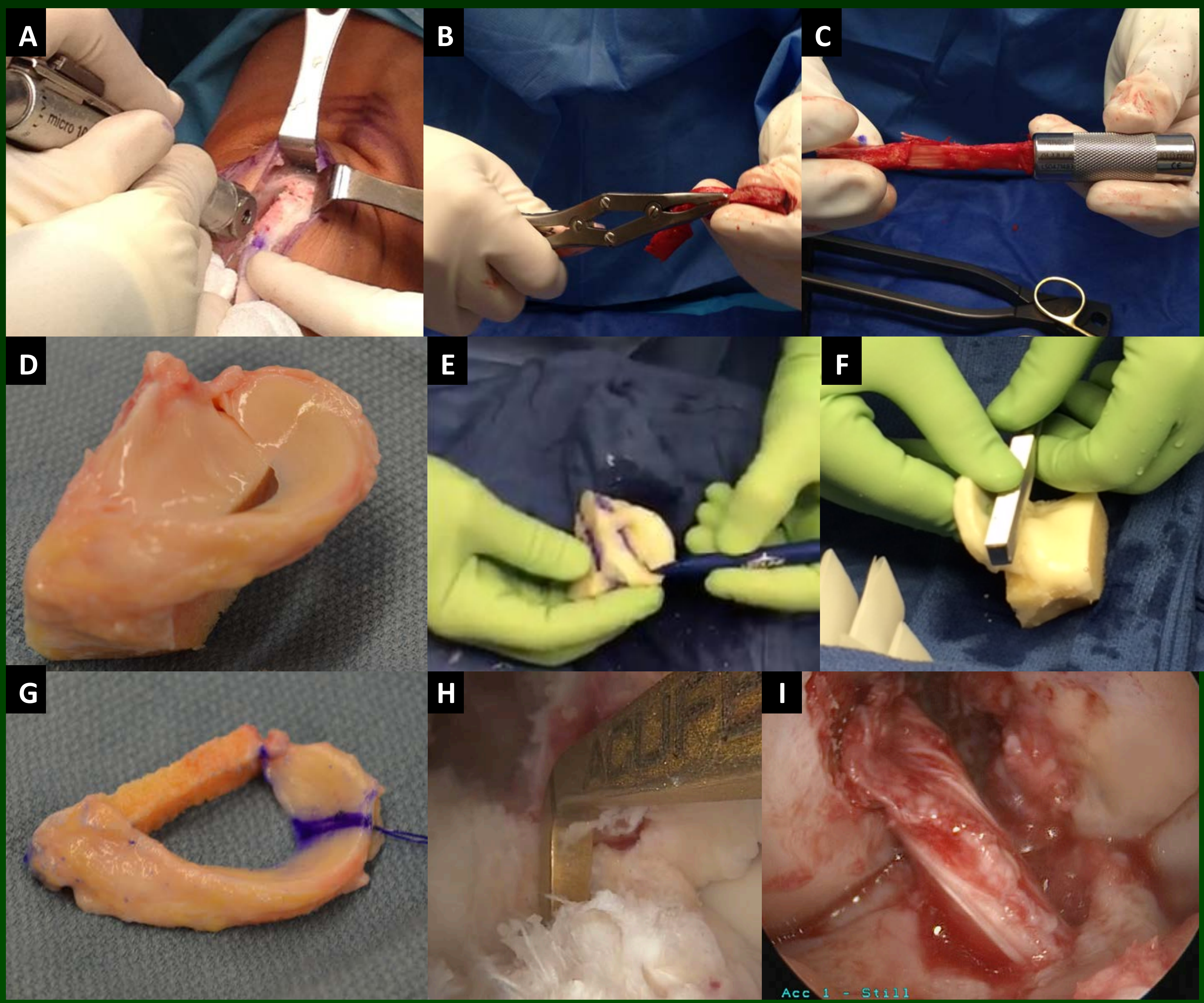
- Malalignment → known risk factor for failure in patients undergoing isolated MAT (Van Arkel et *al,* De Boer *et al,* Verdonk et *al)*
- HTO with medial MAT improves contact pressures and protects the transplanted meniscal tissue (Van Thiel *et al)*
- For neutral knees, correction to 3 degrees of mechanical valgus results in maximum benefit and realignment to varus improves contact pressures (Van Thiel *et al)*
- **MAT should be performed prior** to HTO because insertion of the meniscus requires significant varus and valgus stress that could compromise the osteotomy

Pearls

- First → ligament reconstruction (ACL, PCL) and MAT → can be performed concurrently and should be performed prior to osteotomy
- ***KEY*** → be sure **not** to tie down meniscus sutures at this time
- Second → articular cartilage restoration (osteochondral allograft transplantation, autologous chondrocyte implantation, microfracture, etc)
- Third → HTO or DFO
  - Osteotomy is last major step due to the significant valgus/varus stresses often required for the other procedures



Intraoperative photographs of a 28 year old male undergoing a right knee medial opening wedge HTO with concomitant medial femoral condyle osteochondral allograft transplantation. Shown here several aspects of the osteochondral allograft portion of the procedure: A) medial arthrotomy to gain exposure to medial femoral condyle, B) identification of medial femoral condyle full-thickness defect, and C) preparation of defect bed prior to measurement and transplantation of prepared allograft, D) allograft harvest from fresh femoral hemicondyle, E) sizing of allograft with circular saw, F) measurement of defect depth with ruler, G) measurement of allograft plug with ruler to confirm appropriate depth prior to cutting, H) creating appropriately sized allograft with sagittal saw, H) final allograft placement into medial femoral condyle



Intraoperative photographs of a 25yo female undergoing a right knee medial opening wedge HTO with concomitant medial MAT and ACLR utilizing bone patellar tendon bone autograft. Shown here several of the preparative steps for the ACLR and MAT portions of the procedure: A) patellar tendon autograft harvest, B) preparation of the bone plugs from the harvested graft, C) confirmation of the size of the bone plugs, D) fresh meniscus allograft with attached proximal tibia, E) measurement of bone slot for bridge-in-slot preparation of graft, F) confirming size of bone slot prior to cutting, G) prepared meniscal allograft prior to transplantation, H) arthroscopic photo demonstrating anticipated tibial tunnel placement, F) final arthroscopic appearance of patellar tendon allograft following ACLR

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Other Considerations

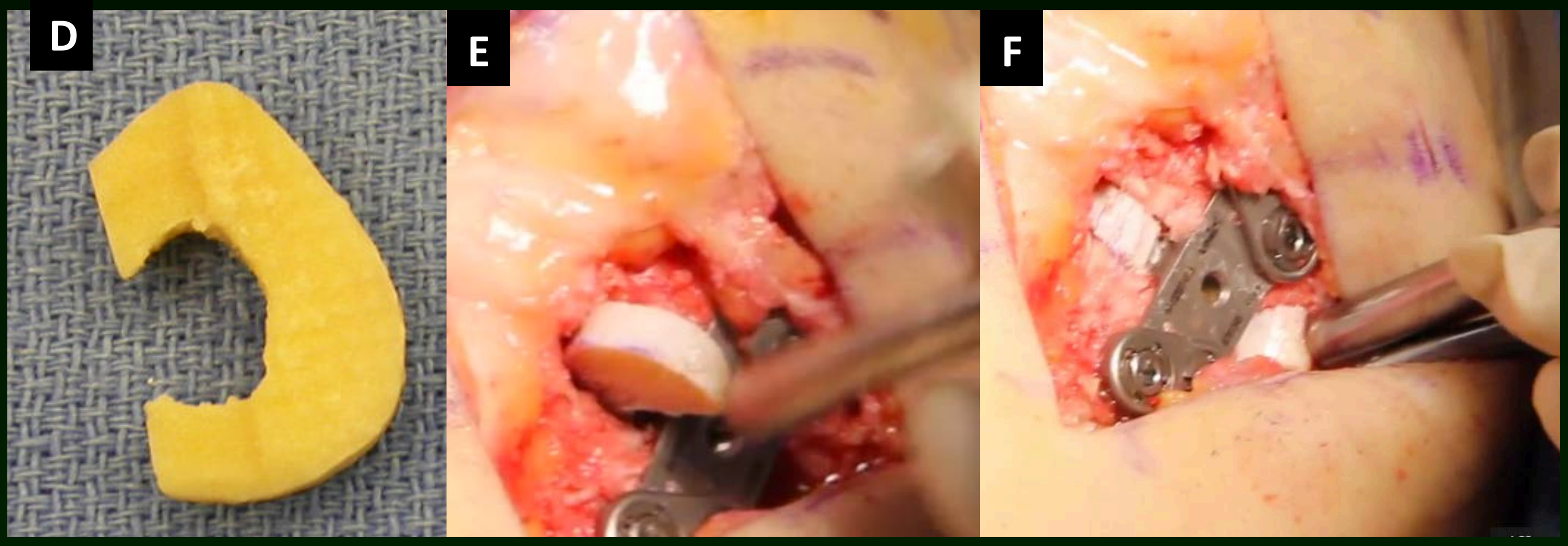
Bone Graft Options:

- Iliac Crest Bone Graft (ICBG) → most common autograft option; contains osteoprogenitor cells, BMPs, and growth factors; shown to have higher union rates compared to allograft (Lash *et al* 2015)
- Tricortical Iliac Crest Allograft → less structurally sound than ICBG but comparable efficacy to autograft without donor site morbidity; lower union rates than autograft, higher union rates than synthetic (Lash *et al* 2015)
- Corticocancellous Tibial Allograft → less literature but historically good results, average 12 weeks to union, no donor site morbidity (Yacobucci *et al* 2008)
- Cancellous allograft chips → longer time to union but less operative time, less morbidity related to graft harvest
- Synthetic Options → typically calcium and phosphate-based; similar porosity to cancellous bone to allow new bone formation
- Demineralized Bone Matrix (DBM) → reduces plate stress and lateral hinge stress, increases break load
- **PEARL → can usually allow weight-bearing at 8 weeks**
- **PEARL → union expected by 12 weeks**

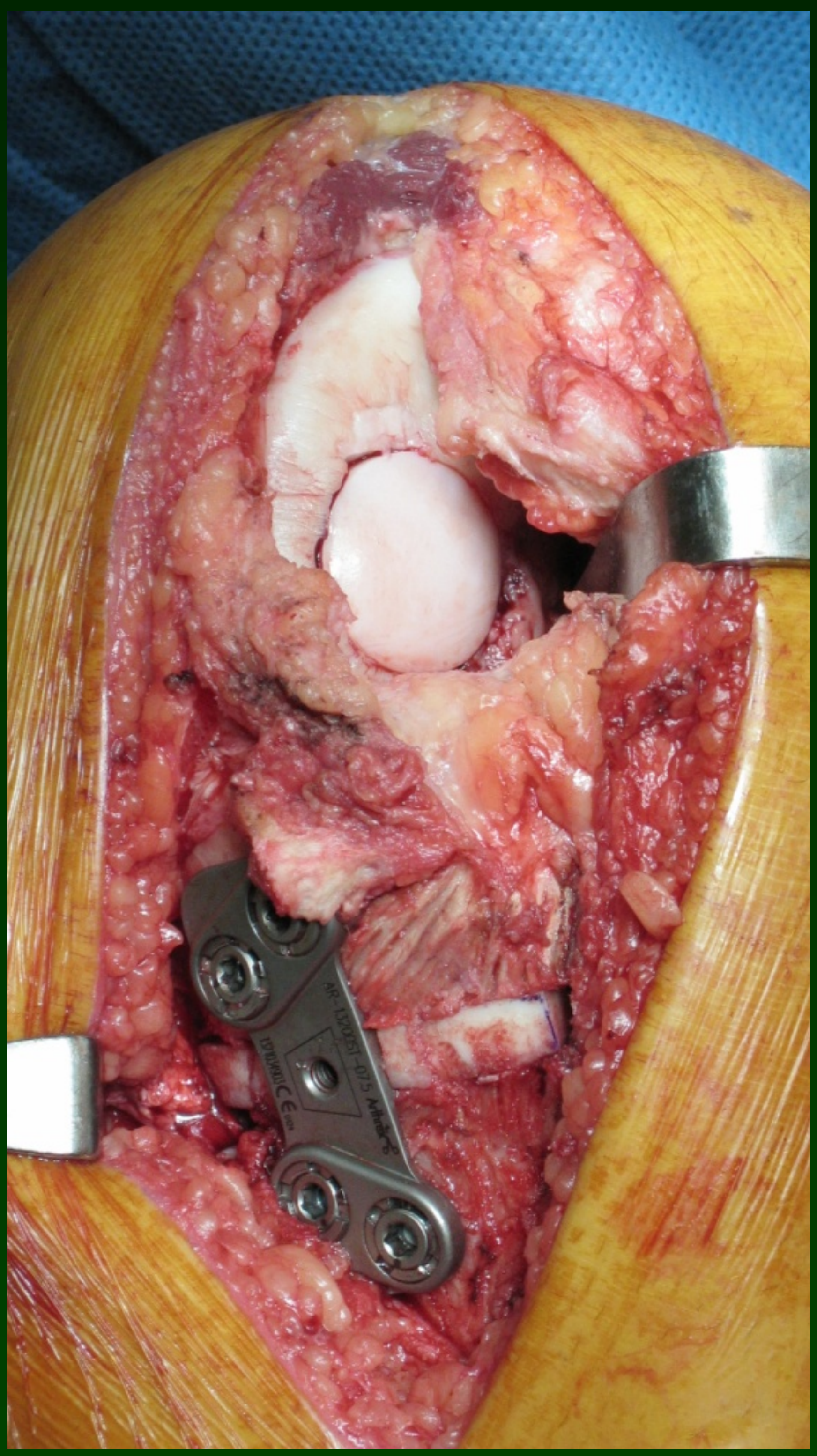
Addition of Biologics:

- Platelet Rich Plasma (PRP) and bone marrow aspirate have been described to augment osteotomy healing by increasing osteogenic potential of lyophilized bone chips (Savarino *et al* 2007, Wong *et al* 2013, Marmotti *et al* 2013)

Example of A) cancellous allograft chips filling in the defect site after medial opening wedge HTO (B and C)



Example of A) tricortical iliac crest allograft preparation and B) placement and C) impaction into the defect site after medial opening wedge HTO


Intraoperative photograph of a 31 year old female undergoing left knee medial opening edge HTO with concomitant medial femoral condyle osteochondral allograft transplantation

Clinical Outcomes:

- **2014 Cochrane Database Systematic Review** (Brouwer *et al* 2014) → 21 studies with 1065 patients
  - Valgus producing HTO → improves pain and function; no differences between osteotomy techniques
  - No support for/against osteotomy versus UKA or non-operative management
- **Osteotomy with articular cartilage restoration, MAT, and/or ACLR** → Excellent short and mid-term outcomes following isolated osteotomy and osteotomy with concomitant procedures (Harris *et al* 2013, Gomoll *et al*2009)
  - 56% reoperation rate, but low TKA conversion rate (6%) (Harris *et al* 2015)
- **Open versus closed wedge HTO** → No clinical or radiographic differences in patients without conversion to TKA at an average 6 years (Duivenvoorden *et al* 2014)
  - Opening wedge → increased complications
  - Closing wedge → increased TKA conversion
- **Medial opening wedge HTO** → Significant improvements in objective and subjective clinical outcomes at 3-5 years (LaPrade *et al* 2012, Bonasia *et al* 2014)
  - 80% survival rate at 7.5 years (Bonasia *et al* 2014)
- **Lateral opening wedge DFO** → Comparable survival to medial closing wedge DFO (74-92% at 5 years), but with relatively high reoperation rates, mostly due to hardware irritation (Saithna *et al* 2014, Cameron *et al* 2012)
- **HTO with ACLR for ACL deficient knees with medial compartment arthritis** → Systematic review of 11 studies with 218 patients → improvement in subjective and objective outcomes; predictable return to recreational sports (Li *et al* 2015)
- **HTO with ACLR for ACL deficient knees with varus deformity** → 6% failure rate at 6.5 years (Zaffagnini *et al* 2013)

Conversion to Arthroplasty:

- **Total Knee Arthroplasty (TKA)** → No difference in TKA outcomes in patients with versus without history of HTO (van Raaij *et al* 2009, Meding *et al* 2000)
- Technically more challenging than compared to primary TKA (Cerciello *et al* 2014)
- **Unicompartmental Knee Arthroplasty (UKA)** → significantly higher revision rate following HTO compared to primary UKA, thought to be due to progression of lateral compartment wear (Rees *et al* 2001)

Complications:

- 37% complication rate (Miller *et al* 2009)
- **Most common** → loss of correction
- Lateral cortex fracture →
  - Intraoperative
  - Postoperative
- Deep vein thrombosis
- Neurovascular injury
- Delayed union
- Nonunion
- Symptomatic hardware

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Disclosures:

The authors report no conflict of interest in the authorship or production of this exhibit.

FDA approval is not applicable to the results discussed in this study.

Full Disclosures: Frank, Tilton, Mellano, Erickson, Cvetanovich, Bush-Joseph, Bach: None; *Verma: advisory board of Smith and Nephew and Vindico Medical, royalties from Smith and Nephew, consultant for Smith and Nephew, research support from Arthrex, Ossur, and Linvatec; Cole: royalties from Arthrex and DJ Orthopaedics, consultant for Arthrex, DJ Orthopedics, Johnson&Johnson, Regentis, Zimmer, research support from Johnson&Johnson, Medipost, Zimmer, Stock in Carticept, Regentis*