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

Rachel M. Frank MD, Annie Tilton BS, Christopher Mellano MD, Brandon Erickson MD, Gregory Cvetanovich MD, Nikhil N. Verma MD, Charles A. Bush-Joseph MD, Bernard R. Bach Jr. MD, and Brian J. Cole MD MBA

Section of Sports Medicine, Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, IL
**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.
Diagnos)c 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

MUST assess for:
- Ligamentous instability
- Degree of malalignment
- Bone loss
- Patellofemoral symptoms
- Range of motion contracts
- 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

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

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
Preoperative 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 plateau
- 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

Example of Anticipated Correction

A) 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

B) 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

C) 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

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
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
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 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:**
- 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 superior side 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
Malalignment

Patients undergoing revision ACLR may have more medial compartment overload may be implicated in certain cases of ACLR failure (Noyes et al, van de Pol et al).

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).

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

Concomitant Pathology Management

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, I) final allograft placement into medial femoral condyle

Intraoperative photographs of a 25yo female undergoing a right knee medial opening wedge HTO with concomitant medial femoral condyle osteochondral allograft 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, I) final arthroscopic appearance of patellar tendon allograft following ACLR
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, increased bone 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 (Savario et al 2007, Wong et al 2013, Marmott et al 2013)

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 particular 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 (Saithia et al 2014, Carmichael et al 2014)
- 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
- Deep vein thrombosis
- Neurovascular injury
- Delayed union
- Nonunion
- Symptomatic hardware

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Intraoperative photograph of a 31 year old female undergoing left knee medial opening wedge HTO with concomitant medial meniscal cordyli osteochondral allograft transplantation

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

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