Malalignment: A Requirement for Cartilage and Organ Restoration

Alexander E. Weber, MD, Matthew E. Gitelis, BS, Mark A. McCarthy, MD, Adam B. Yanke, MD, and Brian J. Cole, MD, MBA

Abstract: The treatment of combined knee pathology is a challenging problem that requires careful attention to all aspects of the underlying disease. This is true of the interplay among malalignment and meniscal or articular cartilage restoration in the knee. Optimal outcomes are contingent on a comprehensive preoperative evaluation of patient-specific factors (patient expectations, patient age, and activity level), as well as disease-specific factors of the knee. Surgical intervention for meniscal or chondral deficiencies without attention to malalignment will lead to inferior outcomes. The focus of this review is to highlight the importance of malalignment correction when treating meniscal and articular cartilage pathology. This objective will be accomplished by outlining the approach to the preoperative evaluation, discussing the indications for surgical intervention, reviewing the preferred surgical techniques for correcting coronal malalignment of the knee, and providing a discussion of clinical outcomes.

Key Words: limb malalignment, knee cartilage restoration, allograft meniscal transplantation, high tibial osteotomy, distal femoral osteotomy

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Combined knee pathology poses a challenging problem that requires the caring surgeon to carefully consider all possible pain-generating pathology. Classically, in the knee, this is true of the interplay among malalignment, meniscal injury, articular cartilage pathology, and ligamentous instability. Each case requires a comprehensive preoperative evaluation of patient-specific factors (patient expectations, patient age, and activity level), as well as the aforementioned disease-specific factors of the knee.[1–4] Failure to surgically correct any one of the symptomatic knee pathologies will lead to inferior outcomes.[1–4] Medial meniscal deficiency or a medial femoral condyle defect in the setting of varus alignment is addressed with a concomitant high tibial osteotomy (HTO), whereas lateral meniscal deficiency or a lateral focal chondral defect in the setting of valgus malalignment is addressed with a concomitant distal femoral osteotomy (DFO). In either case, the osteotomy serves to offload the diseased compartment. The focus of this review is to highlight the importance of malalignment correction when treating meniscal and articular cartilage pathology. This objective will be accomplished by outlining the approach to the preoperative evaluation, discussing the indications for surgical intervention, reviewing the preferred surgical techniques for correcting coronal malalignment of the knee, and providing a discussion of clinical outcomes.

From the Department of Orthopaedic Surgery, Division of Sports Medicine, Rush University Medical Center, Chicago, IL.
Disclosure: The authors declare no conflict of interest.
Reprints: Brian J. Cole, MD, MBA, Midwest Orthopedics at Rush, 1611 W. Harrison Street, Suite 300, Chicago, IL 60612.

PATHOPHYSIOLOGY OF MALALIGNMENT

The anatomic axis of the lower extremity is measured along the long axis of the femur and the long axis of the tibia. The mechanical axis of the lower extremity is measured from the center of the femoral head to the center of the tibial plafond.[5] The difference between the anatomic axis and the mechanical axis results in the normal knee being in 3 to 5 degrees of valgus.[6] In addition, in the normal knee, approximately 60% of the weight-bearing force is transmitted through the medial compartment.[7] Malalignment of the lower extremity results in a redistribution of the weight-bearing loads. Varus or valgus malalignment preferentially increases the weight-bearing mechanical loads imparted on the medial meniscus and cartilage or the lateral meniscus and cartilage, respectively. The result of excessive load over time is meniscal and chondral damage, which ultimately increases the risk of unicompartmental degenerative joint disease.[8,9]

PREOPERATIVE EVALUATION

Patient Presentation

Patients presenting with concomitant malalignment and meniscal and/or chondral injuries often complain of unicompartmental knee pain. The history as it relates to knee pain is often described as a chronic course rather than any 1 specific inciting event. This speaks of the nature of malalignment and associated joint degeneration, which typically develops gradually over time. The pain should ideally be described at the joint line and may also be associated with swelling. Aside from the current symptoms, the timing and development of symptoms is also important. For instance, patients who undergo meniscectomy should ideally have a pain-free interval where they responded well to the surgery initially. This can be followed by slow progression of the described symptoms above. The exact nature of the previous treatment can also help dictate further cartilage restoration procedures, treatments such as microfracture may burn a bridge for cellular treatments like autologous chondrocyte implantation (ACI). Although not the focus of this review, one should also pay attention to previous failed ligamentous reconstructions that may be associated with instability, as these also need to be addressed.

Physical Examination

Complex knee pathology requires a detailed examination of the affected as well as the unaffected lower

TABLE 1. Comprehensive Physical Examination in Complex Knee Pathology

Categories	Examination
Inspection	Alignment
	Muscle bulk
	Prior surgical incisions
Palpation	Tenderness
	Crepitus (medial, lateral, patellofemoral)
Active and passive range of motion	Hip
	Knee
Strength	Core
	Lower extremity
Flexibility	Ober test
	Hamstring
Neurovascular examination	Bilateral lower extremity
Patellar examination	Tilt
	Apprehension
	J sign
	Static and dynamic Q angle assessment
	Crepitus
Knee tests of stability and special tests	Pivot shift, Lachman, anterior drawer
	Posterior drawer
	Varus and valgus stress (at full extension and at 30 degrees of flexion)
	McMurray, Thessaly
	Anteromedial rotary instability
	Posterolateral rotary instability

extremities. A comprehensive examination can be subdivided into gait analysis, alignment, limb inspection, soft tissue palpation, range of motion assessment, strength testing, and ligamentous stability (Table 1). Leg length discrepancy and gait assessment should be performed on each patient, with careful attention to the overall alignment and the presence or absence of a varus or valgus thrust. The inspection of previous surgical incisions is paramount for preoperative planning. Palpation of an effusion in the chronically symptomatic knee is likely to indicate cartilage pathology. Tenderness to palpation along the joint line with the knee at 90 degrees can be consistent with meniscal or chondral injury, whereas tenderness over the femoral condyles with the knee in flexion can indicate articular cartilage damage. Patients indicated for cartilage restoration procedures and realignment typically do not have limited knee motion; however, they may have developed quadriceps atrophy. Hip motion and strength should also be assessed to rule out referred symptoms.

Diagnostic Imaging

The first line of diagnostic imaging for the patient with complex knee pathology and physical examination confirmed that malalignment includes a standard weight-bearing radiographic series (anteroposterior, Rosenberg, lateral, and merchant views) and weight-bearing long-leg alignment views (Fig. 1). The standard radiographic series is used to evaluate joint degeneration and overall alignment. Measurements of the mechanical axis are documented on the long-leg radiographs (Fig. 2). The radiographs can also be evaluated for evidence of previous surgical procedures and existing hardware should be noted. Sizing radiographs are performed in allograft meniscal transplantation or osteochondral allograft transplantation candidates. Standardized sizing posteroanterior radiographs are performed weight-bearing with the knees flexed 45 degrees and the beam angled 10 degrees in the caudal direction. A calibration marker is placed at the level of the joint on the affected side. A lateral non–weight-bearing, sizing radiograph is also performed with the markers placed at the level of the patella and the joint line.

Magnetic resonance imaging is implemented to evaluate the soft tissues of the knee and the presence or absence of soft tissue fluid or joint effusion. The articular cartilage, menisci, and ligaments should be closely evaluated. Unicompartmental bone edema can be an indicator of chronic compartment overload. Meniscal volume can be assessed using the coronal and sagittal sequences; however, caution should be used in evaluating meniscal injury after a previous meniscal surgery. Gradient echo sequences are used to decipher articular cartilage from the surrounding joint fluid and subchondral bone; however, they are not able to identify intrasubstance cartilage defects. T2-weighted or short tau inversion recovery fluid sequences are used to evaluate internal signal within the cartilage or subchondral bone edema. Computed tomographic scans are a helpful adjuvant in the cases of previous anterior cruciate ligament reconstructions in which there is concern for bone tunnel enlargement. These scans can also help evaluate osseous overgrowth in the setting of a failed previous cartilage restoration procedure.

INDICATIONS AND CONTRAINDICATIONS FOR MALALIGNMENT CORRECTION

In cases where meniscal allograft transplantation (MAT) and/or osteochondral allograft transplantation is indicated, malalignment correction should be concomitantly performed if the mechanical weight-bearing axis crosses the knee in the affected compartment of planned surgical intervention. The general indications and contraindications for performing an osteotomy should also be considered (Table 2). Young, active patients who are willing to comply with the rehabilitation protocol are generally considered for osteotomy with allograft transplantation. Older, less active patients with unrealistic expectations may be contraindicated.

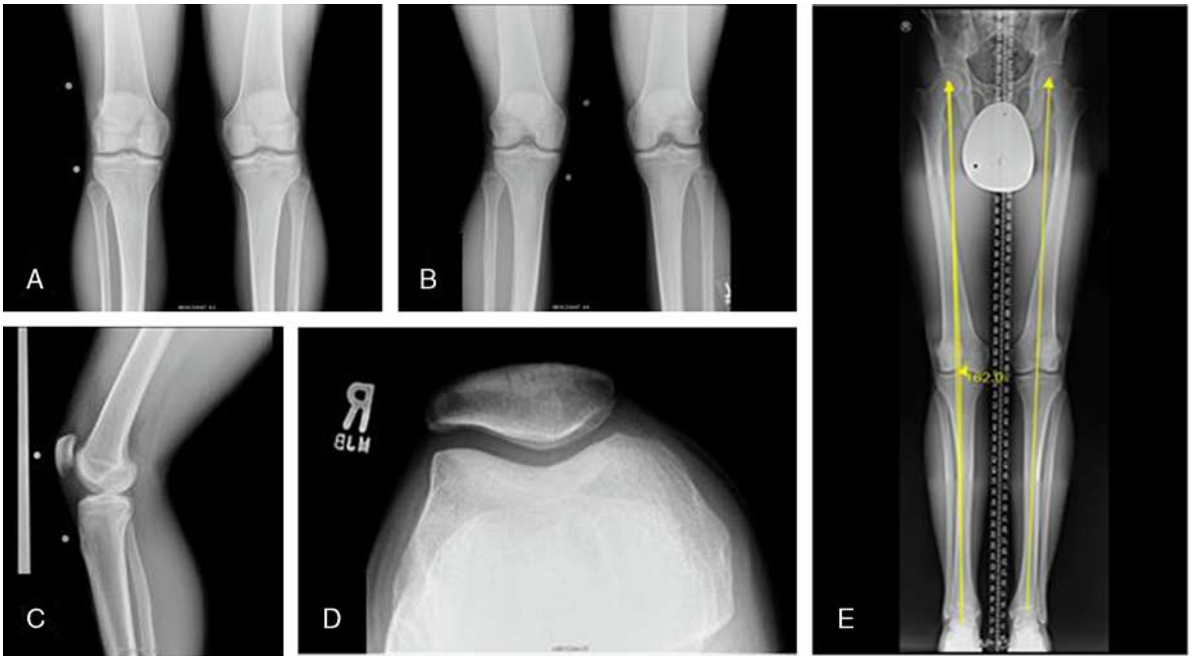

FIGURE 1. Standard knee series for knee pathology with malalignment. Anteroposterior (A), Rosenberg (B), lateral (C), merchant (D), and standing long-leg alignment (E) radiographs, demonstrating a right knee valgus deformity in a 20-year-old male patient.

PREOPERATIVE PLANNING

It is our standard of practice to ask any patient with previous surgical intervention on the affected knee to bring operative reports and arthroscopic pictures for preoperative planning purposes. In patients with combined knee pathology, careful attention must be paid to identify the injuries that are symptomatic and to delineate symptomatic from asymptomatic pathology before entering the operating room. In our experience, this is especially true for asymptomatic, incidentally identified chondral lesions.

Osteotomy correction with concomitant meniscal or osteochondral allograft transplantation is typically performed to the midline of the knee or to the opposite tibial spine.[10] This is in contrast to osteotomy correction for osteoarthritis, which is typically performed to a point 62% across the medial to lateral width of the tibial plateau for varus arthrosis.[11] For correction of coronal malalignment, the point of desired correction is identified on the long-leg anteroposterior standing radiographs and marked on the tibial plateau. A line is drawn from the center of the

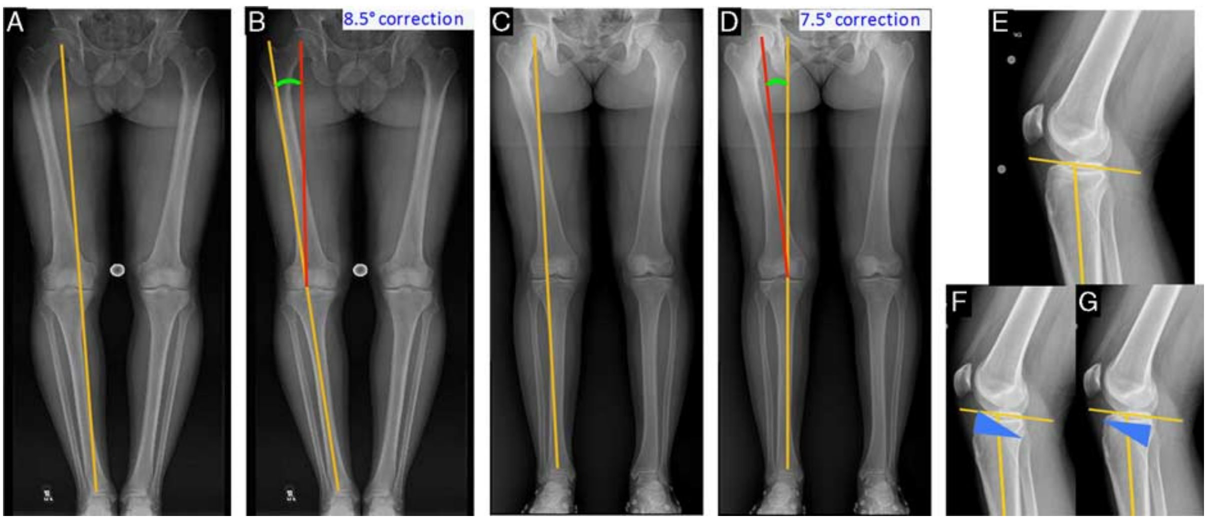

FIGURE 2. Preoperative planning for knee malalignment. A and B, Standing long-leg alignment radiographs of a 30-year-old man with a right knee varus deformity: weight-bearing axis (yellow line) passing medial to medial tibial spine (A), anticipated 8.5-degree correction with an high tibial osteotomy (B). C and D, Standing long-leg alignment radiographs of a 36-year-old woman with a right knee valgus deformity: weight-bearing axis (yellow line) passing lateral to medial tibial spine (C), anticipated 7.5-degree correction with a distal femoral osteotomy (D). E–G, Lateral radiograph demonstrating the ability of osteotomy to (F) increase tibial slope with spacer wedge placed anteriorly and (G) decrease tibial slope with spacer wedge placed posteriorly.

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TABLE 2. General Indications and Contraindications for Performing an Osteotomy

Indications	Absolute and Relative Contraindications
Age less than 60 y old	Tricompartmental arthritis
Symptomatic unicompartmental arthritis	Opposite compartment articular surface pathology
Malalignment with or without cartilage deficiency	Coronal deformity > 15 degrees
Malalignment with or without meniscal deficiency	Flexion contracture > 10 degrees
Normal, or correctable, ligamentous status	Baseline knee flexion < 90 degrees
Willing to comply with rehabilitation	Medial/lateral tibial subluxation > 1 cm
	Inflammatory arthritis
	Body mass index > 35 kg/m^2
	Smoker unwilling to quit

femoral head to the desired correction point on the tibial plateau. A second line is drawn from the center of the tibial plafond to the desired correction point. The acute angle formed by the bisection of these 2 lines is the degree of correction needed to bring the mechanical axis to the desired correction point (Fig. 2). Although outside the realm of this review, it is important to consider sagittal plane malalignment as well. Increasing tibial slope will improve the stability of the posterior cruciate ligament deficient knee, whereas decreasing tibial slope will improve the stability of the ACL deficient knee (Figs. 2, 3).[12–14]

SURGICAL TECHNIQUE

Overview

There are a number of periarticular plating systems available for stabilizing the osteotomy and the surgeon should be familiar with the instrumentation and setup before the case. A discussion should be carried out with the anesthesia team and the patient in regard to an anesthetic plan (general vs. regional). Intraoperative fluoroscopy is recommended to assess osteotomy position, alignment correction, and hardware placement. One option is to use a standard C-arm and a radiolucent table. To limit radiation to the patient and the surgical team, we prefer a mini C-arm. The mini C-arm is brought in from the ipsilateral side of the bed to facilitate surgeon manipulation for appropriate images. A tourniquet is routinely used; however, it should be let down to inspect for bleeding and assurance of hemostasis during the closure.

Medial Opening Wedge—HTO

After prepping and draping the operative leg free, pertinent landmarks and the planned incision are marked out (Fig. 4). In the setting of concomitant meniscal or cartilage procedures, those incisions are to be marked out as well. The typical HTO incision should be planned in a longitudinal manner halfway between the tibial tubercle and posteromedial aspect of the tibial metaphysis (Fig. 4A). Longitudinally the incision should begin 1 cm distal to the medial joint line and extend approximately 6 cm distally. The patellar tendon is dissected along its medial border, and is protected with a retractor. The pes anserinus and the superficial medial collateral ligament are raised subperiosteally in a posterior-based flap. Next, a Cobb elevator is used to gently elevate the soft tissues off the posterior cortex, and retractors are placed to protect the posterior neurovascular bundle (Fig. 4B).

Once exposure is complete, 2 parallel guide pins are placed under fluoroscopic guidance (Fig. 4C). The starting point should be 4 cm distal to the joint line, aiming proximally toward the tip of the fibular head. Next, the osteotomy is begun with a small oscillating saw (Fig. 4D). Note that the osteotomy should be placed inferior to the pins to help protect from potential propagation of fracture lines into the joint. The surgeon must ensure that the osteotomy extends anteriorly and posteriorly to include the cortex. Stacked osteotomes are then used, seated under fluoroscopic guidance, to 1 cm from the lateral cortex (Fig. 4F). Once the osteotomy can be mobilized

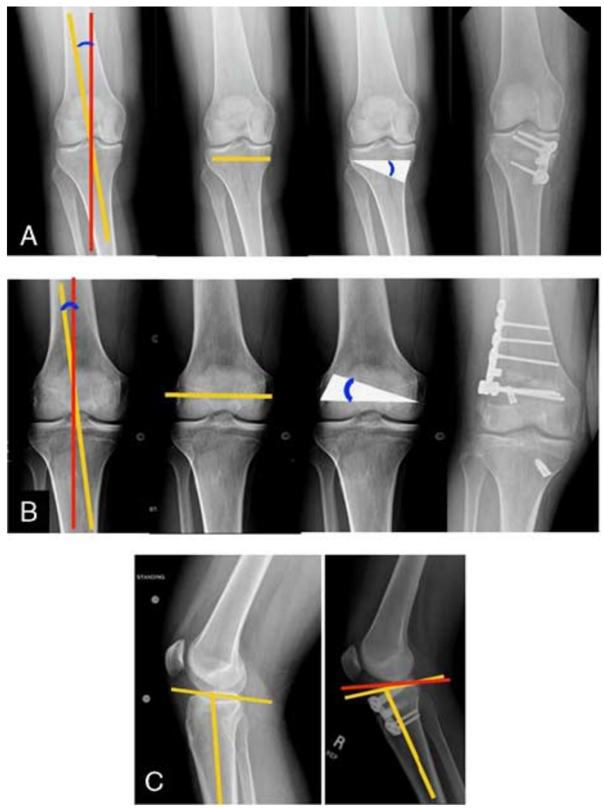

FIGURE 3. Examples of alignment correction. Examples of coronal plane and sagittal plane alignment correction. A, Demonstration of correction of varus deformity utilizing a medial opening wedge high tibial osteotomy (HTO). B, Demonstration of correction of valgus deformity utilizing a lateral opening wedge distal femoral osteotomy. C, Demonstration of a sagittal plane correction of tibial slope in a chronically posterior cruciate ligament deficient knee. The HTO plate is preferentially placed anteriorly to increase the posterior tibial slope, red line as compared with yellow line.

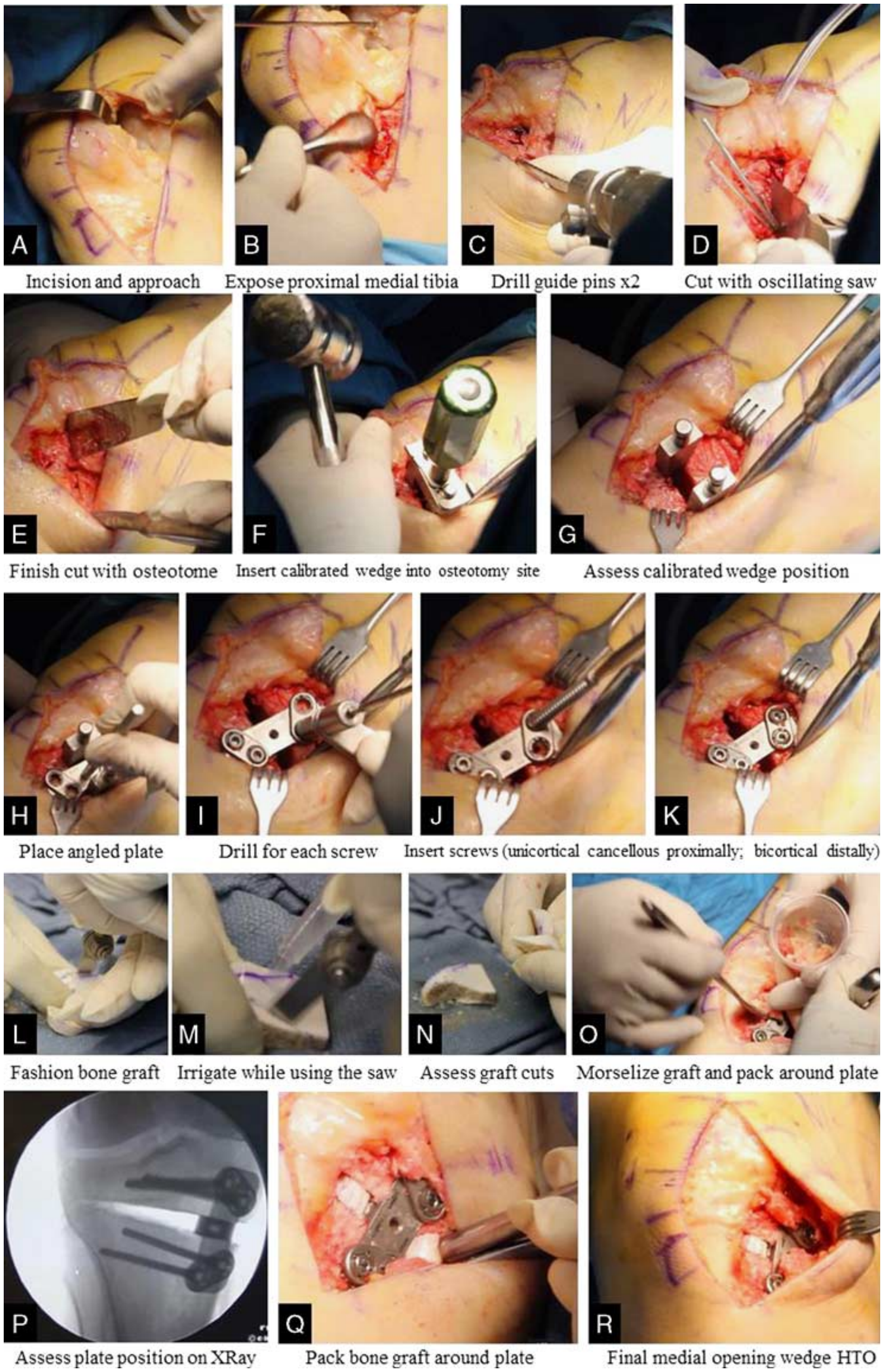

FIGURE 4. Varus malalignment corrected with high tibial osteotomy (HTO).

appropriately, anterior and posterior calibrated wedges are placed to the preoperative calculated height associated with the degree of correction (Fig. 4G). Although intraoperative alignment guides are inherently inaccurate, they can be used to grossly confirm correction of malalignment before osteotomy stabilization.

The anterior wedge is removed, and the osteotomy plate applied, ensuring that the corrective wedge on the plate is completely seated in the osteotomy site (Fig. 4H). For coronal plane correction, a posterior position should be sought to decrease incidental increase in posterior slope in the sagittal plane, which can propagate after surgery.[15]

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Screws are sequentially placed using fluoroscopy to ensure that no joint penetration or hardware complication has occurred (Figs 4J–K). If a concomitant osteochondral allograft is performed, wedges can be made from the left-over graft and placed in the osteotomy site. Otherwise, a combination of cortical and cancellous bone allograft chips can be used (Fig. 4O). With the osteotomy stabilized and grafted, the tourniquet is released to ensure that no vascular complications have occurred. Hemostasis is achieved and the incision is irrigated and closed in layers (Fig. 4R).

Lateral closing wedge HTO is also an option for correction of varus malalignment; however, it is not our preferred technique. An advantage of a closing wedge osteotomy is the large cancellous bone surface of the osteotomy which aides in osteotomy site healing. The major disadvantages include potential peroneal nerve injury, elevation of the tibial tubercle, loss of tibial bone stock, and the need for a fibular osteotomy. With proper surgical technique, both approaches have demonstrated comparable clinical results and complication rates in the literature.[16–19]

Lateral Opening Wedge—DFO

Patient positioning and operating room setup mirrors that of the HTO in the authors practice (see previous section) (Fig. 5). The planned incision is marked out on the lateral thigh beginning 2 to 3 cm distal to the lateral femoral epicondyle and extending proximally 12 to 15 cm. The skin is incised and the subcutaneous tissues are dissected to the iliotibial band (Fig. 5A). The iliotibial band is incised in-line with the skin incision (Fig. 5B). Care is taken to incise only the tendinous portion of the iliotibial band and not the vastus musculature deep to it. The vastus lateralis is bluntly elevated anteriorly off the posterior intermuscular septum (Fig. 5C). Cautery is used to coagulate any large femoral perforating vessels as they are encountered. Once the distal femur is exposed, retractors are carefully placed anteriorly and posteriorly to protect the soft tissue and neurovascular bundle, respectively.

Once the exposure is complete, the knee is extended and under fluoroscopic guidance a guidewire is inserted mirroring the trajectory of the osteotomy. The appropriate guidewire starting position is 2 cm proximal to the lateral epicondyle, aiming distally toward the proximal aspect of the medial epicondyle. A second guidewire is placed parallel to the first (Figs 5D–E). A small oscillating saw is used to initiate the osteotomy on the lateral cortex (Fig. 5H). Again, cutting proximal to the parallel pins, further from the joint surface, decreases the likelihood of stress-riser propagation into the articular surface. The saw is followed by osteotomes in a stacked manner to a depth of 1 cm from the medial cortex. Calibrated anterior and posterior wedges are placed to the planned preoperative level of correction (Fig. 5J). The anterior wedge is removed and the plate is placed in the osteotomy site and secured with sequential screws (Figs 5L–O). Care should be taken to ensure that the plate wedge is secured in the osteotomy site (Fig. 5P). Cortical and cancellous allograft can be used in the osteotomy site. The tourniquet is released and hemostasis is achieved. The wound is then irrigated and closed in a standard layered manner (Fig. 5Q).

Postoperative Care

Osteotomies with concomitant MAT and/or cartilage restoration procedures are performed as an outpatient procedure at our institution. However, these procedures can be long in duration and an overnight stay is reasonable. At the conclusion of the sterile dressing, patients have a cooling unit incorporated into the dressing and a hinged knee brace locked in extension placed on the operative leg. The weight-bearing status is dictated by the concomitant procedures; however, 4 to 6 weeks of non–weight-bearing is customary. For isolated osteotomies, with newer locking plate technology, early weight-bearing may be appropriate but at the surgeon's discretion. The range of motion is encouraged in the early postoperative period. Progressive weight-bearing begins at 4 to 6 weeks with a goal of full weight-bearing without a brace at 8 to 10 weeks.

DISCUSSION

When the proper indications are used, isolated osteotomies have the ability to predictably prolong the life of the native knee for up to 10 to 15 years.[18,20–22] Newer techniques and instrumentation have improved the outcomes and patient satisfaction. The long-term lack of activity restrictions after an osteotomy makes this an ideal surgery for the young, active patient with the goal of returning to high-level activities. Osteotomies have also been impactful on the young, active patient with meniscal or cartilage injuries.[1–4,23–30] There is a subset of patients with meniscal or cartilage deficiencies who would otherwise be contraindicated for allograft transplantation if it were not for the correction of malalignment. For this reason, concomitant osteotomy and cartilage and/or meniscus restoration procedures are increasing in frequency. The increase in frequency in which these procedures are being performed is grounded in sound biomechanical data.[31] Van Thiel et al[31] performed a biomechanical study evaluating the effects of HTO on the peak pressures of the medial compartment in the setting of MATs. The authors found that, in a cadaver model, correcting varus alignment with an HTO significantly decreases the contact pressures in the medial compartment. Furthermore, the largest decrease in medial compartment pressure occurred between neutral alignment and 3 degrees of valgus, suggesting a benefit to consider HTO with concomitant medial meniscal transplant in the neutrally aligned knee. Unloading the medial compartment from neutral to 3 degrees of valgus may significantly decrease the peak pressures on the transplant and potentially lead to increased survival of the graft.[31] In addition, biomechanical and animal studies have demonstrated the benefits of off-loading cartilage restorative procedures.[32–34] Agneskirchner et al[32] performed a cadaveric study examining the contact pressures on the medial and lateral chondral surfaces of the knee and found that valgus-producing HTO significantly decreased the peak contact pressures on the medial compartment chondral surfaces. Mina et al[34] used a similar cadaveric model to demonstrate the beneficial effects of an HTO on both the contact pressures and the area of osteochondral defects in the medial compartment.

The biomechanical data suggesting the efficacy of combined malalignment correction concomitantly with meniscal and cartilage restoration has been corroborated with clinical studies (Table 3).[1–4,23–30] It is difficult to compare knee restorative procedure success between the neutral-aligned patient and the patient with malalignment because of the increased complexity of knee pathology with the inclusion of malalignment. However, clinical studies suggest that combined osteotomy with meniscal transplantation or

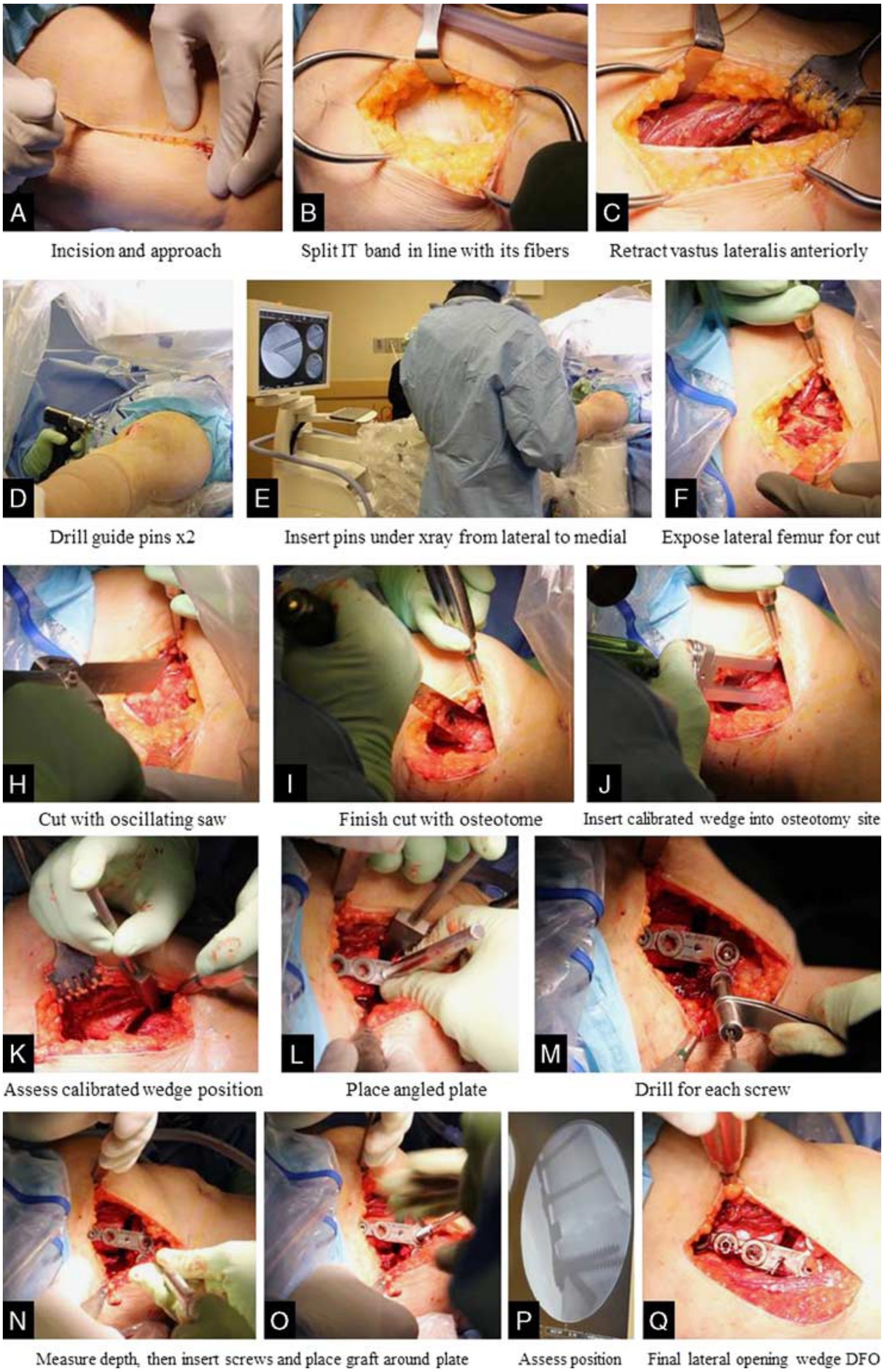

FIGURE 5. Valgus malalignment corrected with distal femoral osteotomy (DFO).

cartilage restoration (microfracture, ACI, osteochondral allograft, or osteochondral autograft) can lead to comparable results with those achieved for isolated MAT or cartilage restoration.[23–26,28–30,36] Kazi et al[23] recently reported the largest series to-date of MAT with concomitant osteotomy. The authors found that there was comparable survival for MAT combined with osteotomy, when malalignment was present, as compared with isolated MAT in the neutral-aligned cohort.[23] In 2014, Harris et al[24] examined a cohort of patients with lateral focal chondral defects and found that addressing the cartilage defect in combination with malalignment (DFO) and meniscal deficiency (MAT) lead to

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TABLE 3. Clinical Outcomes of Concomitant Osteotomy and Cartilage Restoration and/or Meniscal Allograft Transplantation

References	Cohort Size	Biological Knee Procedure	Type of Osteotomy	Average Follow-up	Results/Conclusions
Kazi et al[23]	85	MAT	HTO, DFO	15 y	Concomitant osteotomy in 53 patients. Survivorship comparable between isolated MAT and combined MAT/osteotomy
Harris et al[24]	35	MAT, cartilage restoration (MFx, ACI, OATS, OA graft)	DFO	2 y	Results with concomitant DFO comparable with cartilage restoration alone No conversions to TKA
Bode et al[35]	43	Cartilage restoration (ACI)	HTO	6 y	For MFC focal chondral defects in varus (1-5 degrees), ACI + HTO leads to greater survival than ACI alone
Minzlaff et al[27]	86	Cartilage restoration (OATS)	HTO	7.5 y	Significant improvements in Lysholm and VAS scores after combined OATS and HTO. 90.1% survival at 8.5 y
Harris et al[25]	4557	MAT, cartilage restoration (MFx, ACI, OATS, OA graft)	HTO	Up to 20 y	Isolated and combined HTO with MAT or cartilage surgery provide excellent survival and clinical outcomes at 10 y
Pascale et al[26]	40	Cartilage restoration (MFx)	HTO	5 y	Patient satisfaction was higher among patients who underwent combined HTO/MFx vs. isolated HTO. Both groups demonstrated improved outcomes at 5 y postoperative
Sterett et al[28]	106	Cartilage restoration (MFx)	HTO	7 y	Combined MFx and HTO had 91% survivorship at 7 y
Gomoll et al[1]	7	MAT, cartilage restoration	HTO, DFO	2 y	6/7 returned to unrestricted activity 7/7 increased function Combined MAT/cartilage/osteotomy is an activity increasing surgery
Farr et al[3]	29	MAT, cartilage restoration (ACI)	HTO	2 y	6 subjects had combined MAT/ACI/HTO with comparable results to MAT/ACI
Verdonk et al[29]	27	MAT	HTO	10 y	83.3% survival for combined MAT/HTO vs. 74.2% for MAT only
Cameron and Saha[30]	67	MAT	HTO	2.5 y	34 knees with MAT/HTO demonstrated comparable results to isolated MAT

ACI indicates autologous chondrocyte implantation; DFO, distal femoral osteotomy; HTO, high tibial osteotomy; MAT, meniscus allograft transplantation; MFx, microfracture; OA, osteoarthritis; OATS, osteochondral autograft transfer system; TKA, total knee arthroplasty.

comparable clinical outcomes at 2 years as compared with isolated cartilage procedures.

In addition, clinical studies have demonstrated that failure to address alignment in the setting of surgical intervention for cartilage and meniscal insufficiency will lead to inferior clinical outcomes and survival of transplanted tissue.[2,4,23,29,35] The controlled laboratory study by Van Thiel and colleagues on the implications for a MAT with compartment overload has been clinically exemplified by Verdonk et al[29] who examined the results of their medial MAT with and without HTO. Although their results are some of the earliest long-term clinical outcomes, they found that the medial MAT with HTO had significantly greater improvements in the modified HSS score as compared with the medial MAT without HTO.[29] In terms of cartilage restoration, there may be no better example of the effects of malalignment than a recent study by Bode et al.[35] Bode and colleagues prospectively enrolled 43 patients with varus malalignment between 1 and 5 degrees and concomitant medial femoral condyle focal chondral defects. Half of the cohort had their chondral defects treated in isolation with ACI, whereas the other half of the cohort had ACI with a concomitant HTO. At follow-up of approximately 6 years, the group with combined ACI/HTO had significantly higher survival and a trend toward improved clinical outcomes. Combined procedures also lead to decreased reoperation rates.[35]

CONCLUSIONS

The treatment of combined knee pathology is a challenging problem that requires careful attention to all aspects of the underlying disease. This is true of the interplay among malalignment and meniscal or articular cartilage loss in the knee. Malalignment was initially considered a contraindication to MAT or cartilage restoration. Now, through a combined approach, patients previously contraindicated for the aforementioned procedures can undergo concomitant osteotomy. The results and survival of such combined procedures are comparable with restorative procedures in the neutrally aligned patient. Furthermore, performing restorative cartilage and meniscal procedures in the setting of malalignment, without correction of alignment, lead to inferior survivability and clinical results. Treatment of combined knee pathology requires a comprehensive clinical examination to identify pain-generating pathology, a discussion of patient expectations, and proper surgical technique.

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