Role of osteotomy in multiligament knee instability

Anshu Shekhar[1], Anoop Pilar[1], Sachin Tapasvi[1]

Abstract

Alignment of the lower limb (coronal, sagittal and axial) has a significant effect on knee stability in a multiligament injured knee. This malalignment can be due to a pre-existing condition like tibia vara, an abnormal tibial slope, a malunited intra articular fracture with ligament injury, or can develop later in a neglected case of instability. Restoration of limb alignment is one of important factors to restore the stability in these patients. The importance of performing an osteotomy in a ligament-deficient knee is to further prevent the articular cartilage wear, to protect the graft(s) from abnormally high stress, to restore stability and to restore geometry. Thus, an osteotomy has a more profound bearing in restoring knee laxity and reducing graft stress after any soft tissue reconstruction. An osteotomy can be performed either alone or with simultaneous ligament reconstruction, or as a staged procedure. This review analyses the importance of lower limb alignment, its impact on knee ligamentous stability, decision making and planning for an osteotomy and briefly discuss technical aspects of performing an osteotomy.

Keywords: Knee dislocation, Ligament injury, Osteotomy, Instability, Malalignment

Introduction

Ligamentous injuries of the knee can have a profound impact on knee biomechanics and alter load distribution, leading to secondary consequences. However, when such injuries exist with abnormal bone morphology, the problem gets compounded. This abnormal bone morphology may occur in three settings: (a) a pre-existing condition like tibia vara or abnormal tibial slope; (b) a malunited intra/extra articular fracture (as in KD V) (c) neglected instability leading to osteoarthrosis. This review analyzes the importance of lower limb alignment, it's impact on knee ligamentous stability, decision making and planning for an osteotomy and briefly discuss technical aspects of performing an osteotomy.

The Importance of Alignment

The normal mechanical alignment of the lower limbs is such that the hip, knee and ankle joint centers are in one straight axis in the coronal plane. The weight bearing axis or Mikulicz line passes the knee in between the medial and lateral tibial spines in the coronal plane, in what is called the neutral alignment. A medial deviation of the Mikulicz line by 15 mm is defined as varus, while a lateral deviation by 10 mm is a valgus of the knee [1]. This may however, not always be the case since a significant number of patients have a "constitutional varus" wherein the mechanical axis is in 3^0 or more of varus (Fig. 1). In the cohort of Bellmans from Belgium, this rate was 32% in males and in 17% females [2]. An even higher percentage of constitutional varus (20%) has been reported in females in Asia [3]. Further, this constitutional varus alignment has been found to be associated with increased physical activity like intensive football training during growth phase, varus femoral bowing, more varus neck-shaft angle and higher femur anatomic mechanical angle [2,4].

The knee joint is a large and complex joint with peculiar biomechanics due to its large lever arm. The long femur proximally and long tibia distally create large loading moments at the knee. The axial force through the knee is about three times the body weight when walking on even ground and about four times when climbing stairs [5]. During the stance phase of gait cycle, the loaded hip and tibia are in adduction in the coronal plane due the central positioning of the foot. This creates an adduction moment at the knee. This causes the force vector generated from the ground reaction force to pass through the medial compartment of the knee and the lateral compartment to get transiently off-loaded [6]. Medial overload can have deleterious consequences for the cartilage, leading to its breakdown, and leads to the onset or progression of osteoarthritis. The rate of cartilage breakdown has direct correlation with the peak adduction moment at the knee during gait [7]. Once the cartilage degeneration starts, increasing varus accentuates the adduction moment, setting in motion a vicious cycle where greater loading further increases chondral wear [6]. The concepts of primary, double and triple varus were proposed by Noyes. Primary varus deformity is an abnormality of the tibiofemoral geometry only, with some contribution from a deficient medial meniscus or articular cartilage. A double varus deformity is an exaggerated deformity due to stretching out of the lateral collateral ligament, causing lateral joint opening. A superadded external rotation and hyperextension deformity due stretching out of posterolateral corner (PLC) structures is called a triple varus deformity [8]. The adduction moment at the knee is countered primarily by structures of the posterolateral corner. The fibular collateral ligament, popliteus, popliteofibular ligament and to some extent even the cruciate ligaments, stabilize the knee from abnormal or increased varus opening. A varus deformity increases tensile forces on the lateral structures, causing them to stretch out over a period of time, as is commonly seen in severe varus osteoarthritic knee. Consequently, a posterolateral

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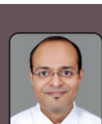
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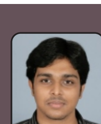
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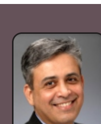
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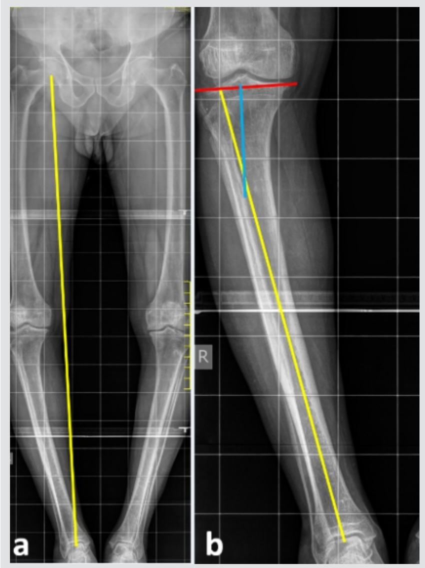


Figure 1: (a) Anteroposterior scanogram of a patient with varus deformity of the knee, the Mikulicz line (yellow) is passing the knee joint medial to its center. (b) The anatomic axis of tibia extended proximally from the center of ankle joint (yellow line) usually ends between the tibial spines, because the anatomic and mechanical axes are the same in tibia. In this case, the line ends lateral to the lateral spine. The knee joint line (red) is drawn and a perpendicular to this (blue line) bisects the anatomic axis (yellow line). This angle thus formed (12^0 in this case), is the degree of constitutional varus. The varus deformity in this patient is thus, primarily metaphyseal in the tibia.

reconstruction in a varus knee is likely to fail due to the increased forces on the reconstructed ligaments [9]. A similar situation is possible if the knee is in valgus and an MCL reconstruction is performed without tackling the mal-alignment first. This scenario is rare, because the knee has an adduction moment and the valgus must be severe to cause this effect [10].

In the sagittal plane, the proximal tibia slope or the posterior distal femur angle can have powerful effects on the knee kinematics or range of motion. The normal tibia slope is between 7^0-10^0. A high proximal tibial slope can cause the tibia to sublux anteriorly. Griffin has demonstrated that increasing the slope by 4^0 results in 3 mm anterior translation of the tibia [11]. In contrast, reducing the slope would protect the anterior cruciate ligament (ACL) but increase stress on the posterior cruciate ligament (PCL). Also, reducing the slope can cause hyperextension of the knee which not only stresses the PCL, but also causes loading of the patellofemoral joint during gait. The posterior distal femur angle (PDFA) can be altered after a mal-united Hoffa's fracture of the femur. A flexion deformity which reduces the PDFA can cause loss of extension of the knee. The resultant flexion deformity increases energy expenditure for quadriceps contraction to prevent from buckling and results in fatigue [12].

When the deformity is within 3^0 compared to the contralateral normal knee, only a soft tissue reconstruction is sufficient. However, deformity in any plane greater than 3^0 warrants an osteotomy to correct the alignment, while taking in to account the role of ligamentous laxity in the overall mal-alignment [10]. A varus or valgus mal-alignment in the coronal plane or an abnormal slope in the sagittal plane can thus, cause significant alteration of biomechanics during gait. There are therefore, three goals of an osteotomy in an unstable knee: (1) to prevent further unilateral compartment deterioration in a knee that is demonstrating signs of articular cartilage wear (2) to protect the graft(s) from abnormally high stress in a mal-aligned knee, and (3) to help restore stability.

How a Realignment Osteotomy works in an unstable knee

Recent biomechanical studies and clinical experience have helped us understand the influence of sagittal and coronal plane malalignment on knee stability. A caveat applies that this knowledge is mostly from single ligament studies, whereas multiligament injuries are more complex and extrapolation of such data must be done with caution.

A HTO performed concomitantly with an ACL reconstruction causes substantial and sustained changes in gait biomechanics. The osteotomy reduces peak external knee adduction and flexion moments due to the intended mediolateral shift in knee loads. These changes are maintained even after 5 years, though with slight reduction [13]. It has also been reported by the same authors in a comparative study, that a MOWHTO alone causes reduction in knee flexion moment which is maintained after 5 years. The addition of a simultaneous ACL reconstruction preserves the peak flexion moment, which may be detrimental [14]. The higher peak knee flexion moment has been shown to increase joint loading and contribute to progression of cartilage degeneration [15]. Concomitant MOWHTO and ACLR has shown sustained laxity control even after 10 years and no radiographic progression of tibio-femoral degeneration in 61% patients. However, only one third of the patients could return to sports in this series [16]. Combined MOWHTO and ACLR has been shown to be safe and effective procedure for symptomatic varus osteoarthritis in young patients [17].

Varus malalignment has implications for PCL laxity as well. Noyes et al noted a varus deformity in 31% of cases is a series of 52 failed PCL reconstructions. They emphasized the need to manage this mal-alignment to reduce failures [18]. Osseous valgus mal-alignment has also been reported to increase ACL graft forces on axial compressive loading in a cadaveric experiment. This stress was aggravated in the presence of posteromedial corner (PMC) deficiency. While a PMC reconstruction alone reduced the stress on ACL, correction of the mal-alignment alone by a distal femur osteotomy was more effective in this regard as shown by Mehl et al. [19]. Thus, an osteotomy has a more profound bearing in restoring knee laxity and reducing graft stress than any soft tissue reconstruction.

The sagittal plane and posterior tibial slope (PTS) has gained attention recently in the backdrop of ACL re-tears. A PTS of more than 12^0 is a very strong predictor of ACL re-tear and this negative effect is far more pronounced in adolescents [20]. The early functional outcomes of tibial de-flexion (slope reduction) osteotomy and a second revision ACL reconstruction have been reported to be satisfactory [21, 22]. The biomechanical effect of a slope reducing osteotomy has been studied in cadaveric experiments [23-25]. The tibial slope has been shown to have a strong linear co-relation with the force experienced by an ACL graft when the knee is axially loaded, in all flexion angles [24]. Yamaguchi studied anterior tibial translation and ACL force between 0-50^0 knee flexion before and after a 10^0 closing wedge osteotomy. Both these parameters reduced significantly after the osteotomy on application of axial loading, anterior force and valgus moment. However, when internal torque was applied, the benefits of osteotomy was negated [23]. Imhoff et al. also reported reduction in anterior tibial translation in both ACL deficient and reconstructed state, on axial loading. They stressed that a de-flexion osteotomy has a protective effect on the ACL graft, especially in a revision scenario [25].

On the other hand, increasing the tibial slope in a PCL deficient knee has been shown to reduce posterior sag by shifting resting position of tibia anteriorly. This sag is further

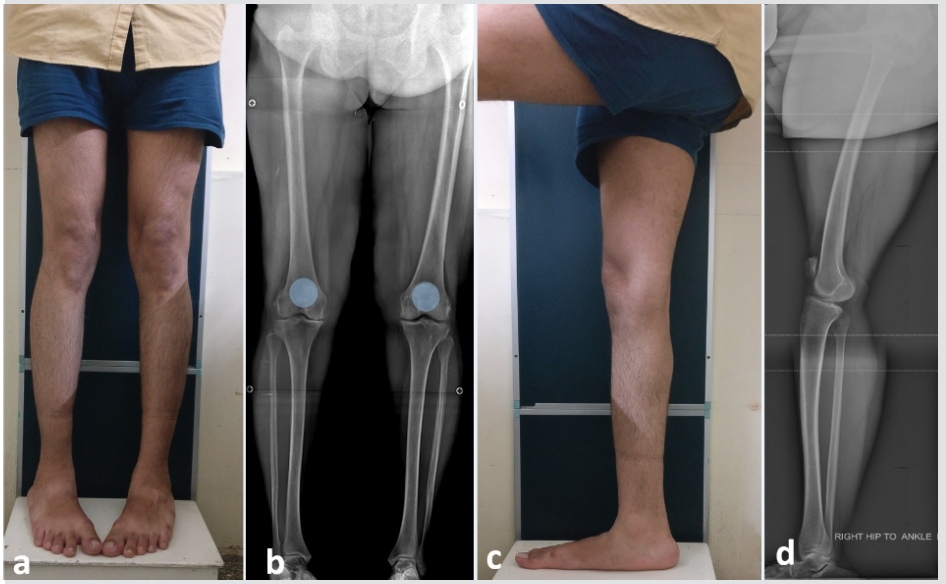


Figure 2: (a) The correct method of positioning a patient for an anteroposterior scanogram. Note that foot is internally rotated about 10-15^0 so that the patella faces forward. (b) The scanogram thus obtained has the patella centered in the distal femur. (c) The correct patient position for a monopedal stance lateral scanogram with the patient's foot externally rotated about 10-15^0 and knee maximally extended. (d) The radiograph shows overlapping of the posterior femoral condyles as is required.

reduced on axial loading of the knee [11]. A low PTS has been found to be a risk factor for contact and non-contact PCL tears [26]. However, the PTS has not been found to co-relate with posterior tibial translation on stress radiography after a double-bundle PCL reconstruction [27].

A HTO is an important and sometimes, a necessary operation in the presence of posterolateral corner deficiency. The double varus or triple varus thrust can be effectively managed by this procedure [28]. A cadaveric study was performed by LaPrade et al. to analyze the effect of medial open wedge HTO (MOWHTO) on posterolateral knee stability. The PLC was sectioned and then an osteotomy performed. They found significant reduction in varus and external rotational laxity after the MOWHTO in PLC sectioned knees in 30 and 90 degrees of knee flexion. Interestingly, the superficial MCL force was significantly increased after the osteotomy and the authors believed that this phenomenon contributes to the stability achieved after a MOWHTO [29]. In the clinical setting also, a one stage MOWHTO and PLC reconstruction has been shows to have satisfactory outcomes with a low complication rate [30].

Clinical Assessment and Planning:

Patient's history is of utmost importance to understand the mechanism of injury and chronicity of the problem. The presence of pain points to cartilage or meniscus pathology. Since an osteotomy is being contemplated, it is important to elicit the presence of patient factors which can compromise bone healing such as smoking, diabetes mellitus, immunocompromise of any kind or pre-existing metabolic bone disease [31]. A thorough clinical examination can almost always reveal the type and extent of knee instability in the coronal, sagittal or rotational planes. Any limb length discrepancy has to be taken in to account as this has a bearing on planning the osteotomy. Gait examination is essential to look for phenomenon like the varus thrust or the hyperextend triple varus deformity and a complete gait analysis is of value [9]. No planning should be considered complete unless the vascular and neurologic status of the lower limb has been carefully evaluated.

A correctly performed standing anteroposterior (AP) long leg scanogram with the patella centered and a monopedal stance lateral view with overlapping femoral condyles are sine-quo-non for planning any osteotomy (Fig. 2). These radiographs must be calibrated with a marker to obtain an accurate pre-operative plan. Axial plane deformities are assessed with a Torsion Profile CT scan series. A 3D CT scan of the knee is helpful if the deformity appears complex and multiplanar. An MRI scan accurately defines the morphology of all ligaments, status of the menisci and articular cartilage and aids in decision making for reconstruction. The correction to be made in each patient has to be tailored and carefully planned prior, to achieve all the goals whilst avoiding any over-correction which can have disastrous consequences. An example of this a patient with ACL/PLC laxity and a varus knee. A medial open wedge HTO would correct the alignment and reduce stress on the ACL and PLC reconstructions. Managing the tibial slope in such a case is tricky and would be guided by the existing slope angle and knee hyperextension. A reduction (inadvertent or intentional) of tibial slope would off-load the ACL but worsen hyperextension and increase strain on the PLC reconstruction. Hence, there cannot be an "ideal alignment" in such complex scenarios and careful planning and meticulous execution is necessary.

The planning can be performing on printed radiographs and using a pen and compass or using computer softwares like Trauma Cad® (BRAINLAB, Munich, Germany) or Bone Ninja® (International Center for Limb Lengthening, Baltimore, MD). Whatever be the tool, the principles do not change, and one may choose any of the methods described by Miniaci or Dugdale or Coventry [32-34]. The steps in planning a corrective osteotomy are described briefly as the details are beyond the scope of this paper [5, 35]:

1. Drawing a MAP

(a) Measuring the mechanical axis deviation by dropping a line from the center of hip to center an ankle

(b) Analyzing joint angles (mechanical) especially the lateral proximal femur angle (LPFA), lateral distal femur angle (LDFA), medial proximal tibial angle (MPTA), lateral distal tibial angle (LDTA) and proximal posterior tibial angle (PPTA)

(c) Choosing the deformed bone(s) for performing the osteotomy.

2. Planning the ABCs

(a) Apex of the deformity is identified. This is usually metaphyseal or sometimes intra-articular.

(b) Bone cuts are planned where they are feasible. Based on the geometry, the osteotomy maybe an open wedge, closed wedge or dome. It may be a uniplanar or biplanar based on the correction planned.

(c) Correction of angulation to be made in millimeters of opening or closing a wedge. While this is very variable in the coronal plane, in the sagittal plane, each mm of bone generally changes the slope by 2 degrees.

3. Deciding the technique and fixation

Most osteotomies of the proximal tibia are currently open wedge biplanar medial osteotomies due the distinct advantages it offers [36]. For distal femur varization osteotomies, a medial close wedge biplanar approach is now increasingly gaining popularity [37]. All these osteotomies can be performed by using conventional methods and tools or computer navigation [38] or patient specific instrumentation [39]. The current standard of care for fixation of a distal femur or proximal tibia osteotomy in an unstable knee is with an angle stable locked plate of any design. These implants allow earlier weight bearing and good stability even if there is a small hinge fracture. Slope changing osteotomies of the tibia can be fixed with bone staples in most cases.

4. Bone grafting

The void created in open wedge osteotomies can be grafted with autogenous bone or allograft or synthetic bone substitutes. Although this is not always necessary, a lower threshold for grafting in an MLKI knee is probably better as it provides added stability, enhances healing and could allow earlier and aggressive rehabilitation. It is always better to bone graft the open wedge if one is contemplating a second stage ligament procedure. This makes it easier to drill tunnels during the second stage.

5. Evaluation of graft options, tunnel position adjustment

When the osteotomy is performed as a staged procedure, technical complications like tunnel coalition with screw positions can be avoided. Alternatively, plates which allow variable angle screw placement can be used to circumvent this problem. As with any multiligament knee reconstruction, it is imperative to have plenty of graft options (including allografts and synthetic materials) and fixation devices at ones' disposal.

Technical considerations and illustrated examples:

The osteotomy can be performed simultaneously with the ligament reconstructions, or more often in a staged manner before any soft tissue surgery for multiple ligaments. The advantages of a staged approach are that it reduces the complexity of the procedure and sometimes may even provide adequate stability to forego a ligament reconstruction. We present below examples of osteotomies in 3 different planes performed for MLKI.

Case 1:

Presentation

A 43-year-old male with history of road traffic accident almost 6 years ago presented with right knee instability. Clinically, he had ACL laxity, varus laxity and dial test was positive at 30^0 flexion. He had varus deformity and walked with a varus thrust gait. His AP scanogram revealed varus mal-alignment but the PTS was normal (Fig. 3.1). Varus stress

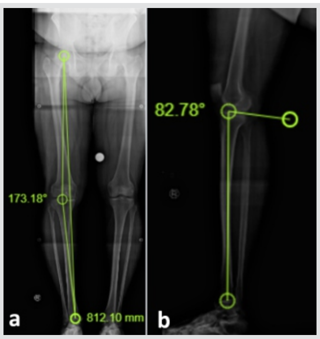


Figure 3.1: Anteroposterior standing scanogram of the patient showing a varus of almost 7^0(a) and a posterior tibial slope of 82.78^0 which is normal (b).

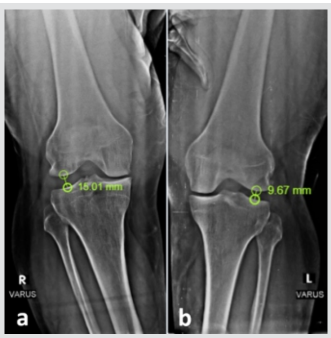


Figure 3.2: Varus stress radiographs of the injured (a) and uninjured knee (b) in 20^0 knee flexion revealed a side-to-side difference of 5.4 mm of lateral opening.

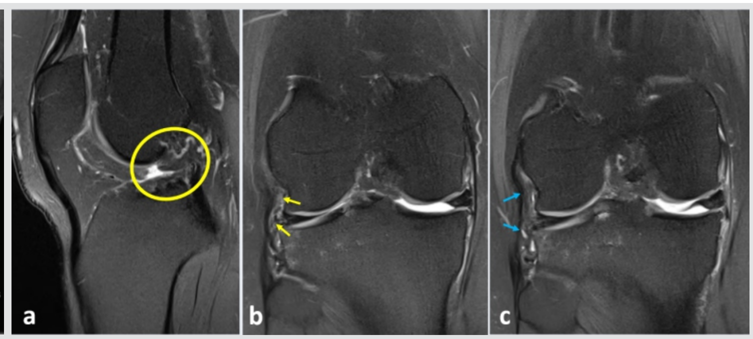
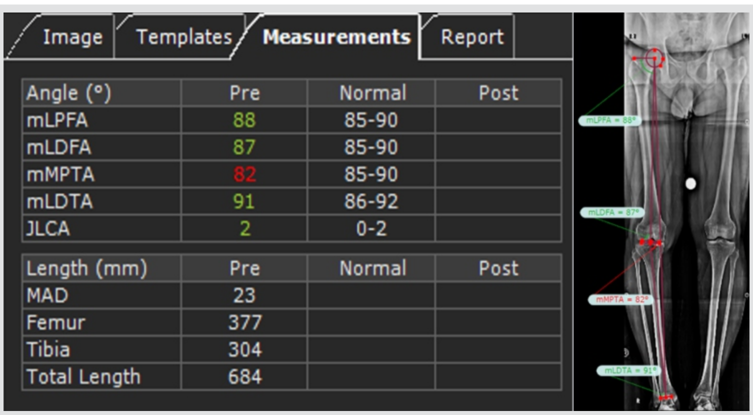


Figure 3.3: MRI Images of the knee in proton-density fat saturated sequence. Sagittal section (a) showing absence of the anterior cruciate ligament (yellow circle). Coronal sections showing (b) disruption of the popliteus tendon (yellow arrow) and (c) fibular collateral ligament (blue arrow).



Angle (°)	Pre	Normal	Post
mLPFA	88	85-90	
mLDFA	87	85-90	
mMPTA	82	85-90	
mLDTA	91	86-92	
JLCA	2	0-2	

Length (mm)	Pre	Normal	Post
MAD	23		
Femur	377		
Tibia	304		
Total Length	684		

Figure 3.4: Osteotomy planning using TraumaCad® software. The MPTA was 82^0 but all other angles were normal. This implies that the varus arises from the osseous mal-alignment in the tibia only. A 7 mm wedge was planned to bring the Mikulicz line to the center.

Figure 3.5: Post-operative radiograph of the patient showing the fixation in-situ.

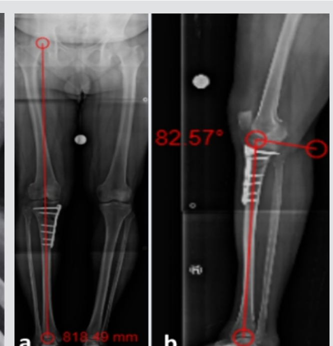


Figure 3.6: Post-operative anteroposterior scanogram (a) showing the Mikulicz line passing through the center of the knee. The posterior tibial slope was not altered (b).

radiographs showed increased lateral joint line opening on the right side (Fig. 3.2). MRI scan confirmed the presence of an ACL and PLC injury (Fig. 3.3).

Planning

This patient had combined ACL and PLC instability with a varus mal-alignment. The plan was to perform a bi-planar MOWHTO to correct the varus whilst maintaining the slope, anatomic ACL reconstruction with quadriceps tendon autograft and PLC reconstruction with semitendinosus autograft by the Modified Larson Technique. The osteotomy was planned using TaumaCad® (Brainlab) software and Miniaci technique (Fig. 3.4). A 7 mm wedge needed to be opened to bring the Mikulicz line to center of the knee.

Procedure

Diagnostic arthroscopy confirmed the diagnosis. The grafts were harvested and prepared. The ACL femoral tunnel was drilled using a FlipCutter® (Arthrex) by the outside-in technique. Lateral exposure was done and common peroneal nerve identified. FCL and popliteus femoral sockets were drilled to avoid coalition with the ACL tunnel. The fibula tunnel was drilled free-hand. Medial exposure was done, a biplanar HTO was performed to open a wedge of 7 mm as planned. The starting point of osteotomy was marked to allow space for ACL tibia tunnel drilling. Fixation of the osteotomy was performed with a Tomofix® (DePuy Synthes) plate (Fig. 3.5). The PLC was fixed first with bio-absorbable screws, followed by the ACL. The follow-up AP scanogram confirmed correction to the midline and no change in posterior tibial slope (Fig. 3.6).

Pearls-

- The osteotomy should be performed at a level low enough to allow for a tibial tunnel to be drilled
- This necessitates need for a biplanar cut
- The plate should be shifted as far posterior as possible to allow for drilling of the tibia tunnel
- Take care to open the osteotomy open posteriorly more than anteriorly to prevent an increase in the PTS.
- Use a short graft for the ACL
- The use of outside in drilling for the ACL femoral tunnel decreases the risk of tunnel coalition
- Drill the ACL femoral tunnel and all the PLC tunnels prior to performing the osteotomy
- Fix the osteotomy securely first and then pass all grafts and fix them sequentially

Case 2:

Presentation

A 37-year-old female suffered an injury to her left knee following a slip and fall. Her BMI was 32 Kg/m². She was diagnosed as having an MCL tibial sided injury and an ACL tear. She was operated after 4 days of injury. Her MCL was repaired with suture anchors (for deep MCL and meniscotibial ligament) and ligament staple (for superficial MCL) and ACL was reconstructed with the trans portal technique using ipsilateral semitendinosus autograft. She slipped and fell again (ultra low velocity trauma) after 7 months. She complained of knee instability and presented to us. An AP scanogram revealed varus mal-alignment and the posterior tibial slope was high (Fig. 4.1). Stress radiography showed no valgus laxity but lateral opening was present (Fig. 4.2). MRI scan showed rupture of the ACL graft and poorly visualized PLC structures.

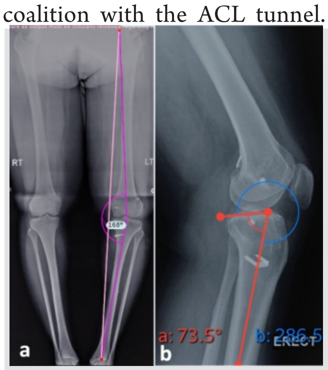


Figure 4.1: Anteroposterior standing scanogram of the patient showing a varus of 12⁰ (a) and a posterior tibial slope of 73.5⁰ which is high (b).

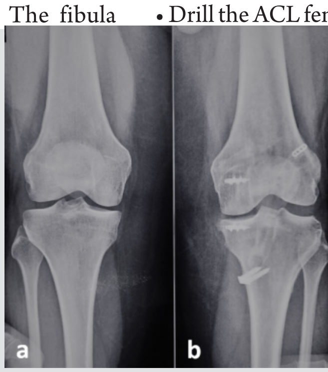


Figure 4.2: Varus stress radiographs of the uninjured right (a) and injured left knee (b) in 20⁰ knee flexion revealed a side-to-side difference of 8.5 mm of lateral opening.

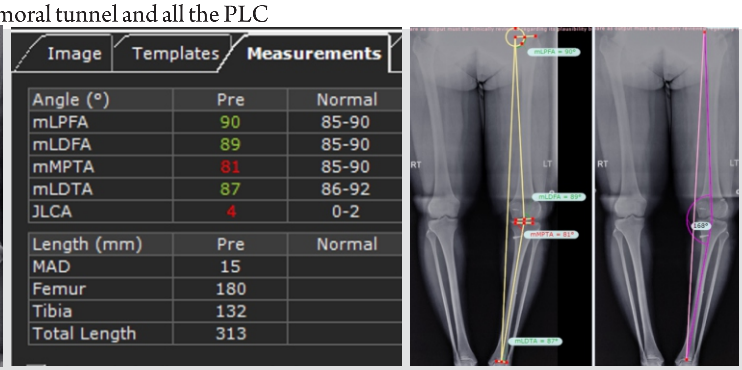


Figure 4.3: Osteotomy planning using TraumaCad® software. The MPTA was 81⁰ and joint line convergence angle was increased. This implies that the varus arises both from the osseous mal-alignment in the tibia and lateral soft-tissue laxity (double varus). A 8.5 mm wedge opening was planned to bring the Mikulicz line to the center.

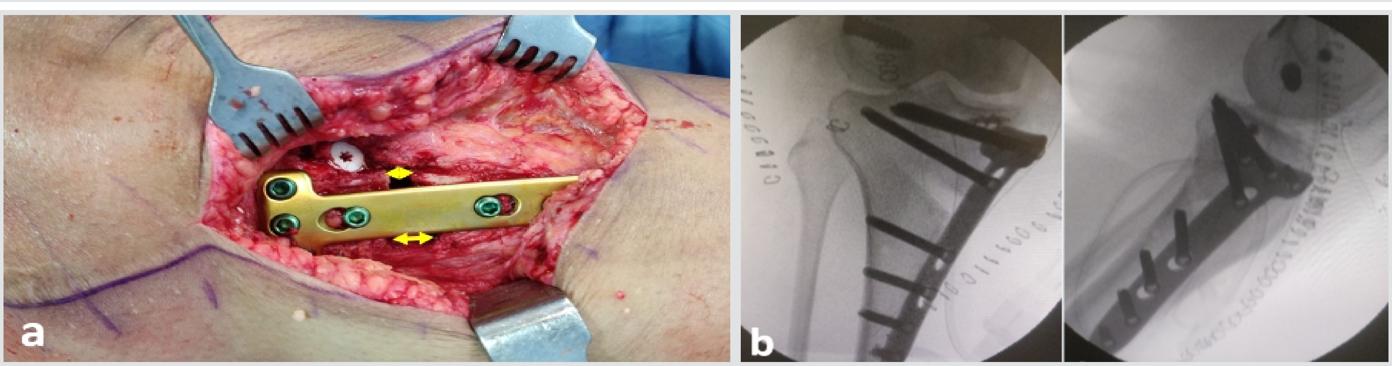


Figure 4.4: Intra-operative clinical picture (a) showing the osteotomy fixation and ACL tibial screw. Note that osteotomy wedge opening anteriorly is almost thrice that of the posterior opening. Intra-operative image-intensifier picture of the patient showing the osteotomy.

Planning

This patient had a missed PLC injury during the first surgery. The varus-alignment would only increase the knee adduction moment during gait. A high posterior slope further increased stress on the ACL, leading to graft rupture. The plan was to perform a bi-planar MOWHTO to correct the varus and reduce the slope, revision ACL reconstruction with quadriceps tendon autograft and PLC reconstruction with peroneus longus autograft by the Modified Larson Technique. The osteotomy was planned using TaumaCad® (Brainlab) software and Miniaci technique (Fig. 4.3). A 8.5 mm wedge needed to be opened to bring the Mikulicz line to center of the knee.

Procedure

The quadriceps tendon with bone plug and peroneus longus grafts were harvested and prepared. The ACL femoral tunnel was by the outside-in technique using a PinPont System® (Smith and Nephew). Lateral exposure was done and common peroneal nerve identified. FCL and popliteus femoral sockets were drilled to avoid coalition with the ACL tunnel. The fibula tunnel was drilled free-hand. Medial exposure was done, ligament staple removed but MCL was not released, as is normally done. A biplanar HTO was performed to open a wedge of 8.5 mm and special care was taken keep the osteotomy trapezoidal, opening more than twice posteriorly in order to reduce the slope. Fixation of the osteotomy was performed with a Tomofix® (DePuy Synthes) plate (Fig. 4.4). The PLC was fixed first with bio-absorbable screws, followed by the ACL.

Pearls-

- It is necessary to release the superficial MCL off the tibia for a successful medial open wedge HTO
- Lack of it's release will predispose to paradoxical higher medial tibio femoral pressures
- One of the scenarios when you do not release the superficial MCL is when there is a MCL laxity that needs to be tightened with the HTO

Case 3:

Presentation- A 40-year-old female had a KD V C injury three years prior to presentation secondary to a road traffic accident. The first surgery was done to fix the bicondylar tibia fracture, repair the popliteal artery and external fixation for the unstable knee. She complained of persistent instability after the fixator removal. Her plates and screws were removed after 2 years and she presented to us. On clinical examination, the patient had ACL, PCL. MCL and PLC laxity. She walked with a varus thrust gait. An AP scanogram revealed varus mal-alignment with lateral subluxation of the tibia. The posterior tibial slope was seen to be reversed on the monopedal stance view. There was posterior subluxation of the tibia (Fig. 5.1). A CT scan was done to better define

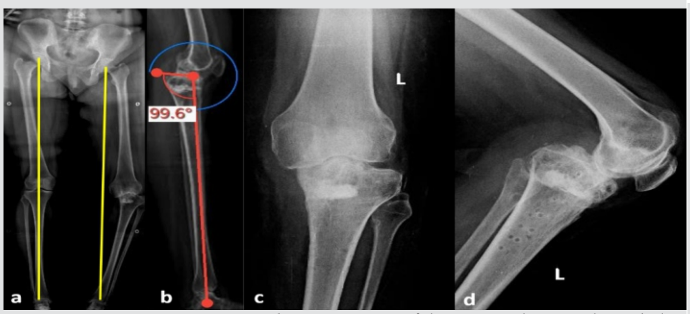


Figure 5.1: Anteroposterior standing scanogram of the patient showing the Mikulicz line passing medial to the knee joint (a). The posterior tibial slope is 99.6^0 indicating reversal of slope. AP weight bearing radiograph (c) showing lateral subluxation and lateral radiograph (d) showing posterior subluxation of the tibia.

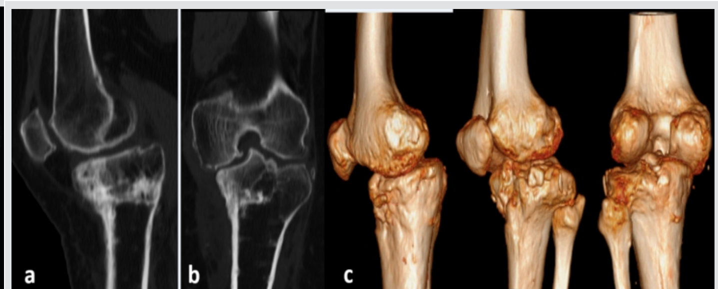


Figure 5.2: CT scan in the sagittal (a), coronal (b) and three-dimensional reconstruction (c) showing the abnormal morphology of the proximal tibia. There is reversal of posterior slope and loss of bone in the medial tibial condyle.

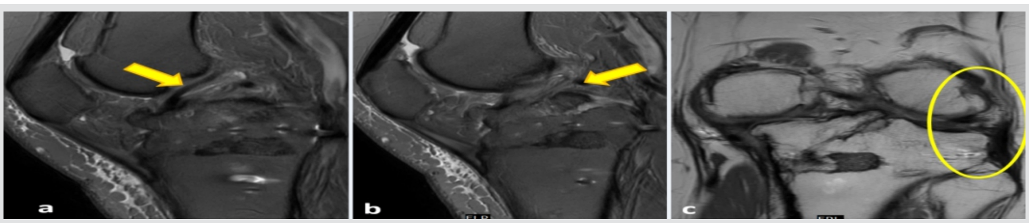


Figure 5.3: MRI Images of the knee. In proton-density fat saturated sequence, sagittal sections showing (a) an elongated anterior cruciate ligament (yellow arrow) and (b) absent posterior cruciate ligament. T2 weight coronal section showing disruption of the posterolateral complex (yellow oval).

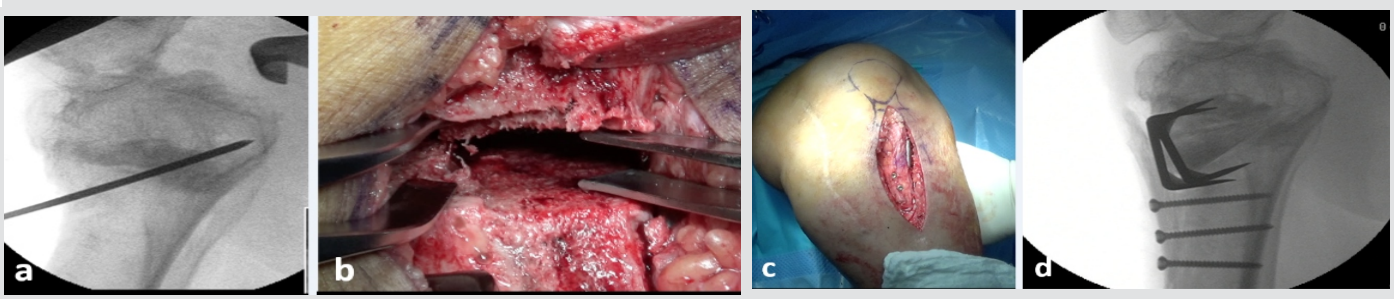


Figure 5.4: Intra-operative images of the osteotomy. The lateral view (a) showing guide wire for osteotomy directed towards the champagne drop-off of the tibia. The osteotomy is opened anteriorly more on the medial side (b) using two lamina spreaders. (c) The completed osteotomy after re-fixation of the tibial tubercle osteotomy (c). Lateral view on image-intensifier (d) showing the completed osteotomy and fixation with staples and bone graft in the opened wedge.

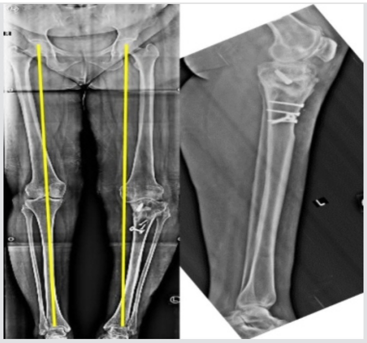


Figure 5.5: Post-operative anteroposterior scanogram (a) showing the Mikulicz line still passing medial to the knee but less so. The posterior tibial slope was normalized (b).

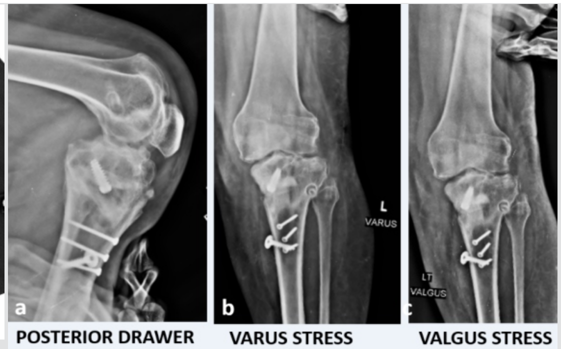


Figure 5.6: Post-operative stress radiographs to test stability of the reconstruction did not reveal laxity on posterior drawer (a), varus (b) or valgus (c) stress.

the proximal tibia morphology (Fig. 5.2). MRI scan confirmed discontinuity of ACL, PCL and PLC (Fig. 5.3).

Planning

This case presents with instability of all four ligamentous structures along with gross distortion of the proximal tibia morphology. It is realistic to expect a joint preservation procedure would improve function of the limb and provide stability but not have normal or near normal knee joint. It was decided to reduce the posterior subluxation of the tibia first. An anterior open wedge osteotomy to bring the tibial slope to 10^0 was planned. This would mean an opening of 10 mm ($100^0 – 80^0 = 20^0 / 2$) as 1 mm opening would increase the slope by 2^0. In the coronal plane, the medial side was to be opened more, both to tension the MCL and reduce the degree of varus. Ligament reconstruction was planned after healing of the osteotomy.

Procedure

An osteotomy was performed in the first stage. An anterior midline incision and tibial tubercle osteotomy was performed to gain access and maintain patella height. The hinge point of this osteotomy lies at the champagne drop off of the tibia. The osteotomy was opened more medially and gap filled with a femoral head fresh frozen allograft. Fixation was performed with staples (Depuy) (Fig. 5.4). Nine months post proximal tibia osteotomy (PTO) healing, the PCL and PLC were reconstructed using autografts (peroneus longus for PCL and Semitendinosus for PLC) from the contralateral limb. The patient was completely relieved of her instability and was walking without a brace or walking aid after 6 months. The follow-up AP scanogram (Fig. 5.5) still had a varus alignment but the lateral monopedal stance radiograph showed a reduced tibia with normal PTS. Stress radiographs were performed to confirm stability of the PCL, PLC and MCL (Fig. 5.6).

Pearls-

- In the algorithm of correcting bone– sagittal plane takes predominance over coronal plane
- In patients with 'Neglected MLKI' it is essential to determine if the posterior subluxation is reducible for not
- Reducible or correctible posterior subluxation can be effectively tackled with a slope altering osteotomy
- Irreducible or fixed posterior subluxation will require a posterior capsular release first followed by a reconstruction procedure
- For opening proximal tibial osteotomy, the tibial tubercle osteotomy is performed over at least 6 cm in length.
- The re-fixed tibial tubercle at completion of the PTO acts like a 'biologic plate'
- Bone grafting is a must
- The PTO is hinged at the PCL insertion point on the posterior tibial cortex. This is also identified as the 'champagne drop off' point on fluoroscopy

Case 4:

Presentation

A 26-year-old female had a KD V L injury of her right knee after a road traffic accident. She had a fibula head avulsion fracture and a lateral tibial plateau fracture (Schatzker type III). The fibula avulsion was fixed with K wires in the first surgery while the tibia fracture was conserved. Six months after this, the fibula implants were removed and an ACL reconstruction with ipsilateral hamstrings and Modified Larson PLC reconstruction with contralateral semitendinosus was performed. The patient had persistent instability which was progressive. At presentation to us, she had ACL + PCL + PLC laxity with knee hyperextension and walked with a triple varus gait (Fig. 6.1). The AP scanogram revealed varus, which was comparable to the contralateral normal limb and PTS was normal (Fig. 6.2).

Planning

A CT was performed to look at the healing of the tibia fracture. It revealed persistent depression in the central lateral tibial plateau (Fig. 6.3). There were thus, two misses in the primary management of this case. First was that the tibial depression which was not addressed and this would contribute to the lateral laxity significantly. Secondly, the PCL was not reconstructed and this is the central pivot of the knee. Both these factors combined lead to the failure of ACL and PLC reconstruction due to increased stress on the grafts. A two stage reconstruction was planned – osteotomy followed by soft tissue reconstruction.

Procedure

As a first stage procedure, an intra-focal osteotomy to elevate the depressed lateral condyle was performed. Fixation was done with a lateral tibia raft plate (DePuy Synthes) and the opening was bone grafted (Fig. 6.4). A LaPrade anatomic PLC reconstruction was done simultaneously to obliterate any lateral (coronal and rotatory) laxity. The ACL tibial tunnel was bone grafted to prepare for the revision. The plate was removed after 9 months

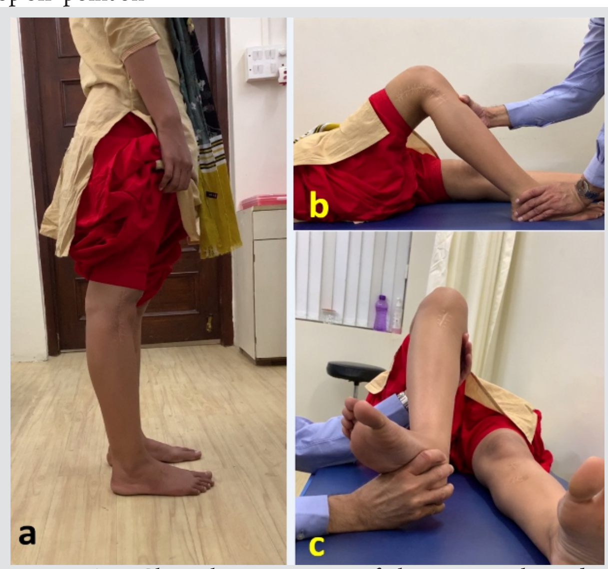


Figure 6.1: Clinical examination of the patient showed a hyperextended knee on the right side (a). The tibia was sagged posteriorly with loss of anterior step-off (b) and dial test was positive at 30^0 and 90^0 knee flexion (c).

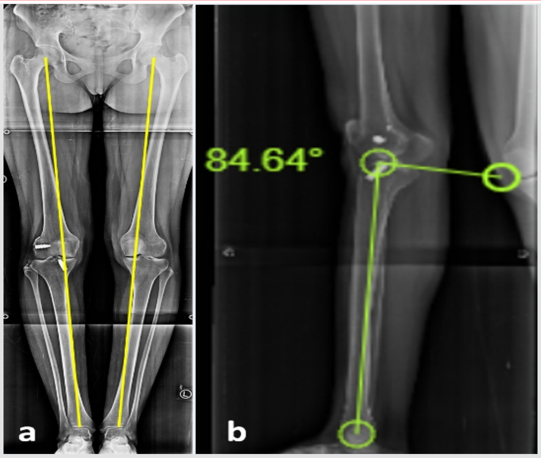


Figure 6.2: Anteroposterior standing scanogram of the Mikulicz line passing medial to the knee center on both side by an equal distance (a). The posterior tibial slope of 84.64^0 was normal (b).

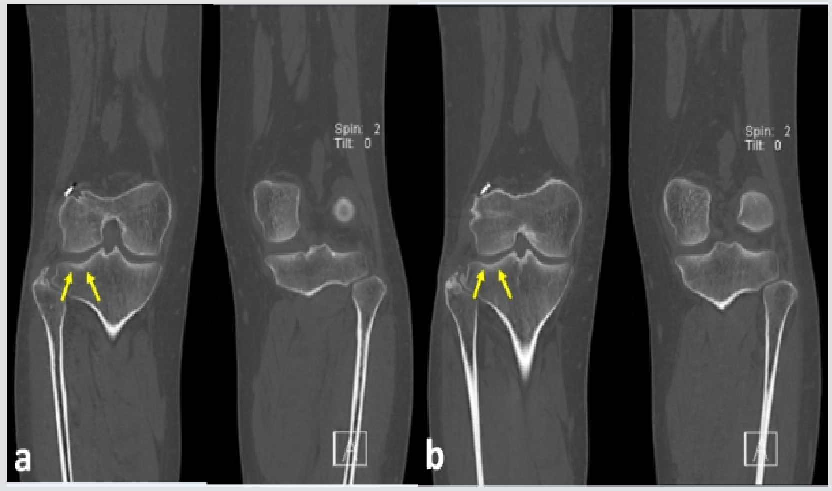


Figure 6.3: CT scan coronal images with matching sections of the injured right and uninjured left knee showing a central depression (yellow arrows).

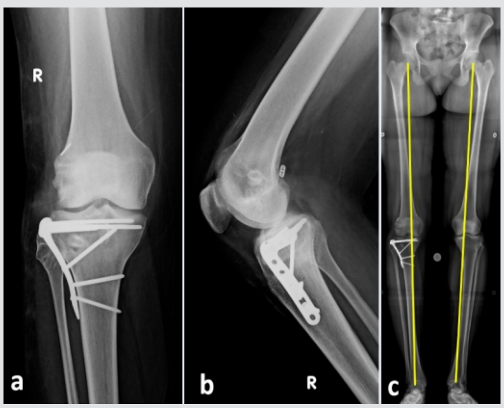


Figure 6.4: Post-operative radiographs after the first stage surgery showing the fixation of the intra-focal osteotomy in AP (a) and lateral (b) views. The AP scanogram showing no change in the varus alignment (c).

Figure 6.5: Post-operative radiographs after removal of the osteotomy implants showing complete healing of the osteotomy and elevation of the lateral joint line.

up on complete healing of the osteotomy (Fig. 6.5). The second stage procedure to reconstruct the PCL and ACL with fresh frozen allografts is planned in the near future.

Pearls-

- Intra-focal osteotomy for correction of malunited intra-articular fractures is a very demanding procedure and requires meticulous planning on CT scan
- For coronal plane intra-focal correction, the hinge point is usually the tibial spine – lateral spine for lateral opening and vice versa
- Conventional trauma plates may be preferred for fixation

Rehabilitation:

It is not possible to have prescribed rehabilitation guidelines where the situation is complex and highly variable from patient to patient. Only some generalizations can be made. The first few weeks are important to control pain and inflammation with cryotherapy and bracing. If the quadriceps activation is not optimal, early electrical muscle stimulation is worthwhile. It is prudent to keep the patient on protected weight bearing for 3-4 weeks till the osteotomy begins to heal. Range of motion (ROM) will depend on any intra-articular reconstructions or meniscal surgery. No ROM is allowed for 4 weeks if a tibial tubercle osteotomy or PCL reconstruction is performed. If only an HTO is performed, there are no restrictions for knee ROM. Arthrofibrosis is frequently encountered after such extensive surgery and can be managed with a manipulation or rarely adhesiolysis. These patients may require prolonged bracing and modalities for muscle strengthening like blood flow restriction therapy. More intensive training for sports is delayed for a year in many cases and a large number can never return to competitive sports

Outcomes of Osteotomy for MLKI:

There is limited scientific data available reporting the functional outcomes of osteotomy for multiligament knee injuries, consisting of small case series. While high tibial osteotomy for ACL deficient knees is now commonly performed, an osteotomy for multiligament injury is still an uncommon undertaking. Noyes published one of the earliest case series of HTO is ACL and PLC deficient knees. Of the 41 patients requiring an HTO, 34 underwent a second stage ACL reconstruction and 18 had PLC reconstruction as well. The mean Cincinnati score improved from 63 to 82 at 4.5 years mean follow up. Gait analysis was performed for 17 patients pre- and post-surgery, which showed that the mean adduction moment, which was 35% higher earlier, had reduced below normal after the osteotomy [40]. In their series of 14 patients with varus knees, Badhe et al. performed both open and closed tibial osteotomies for double and triple varus deformities. Five patients with ACL instability underwent simultaneous reconstruction, nine with PCL and PLC instability had a ligament advanced reconstruction system (LARS) reconstruction, while three patients with triple varus had an osteotomy only. At 2.8 years mean follow-up, 12 knees were stable and the Cincinnati score improved from a mean of 53 pre-surgery to 74 post-operative. No patient returned to competitive sports [41]. Naudie reported the outcomes of medial open wedge HTO in 16 symptomatic patients (17 knees) with a hyperextension varus thrust gait due to PCL/PLC or capsuloligamentous instability. After a mean follow-up of 56 months, nine patients rated their symptoms as significantly better while six felt they were somewhat better after the osteotomy [42]. In a series of 21 patients with chronic PLC deficiency and varus deformity, Arthur et al performed a second stage ligament reconstruction only in those with clinical and functional instability. They were able to get away with only an osteotomy in 6/8 patients with isolated PLC and 10/14 patients with multiligament instability. Most patient with a high velocity knee injury required a ligament reconstruction. The functional results on Cincinnati score was lower in those requiring subsequent ligament surgery [43]. Thus, performing an osteotomy only may relieve the patient of instability and a ligament reconstruction performed later, if needed for residual laxity. Although functional outcomes seem reasonable in the short-term, the activity level achieved, and overall prognosis of the knee is guarded.

Conclusions

The presence of osseous mal-alignment is extremely important in any case of knee instability and more so in a multiligament injured knee. The clinician must be aware of these bony abnormalities in both the acute and especially chronic scenarios of a MLKI knee.Failure to diagnose and treat any mal-alignment can have disastrous consequences on the simultaneous or subsequent soft tissue reconstruction(s). The use of modern implants and techniques have made osteotomy a safe and satisfactory procedure. Nonetheless, the prognosis of these knees is guarded and return to sports is delayed or frequently never possible.

References

1. *Paley D, Pfeil J. Prinzipien der kniegelenknahenDeformitätenkorrektur [Principles of deformity correction around the knee]. Orthopade. 2000;29(1):18–38. doi:10.1007/s001320050004*
2. *Bellemans J, Colyn W, Vandenneucker H, Victor J. The ChitranjanRanawat award: is neutral mechanical alignment normal for all patients? The concept of constitutional varus. ClinOrthopRelat Res. 2012;470(1):45–53. doi:10.1007/s11999-011-1936-5*
3. *Song MH, Yoo SH, Kang SW, Kim YJ, Park GT, Pyeun YS. Coronal alignment of the lower limb and the incidence of constitutional varus knee in korean females [published correction appears in Knee SurgRelat Res. 2015 Sep;27(3):197]. Knee SurgRelat Res. 2015;27(1):49–55. doi:10.5792/ksrr.2015.27.1.49*
4. *Thaller PH, Fürmetz J, Chen F, Degen N, Manz KM, Wolf F. Bowlegs and Intensive Football Training in Children and Adolescents [published correction appears in DtschArztebl Int. 2018 Aug;115(33-34):548]. DtschArztebl Int. 2018;115(24):401–408. doi:10.3238/arztebl.2018.0401*
5. *Galla M., Lobenhoffer P. Physiological axes of the lower limb. In: Lobenhoffer P., van Heerwaarden R, Staubli AE, Jakob RP (Eds). Osteotomies around the Knee. Thieme, Stuttgart.*
6. *Amis AA. Biomechanics of high tibial osteotomy. Knee Surg Sports TraumatolArthrosc. 2013;21(1):197–205. doi:10.1007/s00167-012-2122-3.*
7. *Teichtahl AJ, Davies-Tuck ML, Wluka AE, et al. Change in knee angle influences the rate of medial tibial cartilage volume loss in knee osteoarthritis. OsteoarthrCartil 2009;17:8-11.*
8. *Noyes FR, Simon R: The role of high tibial osteotomy in the anterior cruciate ligament-deficient knee with varus alignment, in DeLee JC, Drez D (eds): Orthopaedic Sports Medicine. Principles and Practice. Philadelphia, WB Saunders, 1994, pp 1401–1443*
9. *Tischer T, Paul J, Pape D, et al. The Impact of Osseous Malalignment and Realignment Procedures in Knee Ligament Surgery: A Systematic Review of the Clinical Evidence. Orthop J Sports Med. 2017;5(3):2325967117697287. doi:10.1177/2325967117697287*
10. *Abdelrahman T., Getgood A. Role of osteotomy in multiligament knee injuries. Ann Joints 2019;4:8. Doi: 10.21037/aoj.2018.12.07.*
11. *Giffin JR, Stabile KJ, Zantop T, et al. Importance of tibial slope for stability of the posterior cruciate ligament deficient knee. Am J Sports Med 2007;35:1443-9.*
12. *Perry J, Antonelli D, Ford W. Analysis of knee-joint forces during flexed-knee stance. J Bone Joint Surg [Am] 1975;57-A:961–967.*
13. *Marriott K, Birmingham TB, Kean CO, Hui C, Jenkyn TR, Giffin JR. Five-year changes in gait biomechanics after concomitant high tibial osteotomy and ACL reconstruction in patients with medial knee osteoarthritis. Am J Sports Med. 2015;43(9):2277–2285. doi:10.1177/0363546515591995*
14. *Marriott K, Birmingham TB, Pinto R, et al. Gait biomechanics after combined HTO-ACL reconstruction versus HTO alone: A matched cohort study. J Orthop Res. 2019;37(1):124–130. doi:10.1002/jor.24157*
15. *Chehab EF, Favre J, Erhart-Hledik JC, et al. 2014. Baseline knee adduction and flexion moments during walking are both associated with 5 year cartilage changes in patients with medial knee osteoarthritis. Osteoarthritis Cartilage 22:1833–1839*
16. *Schneider A, Gaillard R, Gunst S, et al. Combined ACL reconstruction and opening wedge high tibial osteotomy at 10-year follow-up: excellent laxity control but uncertain return to high level sport. Knee Surg Sports TraumatolArthrosc. 2020;28(3):960–968. doi:10.1007/s00167-019-05592-2*
17. *Malahias MA, Shahpari O, Kaseta MK. The clinical Outcome of One-stage High Tibial Osteotomy and Anterior Cruciate Ligament Reconstruction. A Current Concept Systematic and Comprehensive Review. Arch Bone Jt Surg. 2018;6(3):161–168.*
18. *Noyes FR, Barber-Westin SD. Posterior cruciate ligament revision reconstruction, part 1: causes of surgical failure in 52 consecutive operations. Am J Sports Med. 2005;33(5):646–654. doi:10.1177/0363546504271210*
19. *Mehl J, Otto A, Kia C, et al. Osseous valgus alignment and posteromedial ligament complex deficiency lead to increased ACL graft forces [published online ahead of print, 2019 Nov 2]. Knee Surg Sports TraumatolArthrosc. 2019;10.1007/s00167-019-05770-2. doi:10.1007/s00167-019-05770-2*
20. *Salmon LJ, Heath E, Akrawi H, Roe JP, Linklater J, Pinczewski LA. 20-Year Outcomes of Anterior Cruciate Ligament Reconstruction With Hamstring Tendon Autograft: The Catastrophic Effect of Age and Posterior Tibial Slope. Am J Sports Med. 2018;46(3):531–543. doi:10.1177/0363546517741497*
21. *Dejour D, Saffarini M, Demey G, Baverel L. Tibial slope correction combined with second revision ACL produces good knee stability and prevents graft rupture. Knee Surg Sports TraumatolArthrosc. 2015;23(10):2846–2852. doi:10.1007/s00167-015-3758-6*
22. *Sonnery-Cottet B, Mogos S, Thaunat M, et al. Proximal Tibial Anterior Closing Wedge Osteotomy in Repeat Revision of Anterior Cruciate Ligament Reconstruction. Am J Sports Med. 2014;42(8):1873–1880. doi:10.1177/0363546514534938*
23. *Yamaguchi KT, Cheung EC, Markolf KL, et al. Effects of Anterior Closing Wedge Tibial Osteotomy on Anterior Cruciate Ligament Force and Knee Kinematics [published correction appears in Am J Sports Med. 2018 Feb;46(2):NP2]. Am J Sports Med. 2018;46(2):370–377. doi:10.1177/0363546517736767*
24. *Bernhardson AS, Aman ZS, Dornan GJ, et al. Tibial Slope and Its Effect on Force in Anterior Cruciate Ligament Grafts: Anterior Cruciate Ligament Force Increases Linearly as Posterior Tibial Slope Increases. Am J Sports Med. 2019;47(2):296–302.*

doi:10.1177/0363546518820302

25. Imhoff FB, Mehl J, Comer BJ, et al. Slope-reducing tibial osteotomy decreases ACL-graft forces and anterior tibial translation under axial load. Knee Surg Sports TraumatolArthrosc. 2019;27(10):3381–3389. doi:10.1007/s00167-019-05360-2

26. Bernhardson AS, DePhillipo NN, Daney BT, Kennedy MI, Aman ZS, LaPrade RF. Posterior Tibial Slope and Risk of Posterior Cruciate Ligament Injury. Am J Sports Med. 2019;47(2):312–317. doi:10.1177/0363546518819176

27. Bernhardson AS, DePhillipo NN, Aman ZS, Kennedy MI, Dornan GJ, LaPrade RF. Decreased Posterior Tibial Slope Does Not Affect Postoperative Posterior Knee Laxity After Double-Bundle Posterior Cruciate Ligament Reconstruction. Am J Sports Med. 2019;47(2):318–323. doi:10.1177/0363546518819786

28. Herman B, Litchfield R, Getgood A. Role of Osteotomy in Posterolateral Instability of the Knee. J Knee Surg. 2015;28(6):441–449. doi:10.1055/s-0035-1558856

29. Laprade RF, Engebretsen L, Johansen S, Wentorf FA, Kurtenbach C. The effect of a proximal tibial medial opening wedge osteotomy on posterolateral knee instability: a biomechanical study. Am J Sports Med. 2008;36(5):956–960. doi:10.1177/0363546507312380

30. Helito CP, Sobrado MF, Giglio PN, et al. Posterolateral reconstruction combined with one-stage tibial valgus osteotomy: Technical considerations and functional results. Knee. 2019;26(2):500–507. doi:10.1016/j.knee.2018.12.001

31. Martin R, Birmingham TB, Willits K, Litchfield R, Lebel ME, Giffin JR. Adverse event rates and classifications in medial opening wedge high tibial osteotomy. Am J Sports Med. 2014;42(5):1118–1126. doi:10.1177/0363546514525929

32. Miniaci A, Ballmer FT, Ballmer PM, Jakob RP. Proximal tibial osteotomy. A new fixation device. ClinOrthopRelat Res. 1989;(246):250–259.

33. Dugdale TW, Noyes FR, Styer D. Preoperative planning for high tibial osteotomy. The effect of lateral tibiofemoral separation and tibiofemoral length. ClinOrthopRelat Res. 1992;(274):248–264.

34. Coventry MB. Upper tibial osteotomy for osteoarthritis. J Bone Joint Surg Am. 1985;67(7):1136–1140.

35. Standard SC, Herzenberg JE, Conway JD, Siddiqui NA, McClure PK. The Art of Limb Alignment. 8th Ed. Baltimore: Rubin Institute of Advanced Orthopaedics, Sinai Hospital of Baltimore, 2019.

36. Vaishya R, Bijukchhe AR, Agarwal AK, Vijay V. A critical appraisal of medial open wedge high tibial osteotomy for knee osteoarthritis. Journal of Clinical Orthopaedics and Trauma. 2018 Oct-Dec;9(4):300-306. DOI: 10.1016/j.jcot.2018.02.004.

37. Sherman SL, Thompson SF, Clohisy JCF. Distal Femoral Varus Osteotomy for the Management of Valgus Deformity of the Knee. J Am AcadOrthop Surg. 2018;26(9):313–324. doi:10.5435/JAAOS-D-16-00179

38. Nha KW, Shin YS, Kwon HM, Sim JA, Na YG. Navigated versus Conventional Technique in High Tibial Osteotomy: A Meta-Analysis Focusing on Weight Bearing Effect. Knee SurgRelat Res. 2019;31(2):81–102. doi:10.5792/ksrr.17.090

39. Donnez M, Ollivier M, Munier M, et al. Are three-dimensional patient-specific cutting guides for open wedge high tibial osteotomy accurate? An in vitro study. J OrthopSurg Res. 2018;13(1):171. Published 2018 Jul 9. doi:10.1186/s13018-018-0872-4

40. Noyes FR, Barber-Westin SD, Hewett TE. High tibial osteotomy and ligament reconstruction for varus angulated anterior cruciate ligament-deficient knees. Am J Sports Med. 2000;28(3):282–296. doi:10.1177/03635465000280030201

41. Badhe NP, Forster IW. High tibial osteotomy in knee instability: the rationale of treatment and early results. Knee Surg Sports TraumatolArthrosc. 2002;10(1):38–43. doi:10.1007/s001670100244

42. Naudie DD, Amendola A, Fowler PJ. Opening wedge high tibial osteotomy for symptomatic hyperextension-varus thrust. Am J Sports Med. 2004;32(1):60–70. doi:10.1177/0363546503258907

43. Arthur A, LaPrade RF, Agel J. Proximal tibial opening wedge osteotomy as the initial treatment for chronic posterolateral corner deficiency in the varus knee: a prospective clinical study. Am J Sports Med. 2007;35(11):1844–1850. doi:10.1177/0363546507304717

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