

# Posterolateral Corner Reconstruction in the Multiligament Injured Knee: State of the Art

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## Abstract

Posterolateral corner injuries were labelled as the “dark side” of the knee due to the paucity of knowledge on the subject. This has been increasingly studied and we now have a better understanding of this injury. Posterolateral corner (PLC) injuries are a significant cause of knee instability and cruciate reconstruction failures. This paper aims to review the literature over the last 10 years; on PLC epidemiology, anatomy, biomechanics, clinical and radiographic assessment, management and outcomes.

**Keywords:** Posterolateral corner, Knee Repair, Reconstruction.

### Introduction

Posterolateral corner (PLC) injuries remain a clinical entity difficult to diagnose and treat appropriately. PLC injuries are encountered in about 16% of all knee injuries [1]. They are often associated with other knee injuries, especially with Anterior Cruciate Ligament (ACL) and Posterior Cruciate Ligaments (PCL) injuries [2]. Concomitant PLC injuries were found in 13.3% of all ACL injuries diagnosed on MRI [3].

The failure to detect and treat these injuries can potentially result in chronic pain, instability, and failed cruciate ligament reconstruction [4]. Our purpose is to review current concepts of PLC injuries with evidence in the last 10 years.

### Anatomy & Biomechanics

The lateral side of the knee is more unstable due to the lack of conformity between the convex lateral tibia plateau and the lateral femoral condyle. The PLC plays a pivotal role in stabilizing the knee joint with static and dynamic stabilizers to prevent excessive varus angulation and external rotation of the tibia [5, 6]. The main stabilizers of the PLC include the fibulacollateral ligament (FCL), popliteus tendon (PT) and popliteofibular ligament (PFL) [5, 7].

The FCL is the primary varus static stabilizer of the knee and also prevents external rotation

of the knee in lower degrees of knee flexion [5, 7]. The PT serves as the primary dynamic lateral stabilizer of the knee and the contraction of the popliteus muscle assists with unlocking the knee from full extension and also internally rotates the leg. This limits excessive external rotation, particularly when the knee is flexed [8]. An injury of the PT leads to increase in tibia external rotation and posterior translation [9].

The popliteofibular ligament (PFL) originates from the popliteus musculotendinous junction and inserts onto the posteromedial aspect of the fibula head. It prevents excessive external rotation of the knee when the knee is extended [5, 6].

Secondary stabilizers include the iliotibial band (ITB), biceps femoris, fabellofibular ligament, lateral capsule, coronary ligament and lateral meniscus. The ITB provides additional lateral knee stability when the knee is loaded with varus stress while in extension. The biceps femoris is a dynamic stabilizer at varus angulation and controls tibia internal rotation. The lateral capsule is thick and also provides varus stability. The coronary ligament attaches to the posterior aspect of the lateral meniscus and tibia, and provides stability in knee hyperextension and tibial posterolateral rotation [8].

For varus laxity of the knee, the FCL acts as the primary stabilizer to varus stress throughout

knee flexion [7, 10]. The PT and posterolateral capsule contribute as secondary constraints [10]. For control of tibia external rotation, the FCL controls external rotation at beginning of knee flexion mainly from 0° to 30°, following which the popliteus musculotendinous complex becomes responsible at higher degrees of knee flexion. The PCL acts as a secondary restraint for lateral rotation of the tibia, most effectively after 90° [7].

It has been shown that injuries to all structures of the PLC results in biggest increases in external rotatory instability, varus angulation and posterior translation [9]. There is minimal role of PLC in preventing anterior tibial translation in a normal knee [11]. In ACL deficient knees, the PLC acts as a secondary stabilizer mainly in the early degrees of knee flexion. There is increased stress on the PLC with ACL injury and the vice versa. This suggests that in concomitant ACL and PLC injuries, it is ideal to reconstruct both [4, 12].

Posterior tibial translation is predominantly controlled by PCL, but the PLC also acts as a secondary stabilizer mainly in early knee flexion. Concomitant PCL and PLC injuries result in greater degree of posterior tibial translation compared to isolated PCL injuries [7, 8]. It is also shown to have increase in PCL tension after PCL reconstruction with concomitant PLC injuries [4]. This also suggest, that it is important to reconstruct both PCL and PLC in concomitant injuries.

Because of the synergistic effect the PLC has with the cruciate ligaments, failure to treat concurrent PLC injuries will result in additional stresses and potential ACL or PCL reconstruction failure. Lee et al. reported that isolated PCL reconstruction could not restore

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normal knee kinematics in a combined PCL/PLC injury. In such cases, residual laxity after isolated PCL reconstruction can be controlled successfully with additional PLC reconstruction; as such combined reconstruction of PCL and PLC is necessary in such injuries [13].

## Diagnosis

### Clinical Assessment

PLC injuries occur most commonly with sports injuries, road traffic accidents and falls. The mechanisms of injury include direct blow to the anteromedial knee with knee in full extension, combined hyperextension and varus stress, anterior and posterior rotatory dislocations [11]. Pain localized to the posterolateral aspect of the knee is suggestive of an isolated acute PLC injury [8]. Patients may complain of weakness and numbness of the lower leg which is associated with common peroneal nerve injuries [2].

Patients with PLC injuries may have varus alignment of the knee and have varus thrust gait pattern. In chronic PLC injuries, some patients adopt a fixed knee gait, learning to walk with a partially flexed knee to compensate for the instability. There have been several special tests described to assess for PLC injury. They include the varus stress test, posterolateral drawer test, external rotation recurvatum test and the dial test [7].

The dial test is performed with knee in 30° and 90° flexion. Asymmetry of external rotation of more than 10° at 30° knee flexion suggests isolated PLC injury. Asymmetry of more than 10° external rotation at both 30° and 90° knee flexion is suggestive of concomitant PLC and PCL injuries. This is because the PCL acts as a secondary restraint for lateral rotation of the tibia at higher degrees of knee flexion.

Forsythe et al. recently suggested that interpretations of dial test be taken with precaution. They have demonstrated that ACL ruptures can result in 7° of tibial external rotation at both 30° and 90° knee flexion in the presence of intact PLC. Hence, they have proposed that a value greater than the traditional values of 10° to 15° of increased external rotation, at both 30° and 90° of knee flexion between the affected and contralateral normal side for the dial test to be considered positive for PLC injury when there is a presence of possible ACL injury [14].

A positive reverse pivot shift test is demonstrated when the force causes posterolateral subluxation till about 30°-40° flexion, where the ITB causes the tibia to

reduce. This is when the ITB changes from knee flexor to knee extender with extension of the knee. This test is known to have up to 35% false positive rates, and comparison with contralateral leg is essential [2].

The neurovascular status of the distal limb must be examined to exclude popliteal artery and/or common peroneal nerve injuries that are associated in severe knee ligament trauma. Common peroneal nerve injuries are associated with PLC injuries in up to 13% of cases [2]. A detailed examination of sensation over the foot dorsum, ankle dorsiflexion, great toe extension and foot eversion power should be performed.

### Radiological Assessment

Various imaging modalities can be used to evaluate PLC injuries. This include plain X-ray radiographs, stress views and magnetic resonance imaging (MRI). Routine anteroposterior (AP), lateral and skyline plain radiographs should be obtained. In chronic PLC injuries, long leg films assessing for limb alignment should be done to evaluate for the possible need for concomitant alignment correction.

Stress radiographs have been shown to be useful for evaluating PLC injuries [15]. The varus stress knee radiographs should be performed with knee in 20° flexion. LaPrade et al. has demonstrated that varus stress radiographs can help to differentiate the severity of PLC injuries; an isolated FCL tear had a side-to-side difference of approximately 2.7-4.0 mm while grade III PLC injuries had an increase in >4.0 mm [16].

Recent studies by Kane et al. suggest that a slightly lower value of 2.2 mm side to side difference to be indicative of a grade III FCL tear. They also suggest that midpoint of lateral tibia plateau to be most reproducible point for assessing varus gapping [17]. Stress radiographs have also been shown to correspond to severity of the PLC injury seen on MRI evaluation. Varus gapping on stress radiograph of 12.8 mm correlates to partial injury on MRI while 18.6 mm corresponds with complete PLC disruption on MRI [18].

Kneeling PCL stress radiographs also can help differentiate between isolated PCL (4-12 mm) against combined PCL/PLC injuries (>12 mm) [19]. Pre-operative varus stress radiographs are also useful for post op comparisons to objectively assess the stability of PLC reconstruction after surgery [15].

MRI evaluation is helpful to assist in determining the severity of the PLC injury and

evaluation of concurrent injuries. In the setting of acute PLC injuries, bone bruising can be seen in the medial compartment [20, 21]. MRI sequences in coronal oblique T2 weighted views with thin slice (2mm) through the fibula head have been shown to visualize the FCL, PFL and PT injuries well with highest sensitivity [22]. The combination of ACL and lateral meniscal injuries detected on MRI are suggestive of a higher incidence of concomitant PLC injury [3]. Filli et al. showed that FCL complete tears or avulsion, followed by biceps femoris tendon tear are most significant predictors of PLC instability [23]. However, the sensitivity for detecting FCL and PT injuries on MRI are low; they were only detected to be 57.5% and 24.2% respectively [24].

Arterial studies should be performed if there is suspicion of concomitant vascular injury. Nerve conduction studies and electromyogram should be done if any neurological deficit is detected on clinical examination [15].

### Arthroscopic Assessment

Arthroscopy can also provide objective evaluation of PLC structures. During arthroscopy, the drive through sign, seen when there is >1.0 cm of lateral joint line opening with varus stress applied to knee, is pathognomonic of grade III PLC injuries [25]. The Lateral gutter drive-through sign has also been described Feng et al. as an indicator of laxity in the proximal popliteus tendon, and can aid in diagnosing popliteus femoral peel-off lesions. The sign is elicited via passing the arthroscope into the posterolateral compartment; through the interval between the popliteus tendon and lateral femoral condyle [26].

In addition, arthroscopy also allows direct visualization of popliteus complex, coronary ligament of lateral meniscus and the posterolateral capsule injuries. This will subsequently influence surgical planning of incisions for repair or reconstruction of PLC [27].

In their series of 48 consecutive acute posterolateral corner surgery cases, Feng et al. found that 40% had femoral popliteus and FCL peel off lesions. This was based on pre-operative MRI and arthroscopic examinations. The tears were categorized: isolated PT tear (21%), combined PT/FCL tears (37%) and complex tears either intrasubstance and combined fibula tears (37%). 82% of cases showed conclusive evidence of femoral

insertion separation and discontinuity. The correlation of arthroscopic findings of acute avulsion and positive lateral gutter drive through sign were found in 94% [28].

**Grading of PLC injuries**

Management of PLC injuries are dependent on the chronicity, severity of the injury, and

Table 1: PLC injury classification systems	
Modified Hughston Classification	Grade I: 0-5 mm of varus instability, 0°-5° of rotational instability.
	Grade II: 5-10 mm of varus instability, 6°-10° of rotational instability.
	Grade III: >10 mm of varus instability, >10° of rotational instability.
Fanelli Classification	Type A: only rotational instability (injuries involving popliteus tendon and PFL only)
	Type B: rotational instability with mild varus of 5-10mm increased lateral joint line gapping (injuries to FCL, popliteus tendon and PFL)
	Type C: rotational instability with marked varus instability >10mm (injuries to PLC structures and cruciate ligament)

associated injuries. The PLC injury classification currently most in used are the modified Hughston classification and Fanelli's classification. The modified Hughston classification assesses for degree of varus or rotational instability under varus stress of the knee in full extension [29]. Fanelli's classification assesses for posterolateral instability of at least 10° in tibial external rotation compared to the normal knee at 30° knee flexion together with the degree of varus instability which is dependent on the injured structures [30].

The 2018 expert consensus on PLC injuries are in agreement that more research should be looked into developing a classification system that can indicate type of structures injured, chronicity of injury and type of injury (avulsion type versus intrasubstance type). The new classification system should also help guide prognosis and treatment plans [15].

**Management**

**Conservative Treatment**

Grade I and II isolated PLC injuries are generally managed conservatively. Rest, ice, compression and elevation (RICE), knee bracing locked in extension for 6-8 weeks and physiotherapy are prescribed. Favourable long-term outcomes have been demonstrated for conservative treatment for this group of patients with minimal radiographic changes seen at 8-year follow-up [31,32].

Grade III injuries comparatively have been shown to have poor outcomes with conservative therapy alone. Studies have shown poor long-term results with higher numbers of chronic instability and post-traumatic osteoarthritis [31,32]. It has also been shown that increased forces are placed on

ACL/PCL reconstruction with untreated concurrent grade III PLC injury, leading to higher rates of cruciate reconstruction failure [4]. This group of injuries typically benefit from surgical intervention.

**Surgical Treatment**

Surgical treatment is indicated for grade III PLC injuries or grade II PLC injuries with concomitant ACL or PCL injuries. The treatment options are dependent on chronicity (acute < 3 weeks versus chronic > 3 weeks), and other associated ligamentous injuries.

**Acute PLC injuries**

Acute PLC injuries can be treated with surgical repair if there is remnant tissue of sufficient quality. Should repair be not feasible, augmentation or reconstruction will be necessary. The optimal time for surgery in acute PLC injuries has been suggested to be within 3 weeks.

The concept of PLC repair is controversial. Stannard et al. in 2005 reported that reconstruction shows favorable outcomes with only 9% failure rates compared to repair failure rates of 37% [33]. Likewise, Levy et al. in 2010 also reported similar results favouring reconstruction over repair; 40% failures in the repair group versus 6% in the reconstruction group. The authors felt that PLC reconstruction was a more reliable option than repair alone in a multiligament knee injury [34].



**Figure 1:** A Pradiograph demonstrating fibula avulsion fracture



**Figure 2:** Coronal MRI showing fibula avulsion fracture with biceps femoris insertion attached



**Figure 3 :** Sagittal MRI showing fibula avulsion fracture



**Figure 4:** AP radiograph of post-fixation fibula avulsion with headless screw



**Figure 5:** Lateral radiograph of post-fixation fibula avulsion with headless screw

More recently, other authors have reported contrary results. McCarthy et al. suggested that PLC repair can still be considered. They reported PLC repair failure rates of 11% against PLC reconstruction failure rates of 4.7%; which was comparatively better than

reported previously. The repairs were operated within 3 weeks and the repairs were mainly distally based avulsion types with acceptable remnant soft tissue integrity [35]. Similarly, Westerman et al. have also demonstrated low PLC failure rates of 7%, and comparable good outcomes between PLC repair and reconstruction with concurrent ACL reconstruction at 6 year follow up [36]. Repairs are only recommended for injuries involving avulsions especially for structures avulsed off the fibular head (FCL, PFL, popliteus or biceps tendon) or those involving the lateral capsule and meniscocapsular ligaments which can be sutured or anchored back to underlying bone [37]. (Fig 1-5 shows repair of an acute fibula head avulsion) The mid-substance repair can still be performed, but should be augmented with reconstruction of injured structure. This allows preservation of the anatomy, isometry and function of the PLC structure and together with reconstruction procedures, reduces risk of failure [38]. In cases with complete destruction of the lateral knee structures in severe knee ligament trauma (Fig 6), repairs are not possible.



**Figure 6:** Coronal MRI showing complete disruption of lateral knee structures in multiligament knee injury

### Chronic PLC injuries

In patients with chronic PLC injuries, repair is not an option as the structures are retracted and scarred. Therefore, PLC reconstruction techniques are indicated. For these patients, limb alignment must also be assessed. Alignment correction with a proximal tibial osteotomy must be considered if there is more than 3° varus deviation or if the hip-knee axis passes within 30% of medial side of tibial plateau. Uncorrected malalignment can result in increased stresses to the PLC reconstruction and subsequent failure [8].

### PLC Reconstruction Techniques

Reconstruction techniques can be broadly classified into non-anatomic and anatomic based on the ligaments reconstructed and position of the reconstruction tunnels. Anatomical reconstructions surgically reproduce the main three stabilizers to the PLC, the FCL, PFL and popliteus tendon and their anatomical footprints. Non-anatomic reconstructions do not reproduce all three structures, or do so by non-anatomic attachments.

Non-anatomic reconstructions techniques include arcuate complex or bone block advancement, biceps tenodesis and extracapsular ITB slings. Previously, ligament tightening procedures have been described by Hughston et al. and Lerat et al. These procedures aim to tighten the distended posterolateral corner structures. The Hughston technique can be utilized to tighten stretched popliteal tendon at the femur via reinsertion with a bone block above and in front of its insertion with staple or screw. Lerat previously described tightening of posterolateral structures via transposing fibula head and tightening of the posterolateral capsule [39]. However, the resulting isometry differs from original anatomy. Although laxity is controlled in extension, this is lost in flexion when the structures are relaxed and are unable to control lateral rotation of tibia [10, 40].

Various investigators have performed cadaveric studies to evaluate anatomic and non-anatomic PLC reconstructions. Raub et al. in 2010 reported that both the fibula-based and combined posterolateral reconstruction techniques were equally effective in restoring stability after injury [41]. Likewise, Plaweski et al. in their cadaveric study have shown that despite the description of other complex anatomical reconstruction techniques, a single graft fibula-based reconstruction of the FCL and PT can restore varus and external rotation laxity of the knee [42].

In 2011, Yoon et al compared the results of 17 Cases of anatomic PLC reconstruction with popliteal reconstruction and 15 cases of anatomic PLC reconstruction without popliteal reconstruction. They reported that popliteal tendon reconstruction was found to have no effect in PLC reconstruction stability and results [43].

However other recent studies have demonstrated that the more complex anatomic PLC reconstruction were more biomechanically favourable than non-anatomic reconstructions. Kim et al. found

that anatomical reconstruction of PT and FCL showed favourable outcomes compared to biceps rerouting tenodesis [44]. Kang et al. in 2017 have demonstrated that anatomic reconstructions via anatomic tibial based reconstruction or anatomic fibular based reconstruction better restore knee condition and mechanics compared to non-anatomic reconstructions [45].

We now describe some of the more commonly utilized PLC reconstruction procedures by surgeons in this day and age. We have also included technique modifications and technical pearls that have emerged in the literature for PLC reconstruction. These improvements have brought PLC reconstruction in 2020 to a new state of the art level.

### Clancy Procedure

The Clancy procedure involves rerouting the biceps tendon over the origin of the FCL at the lateral femoral epicondyle to mimic FCL function. The procedure aimed to provide varus stability and reinforcing the PLC by tightening biceps tendon attachment to the arcuate complex. This method has previously been shown to result in objective and functionally acceptable knee functions for PLC injuries [46].

### Stannard Reconstruction Technique

The Stannard reconstruction technique is a non-anatomic reconstruction technique that reconstructs the FCL, popliteus tendon and PFL. It utilizes a trans tibial tunnel drilled from anterior to posterior, exiting at the musculotendinous junction on the tibia. A second tunnel is drilled through the fibula from anterior to posterior. The fixation on the femur utilizes a screw washer anterior to where the intersection between FCL and popliteus, taken as the isometric point on the femoral condyle. The graft is passed through the tibia tunnel from front to the back and secured with an interference screw. The free limb of the graft is looped around the femoral screw and rerouted through the fibula from posterior to anterior and then re-secured back to the screw. Although the three major PLC structures are reconstructed in this technique, the reconstruction is considered non-anatomic [47].

### Larson Reconstruction Technique

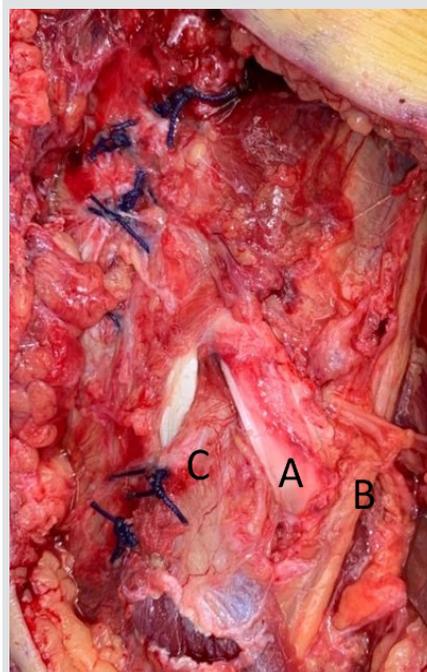
The Larson technique is a fibula-based reconstruction, performed by passing a semitendinosus graft through the fibula head,



**Figure 7:** Coronal pre-op MRI showing PLC deficiency in chronic PCL and PLC injury



**Figure 8:** Coronal post-op MRI after Larson reconstruction with fibula sling, PCL reconstruction in patient with concomitant chronic PCL and PLC injuries



**Figure 9:** Intraoperative photo showing exposure of common peroneal nerve, demonstrating its close relationship to the fibula tunnel and semitendinosus autograft (A semitendinosus graft limb, B common peroneal nerve, C fibula head)



**Figure 10:** AP Radiograph of combined all-inside ACL with semitendinosus autograft and minimally invasive FCL reconstruction with gracilis autograft

followed by fixation of both graft limbs in a single lateral femoral tunnel with an interference screw. (Fig 7, 8) This primarily reconstructs the function of the FCL. The femoral tunnel was placed in an isometric but non-anatomic point. This technique is less technically demanding and offers good functional outcomes [48].

It is important to note that if the fibula tunnel is drilled from anterior to posterior, and if the tunnel direction is not directed medially, the posterior graft limbs can potentially come in close contact with the common peroneal nerve. (Fig9)

Recently, a surgical technique has been described for an all-inside combined ACL and FCL reconstruction, utilizing only the ipsilateral hamstring tendons. The semitendinosus is quadrupled and used as an all inside ACL graft with two adjustable cortical fixation buttons. The gracilis tendon is looped through the fibula head and secured in a single lateral femoral tunnel for FCL reconstruction via 2 minimally invasive incisions [49]. (Fig 10) This technique negates the need for additional autograft or allograft options.

#### Arciero Reconstruction Technique

Arciero described a modification of the Larson's reconstruction technique with a fibula-based reconstruction. The insertion sites of the FCL and PT is done using dual lateral femoral socket/tunnel technique. One graft limb is passed into the popliteus socket and fixed with interference screws. The knee is then flexed 60° with valgus stress and the graft is passed through the 7mm trans fibular tunnel created from distal lateral to proximal medial through the fibular head, ensuring adequate surrounding bone stock. The graft is fixed to the tunnel with interference screw. The other

limb of the graft is then secured into the FCL socket and tensioned with knee 30° with valgus stress with interference screw. This technique has been reported to successfully restores varus angulation and lateral rotation stability [50].

#### LaPrade Anatomic Reconstruction Technique

LaPrade et al. first described an anatomical PLC reconstruction in 2004, that reconstructs the FCL, PT and PFL anatomically. This reconstruction utilizes both fibula and tibial tunnels. The femoral insertion for PT and FCL were identified and two sockets are created. A 7mm trans fibular tunnel is created exiting posteromedially on the fibular head. A 10mm trans tibial tunnel is created starting from a point between the Gerdy and tibial tubercle and exiting in the popliteal sulcus over the posterior tibia. The first allograft is passed via the anatomic course of the PT and through the trans tibia tunnel from posterior to anterior, and is used to reconstruct the popliteus tendon. The second graft is passed via the anatomic course of FCL, through the trans fibular tunnel from lateral to posteromedial, and is used to reconstruct both the FCL and PFL. The knee is then flex to 30°, with neutral rotation and valgus stress where the graft is tensioned and fixed in the fibula tunnel with interference screw. The FCL graft is then pulled through the tibia tunnel from posterior to anterior and both grafts are tensioned with knee flexed to 60°, with neutral rotation and valgus stress and secured with interference screw [51].

#### Popliteal Bypass Graft

The popliteal bypass graft was first described by Werner M in 1982 with the goal of regaining the stabilizing function of the popliteus complex. This graft is reconstructed with graft passing from a tibia tunnel drilled (anterior to posterior, at the PT musculotendinous junction) to the PT insertion on the lateral femur condyle. This PT restoration is critical to limit posterior translation and external rotation in a chronic high-grade PCL deficient knee.

Frosch et al subsequently described an arthroscopic technique for popliteus reconstruction that was reproducible and had high accuracy [52]. He later demonstrated good clinical outcomes with low complication rates for patients that underwent a combined arthroscopic PCL and popliteal bypass graft reconstruction for patients with chronic PCL and PLC instability [53].

### Arthroscopic Posterolateral Capsular Stabilization

The posterolateral capsule has an important role in stabilizing posterolateral rotation. Recent literature has shown surgeons who addressed posterolateral capsular deficiency arthroscopically. Ohnishi et al described an arthroscopic technique to stabilize the posterior joint capsule in patients with posterolateral instability without significant injury to the FCL, PFL and popliteus tendon [40].

The LaPrade, Larson and Arciero techniques has been adopted by surgeons worldwide with modifications in fixation and graft choice. Much work has been put in over the previous decade to optimizing surgical technique. Treme et al reported in their cadaveric study that both the Arciero reconstruction and LaPrade are equally effective at restoring stability to knees with PLC injuries. However, they also reported that neither reconstructions were able to address combined PLC and proximal tibiofibular joint injuries [54]. Van Gennip et al. has also demonstrated recently that Larson's fibular sling reconstruction technique had comparable functional and radiographic outcomes against LaPrade anatomical reconstruction [55].

Kuzma et al. has described a technique of PLC reconstruction combining the principles of Arciero's technique and posterolateral capsular shift technique utilizing single Achilles tendon graft [56]. Tapasvi et al. proposed the use of peroneus longus tendon autograft as a Y graft for anatomical PLC reconstruction. The authors have suggested that the peroneus longus tendon is easy to harvest with less donor site morbidity and provides good graft length and diameter. This is helpful in the setting of multiligament injuries with planned concomitant cruciate ligament repairs [57].

Selim described a technique of combined ACL and PLC reconstruction with hamstring autograft through a single femoral tunnel using graft to graft suspension and fixation. This technique potentially mitigates risk of femoral tunnel conflict, due to close proximity of the ACL and FCL tunnels in lateral femur [58].

Recent advances in arthroscopic PLC reconstruction procedures have been made, minimizing soft tissue dissection and large incisions. Hermanowicz et al. describe arthroscopic minimally invasive anatomic PLC reconstruction [59]. Frings et al. presented an all arthroscopic technique of PLC reconstruction utilizing the principles

from Arciero's technique [60].

Likewise, Kolb et al. has also described an all arthroscopic technique utilizing principles from LaPrade's technique [61]. Ahn et al. also described a novel arthroscopic technique to anatomically reconstruct the FCL, popliteus and PFL ligaments [62]. The authors were able to establish critical landmarks for anatomical reconstruction for FCL, PFL and PT anatomic reconstruction arthroscopically.

### Technical Pearls for Anatomic PLC reconstruction

Recent literature by various authors have helped surgeons to understand the surgical anatomy, radiological-anatomy and technical demands of an anatomic PLC reconstructions. This has aided the replication of the surgical techniques and increased the adoption of this technique worldwide.

The insertion of the FCL on the fibula is located anterior-inferior superficially and the PFL was inserted into the posterior superior deep portion of the styloid process [63]. For anatomical surgery, this means when drilling the fibula tunnel, the start point is from the anterolateral aspect of the fibula styloid (insertion of the FCL on the fibula) 8 mm posterior to anterior margin of fibula 28 mm from the fibula tip. The drill is directed 50 degrees external rotated from midline (tibia) and 60 degrees cephalad (cranial). This direction is posterior-superior-medial to reach the fibula insertion of the PFL [64].

The location of the femoral insertion of the FCL noted in their radiological study was on average 58% across the width of the femoral condyle and 2.3 mm inferior to Blumensaat line [65]. The popliteus tendon was found always to be attached to anterior-inferior portion of the femoral attachment of the FCL, and the average distance from the origin of the PT insertion to the CL insertion was 18.5 mm [63].

Radiologically, the femoral insertion site of the popliteus tendon was found to be a mean 47.5% +/- 5.2% across the width of the femoral condyle, 60.7% +/- 7.8% along the perpendicular bisector of Blumensaat lie, 0.3 +/- 1.7 mm posterior to the extension line of the posterior femoral cortex [66].

In combined ACL and PLC surgery, the safe angle for the creation of the FCL and PT tunnels with an ACL tunnel present are 20° cephalad (anterior) and 10° proximal. This helps to reduce the risk of ACL and PLC tunnel conflict [67].

The ideal point for tibia posteriorly was defined as the musculotendinous junction of the PT near to the insertion of the PFL radiologically, in the coronal plane, the ideal tibia point can be located radiologically located at the crossing of the tangent to the fibular head, parallel to the joint line with a tangent to the medial border of the fibula head [68].

For FCL fixation, the fixation is recommended to be performed in 20° flexion neutral rotation with application of valgus force [69]. The graft is fixed at 20°-30° flexion because biomechanical studies have shown that these are the angles at which the greatest amount of varus instability is created by sectioning the FCL [70].

For the PT reconstruction, the fixation is performed in 90° flexion, 5° internal rotation with a valgus force applied. For the PFL reconstruction, the fixation performed in 90° flexion with a valgus force applied [57].

### Rehabilitation

After PLC reconstruction, patients are put on knee brace and protected bearing status for 6 weeks [6]. Physiotherapy should be commenced immediately with a special focus on knee range of motion (ROM) exercises, oedema control and progressive quadriceps strengthening.

In the first 6 weeks, passive ROM exercise are performed from 0°-90°. After 6 weeks, patients can be allowed full range of motion, full weight bearing and allowed stationary bike exercises. Jogging and more intensive strengthening exercises can be commenced after 4-6 months post-surgery. Return to sports is possible at about 9-12 months post-surgery after checking for stability, range of motion, agility and musculature strength.

### Reconstruction Outcomes

The outcomes of PLC reconstructions in the literature are good. Geeslin AG et al reported that the treatment of grade III posterolateral knee injuries with acute repair of avulsed structures, reconstruction of midsubstance tears and concurrent reconstruction of cruciate ligaments resulted in significantly improved objective stability [71]. Moulton et al. in their 2015 systematic review of 15 studies of 456 patients reported that while surgical techniques varied, the surgical management of chronic PLC injuries had a 90% success rate and a 10% failure rate. The surgical techniques in the review included fibula slings, capsular shifts and anatomic PLC techniques [72].

New evidence has shown that single stage acute multiligament surgery can achieve good outcomes. Tardy et al. reported that acute one stage PLC reconstructions had better subjective outcomes than in chronic PLC reconstructions [73]. Similarly, Godin et al. reported that single stage multiligament knee reconstruction was a reliable procedure in adolescent patients that improves knee function at 2 years follow-up with good patient satisfaction [74].

Recent evidence has also demonstrated the importance of addressing all the ligament deficiencies with combined surgery. The French Arthroscopy Society multicentre study on the combined PCL and PLC surgery in 53 patients revealed that patients could return to functional efficacy; all sedentary workers and 86.7% of non-sedentary patients could return to work [75]. Li et al. reported that patients who underwent combined PCL and PLC repair/reconstruction had improved subjective and objective clinical outcome at minimum of 24 months follow-up. They have suggested that patients with residual positive lateral gutter drive through sign on second look arthroscopy had poorer results [76].

Yates et al. have demonstrated that return to employment and sports is possible with combined ACL/PLC reconstruction. They also showed that at 5 years follow-up,

combined ACL/PLC reconstruction group patients had IKDC scores that were no different from the isolated ACL reconstruction group [77]. Similarly, Moulton et al. suggested that postoperative patient reported outcome scores were not significantly different for patients who underwent concomitant ACL/FCL reconstruction versus those who underwent isolated FCL reconstruction. Their series of anatomic FCL reconstruction with semitendinosus graft in 43 patients yielded high patient satisfaction and significantly improved patient function [78].

The trend towards anatomic PLC reconstructions in the last decade has seen the various authors reporting their results of anatomic PLC reconstructions in the last 5 years. Gormeli et al. reported significant improvement in the objective knee stability scores and clinical outcomes with anatomic PLC reconstruction for the chronic PLC injured knee [79]. Franciozi et al. reported that the anatomic PLC reconstruction using hamstring tendon grafts, combined with other surgical procedures in a multiligament knee injury helped improve outcome scores for patients with chronic PLC injuries [80].

Knee experts have modified the anatomic reconstruction to improve and further replicate anatomy. Yoon et al. in 2016 described an alternate anatomic

femoral-based PLC/PFL reconstruction. This was different from the more commonly performed tibiofibular-based anatomic reconstruction described by LaPrade. These 2 techniques were compared and there were no differences in clinical outcomes and varus stability, though it was noted that the external rotation grade of the tibia was smaller in the tibiofibular based PFL reconstruction group [81].

## Conclusions

The literature over the last 10 years have helped surgeons to better manage posterolateral reconstructions of the knee. We now understand the value of physical and radiological assessment especially stress radiographs to determine the best treatment option. The management of PLC injuries include acute repairs as well as anatomic reconstructions for irreparable acute injuries and chronic lesions. Recent evidence of PLC reconstructions outcomes has confirmed the success of early management of combined injuries and addressing all ligament deficiencies anatomically to restore knee function. This will allow us to achieve best long-term outcomes for the patients.

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