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Assessing "PCL Plus Popliteus" injuries

Stephen O'Neil[a,*], Ashley Nord[c], J. Imani Dupree[c], Matthew Pate[b], Michelle A. Padley[c], Lindsey Behrend[c], Michael Jabara[c]

[a] Department of Orthopaedics, Metro Health-University of Michigan Health, 2215 44th St. SW, Wyoming, MI, 49519, USA
[b] Michigan State University College of Human Medicine, 15 Michigan St. NE, Grand Rapids, MI, 49503, USA
[c] Orthopedic Associates of Michigan, 1111 Leffingwell Ave NE, Grand Rapids, MI, 49525, USA

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ABSTRACT

Objective: To highlight the incidence of grade III PCL injuries with simultaneous PCL & popliteus injury.
Methods: Inclusion criteria: patients who underwent PCL reconstruction for grade III PCL tear & minimum of 1-year follow-up. Exclusion criteria: associated ACL injury & insufficient follow up. Patients seen postoperatively at 2 weeks, 6–8 weeks, 4–6 months, 6–9 months, 1 year, and 1 + years.
Results: 89.5% of patients in this study had an associated popliteus injury.
Conclusions: Isolated grade III PCL injury may not frequently exist, rather undiagnosed & untreated concurrent popliteus injury can have less successful outcomes after isolated PCL reconstruction.

1. Introduction

1.1. Background

Posterior cruciate ligament (PCL) injuries account for about 38% of all acute knee injuries. Roughly 56% of those occur in the setting of poly-trauma and 30% occur in the face of a sports related injury.[1,2] In the setting of trauma, the injury classically occurs when the proximal tibia is translated posteriorly and externally rotated relative to the femur as in the setting of a deceleration motor vehicle accident when the knee hits the dashboard. In athletes, the injury most commonly occurs secondary to a direct blow to the tibial tubercle causing the tibia to translate posteriorly or due to a fall on the knee while the foot is in plantar flexion.[3] It is well known that PCL injuries do not primarily occur in isolation, and has been reported that other ligamentous structures may be involved in up to 95% of PCL injuries.[1,3] The most commonly associated ligamentous and soft tissue injuries include the anterior cruciate ligament (ACL), the posterolateral corner (PLC), and the medial cruciate ligament (MCL).[4] However, isolated PCL tears with no other ligamentous injury seen on imaging have continued to fail after reconstruction. The specific incidence of popliteal injuries in the setting of PCL rupture has not previously been reported. This lack of understanding of the incidence and role of the popliteus in PCL injuries could be one the main reasons PCL reconstructions fail.

1.2. Anatomy

The PCL is the primary restraint to posterior tibial translation. Its femoral insertion is a broad, vertically oriented footprint at the anterolateral aspect of the medial femoral condyle. The PCL runs posterolaterally toward the central posterior aspect of the tibia, inserting on its own fovea approximately 1 cm distal to the joint line, just posterior to the posterior horn of the medial meniscus. The PCL is made up of the anterolateral and the posteromedial fiber bundles.[5]

The popliteus muscle is a thin, flat, triangular muscle that forms part of the floor of the popliteal space. It is an integral component of the posterolateral knee and contributes to varus & rotational stability of the knee. It functions to unlock the knee when walking, medially rotate the tibia, and to help the PCL prevent posterior translation of the tibia in relation to the femur.[6] The popliteus has a wide attachment on the posteromedial tibial surface proximal to the soleal line, forming the floor of the popliteal fossa. It continues superiorly and laterally, forming a long and strong tendon that enters the knee through the popliteal hiatus. The tendon inserts in a depression on the outer side of the lateral condyle of the femur. The tendinous attachment lies anteroinferior to the proximal attachment of the lateral collateral ligament on the lateral epicondyle.[7]

The popliteus musculotendinous unit is an integral part of the posterolateral corner (PLC) of the knee. Discussion of the popliteus will be incomplete without describing the other structures of the posterolateral corner and their intimate relation to the popliteus. The

* Corresponding author. 2163 Glenn Canyon Dr, Caledonia, MI, 49316, USA.
E-mail address: oneilsr@gmail.com (S. O'Neil).

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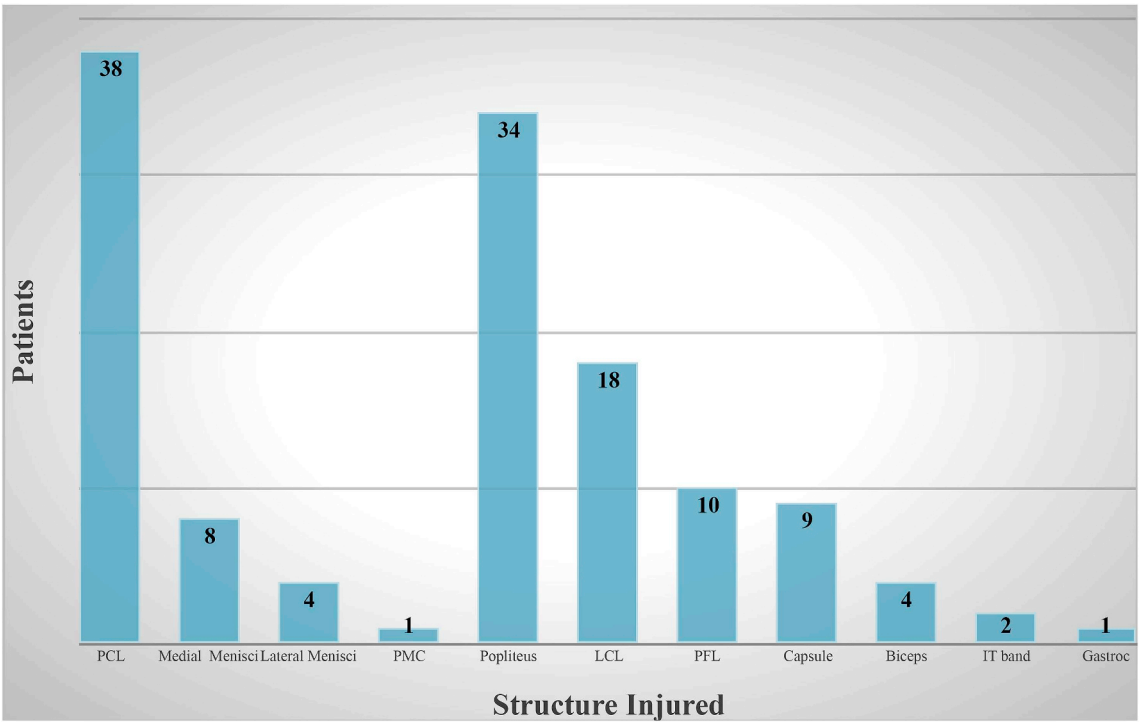
Table 1
Frequency of concurrent injuries.



anatomy of the posterolateral aspect of the knee has been described using a three-layer approach. Layer 1 corresponds to the superficial layer and includes the iliotibial band anteriorly and biceps femoris tendon posteriorly. Layer 2 consists of the lateral patellar retinaculum and patellofemoral ligament. The true lateral collateral ligament is also considered a layer 2 structure. Layer 3 consists of the deep posterolateral structures, which consist of the popliteus muscle and its tendon, popliteofibular ligament, lateral joint capsule, arcuate ligament, fabella, fabello-fibular complex, and peroneal nerve. Thus, the posterolateral corner, also referred to as the arcuate complex, includes the lateral collateral ligament, arcuate ligament, popliteus muscle and tendon, popliteofibular ligament, fabello-fibular ligament, and posterolateral capsule.[8]

1.3. Physical exam

When assessing the stability of the PCL, there are two basic physical exam tests that can be performed in the office. The tests are the posterior drawer test and the quadriceps active test. Each test is performed with the hip flexed to 45° and the knee flexed to 90°. In this position, there is loss of the normal anterior tibial step-off with a PCL injury. In the posterior drawer test, the foot is positioned in neutral rotation, the examiner then immobilizes foot and places the thumbs on the tibial plateau and pushes a posterior directed force to assess for increased translation.[9] In this test we can subjectively grade the level of tear. In a Grade 1 tear, the ligament is stretched and will posteriorly translate 0–5 mm and the tibia remains anterior to the femoral condyles. In a Grade 2 tear, the ligament is partially torn and will posteriorly translate 6–10 mm and the anterior tibia may become flush with the femoral condyles. In a Grade 3 tear, the ligament is completely torn, there is greater than 11 mm posterior translation and tibia is usually posterior to the femoral condyles.[6] However, some studies have reported the posterior drawer sensitivity and specificity to be only 51% and 55% respectively in acute PCL tears.[10]

In the quadriceps active test, the patient is placed in same position as posterior drawer test but patient is asked to contract their quadriceps. In the PCL injured/deficient knee placed in this resting 90° position, the tibia is subluxated posteriorly, but activation of the quadriceps causes the patellar tendon to reduce the tibia. This observable reduction is a positive result.[11] The sensitivity and specificity has been reported as 54% and 98% respectively.[12]

The examiner must also be aware of the dial test and always perform this in conjunction with posterior drawer test and the quadriceps active test in suspected Grade 3 PCL tears in order to ensure there isn't a concurrent PLC and perhaps popliteus injury. The test must be done in the prone position. Both knees are flexed first to 30° (to isolate PLC) and then to 90°, with external rotation applied to the tibias at each position. The test states that if there is a 10-degree increase in external rotation with knee flexed at 30° but not 90° compared to the contralateral side, this is positive for an isolated PLC injury. If the test is positive at both 30 and 90° of knee flexion, the test is positive for both a PLC and PCL injury.[13]

There is no specific test for popliteus injury. Although certain tests can allude to a posterolateral corner injury, including the Dial test, External Rotation Recurvatum Test, and the Posterolateral Rotator Drawer Test, none of these isolate the popliteus.

2. Methods

The cohort for this study consisted of 38 patients and knees that were treated in Grand Rapids, MI from 1/1/2005 through 12/31/14 by the senior author. Data was retrospectively reviewed and extracted from a multi-ligamentous knee injury database and office electronic medial record. Inclusion data was comprised of patients who underwent a PCL reconstruction for a grade III PCL tear and a minimum of 1-year follow-up. Exclusion criteria included an associated ACL injury and insufficient follow up. The patients in the study were seen postoperatively at 2 weeks, 6–8 weeks, 4–6 months, 6–9 months, 1 year, and 1 + years.

PCL tears were graded based on the current grading scale in the literature with a grade I tear including 0–5 mm of posterior translation of the tibia in relation to the femur, a grade II tear including 6–10 mm

Table 2
Injury pattern with all 4 knees without associated popliteus injury.

PCL	Medial Menisci	Lateral Menisci	PMC	Popliteus	LCL	PFL	Concurrent Musculoskeletal Injuries
Yes	Yes	No	No	No	Yes	No	Tibial Plateau Fracture
Yes	Yes	No	No	No	No	No	Tibial Plateau Fracture
Yes	Yes	No	Yes	No	No	No	Forearm Fracture
Yes	Yes	No	No	No	No	No	None

of posterior translation, and a grade III tear including 11 mm or more of posterior translation.[11]

3. Results

38 patients and knees met inclusion criteria for this study. All patients had grade III laxity on pre-operative posterior drawer testing. 35 patients underwent PCL operative reconstruction with allograft, while the other 3 patients underwent operative repair. 89.5% (n = 34) of these patients had an associated popliteus injury as seen during surgery by the senior author (Table 1). MRI findings were reviewed with respect to the popliteus and of those with an MRI (n = 24), 63% (n = 15) either had no comment of popliteus injury, or incorrectly stated that it was intact. Of the 4 knees without a popliteus injury, all 4 knees had medial meniscal tears. No ACL injuries were encountered in this population. Concomitant injured structures noted were MCL injuries (10.5% [n = 4]), medial meniscal injuries (21% [n = 8]), and lateral meniscal injuries (10.5% [n = 4]).

A complication rate of (n = 3) was seen (Tables 1 and 2). These complications consisted of one deep wound infection, leading to irrigation and debridement and finally a revision PCL reconstruction resulting in the end with grade 3 stability; a case of PCL failure leading to revision PCL reconstruction; and a case of gastrocnemius contracture leading to resection of the gastrocnemius.

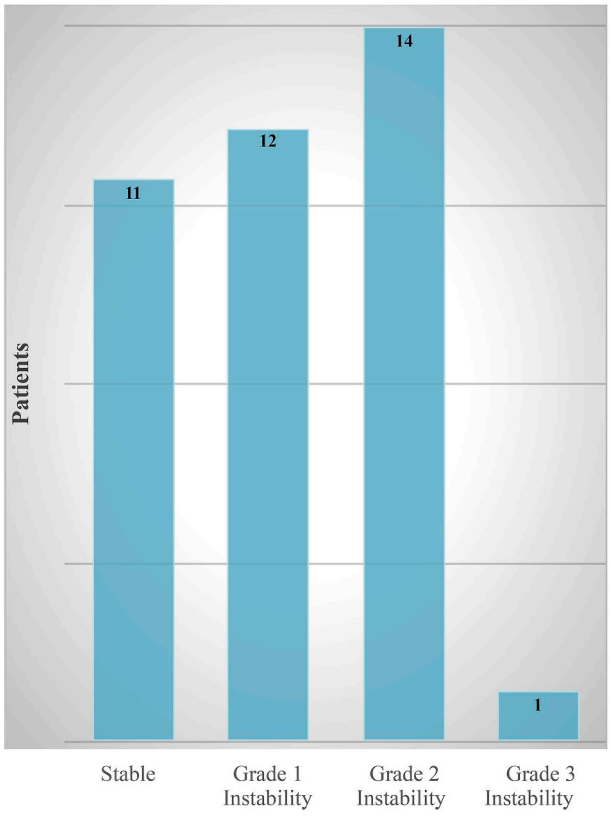
At the latest follow-up, 16 months on average, posterior drawer testing for all patients was classified as 28.9% (n = 11) with stable, 31.6% (n = 12) with Grade I, 36.8% (n = 14) with Grade II, and 2.6% (n = 1) with Grade III laxity. The patient with the Grade III laxity, as described above was one of the patients that required a revision reconstruction secondary to a complication with a deep wound infection (Table 3).

4. Discussion

As seen from this cohort of patients with ligamentous knee injuries, isolated PCL injuries are rare. In the small number of patients from this study, 89.5% of patients with a PCL injury had an associated popliteus injury seen at the time of surgery and 63% of those popliteus injuries were missed on MRI imaging. As previously stated, these combined injuries are a direct result of the anatomy and biomechanics of the PCL with the structures of the posterolateral corner of the knee.

The missed "Popliteus Plus" injury could explain why these seemingly isolated grade III PCL injuries with subsequent reconstruction fail. Studies have proved that isolated PCL reconstructions with a missed posterolateral corner injury fail as a result of the translational forces of the knee. Harner et al. performed a biomechanical analysis of a PCL reconstruction using a robotic universal force moment-sensor testing system. They state that in a combined PCL and PLC injury, deficiency of the posterolateral structures increased posterior tibial translation of the reconstructed knee by 6.0 ± 2.7 mm at 30° and 4.6 ± 1.5 mm at 90° of flexion. External rotation increased up to 14° and varus rotation increased u to 7°. The results in this study demonstrated that a graft that restores knee kinematics for an isolated PCL deficiency is rendered ineffective if the posterolateral structures are deficient.[14]

Table 3
Post Surgical stability.



One question that must be answered is why these popliteus injuries are missed? First, we believe they are missed secondary to the physical exam. The exam of a multi-ligamentous injury can be extremely difficult in the acute trauma setting secondary to swelling and pain. Furthermore, the physical exam maneuvers we have still only isolate posterolateral corner structures as a group and do not isolate specific popliteus injuries. Although the Dial test is used to distinguish PCL and PLC injuries, Krause et al. found that for side-to-side comparison, a difference of > 15° was required for clinical significance.[15] Also, as stated previously, the physical exam maneuvers that signify PLC injuries such as the External Rotation Recurvatum Test, the Posterolateral Rotator Drawer Test, and the Dial Test do not specifically isolate Popliteus injuries; they only group the PLC corner structures as a whole.

Secondly, as seen in this paper, popliteus injuries continue to be missed on MRI even by subspecialty-trained radiologists. In our paper, the MRIs of 24 knees that were known to have popliteus injuries during surgery were reviewed and 15 (63%) of those MRIs made no mention of popliteus injuries or incorrectly stated that the popliteus tendon was intact. This can be accounted for by the complex anatomy and multiple pitfalls that may be encountered while reading MRI images. According to Jadhay et el, on T2-weighted images, a fluid-filled popliteus bursa appears as a well-defined area of high signal intensity surrounding the popliteus muscle and tendon. This bursa may be confused with a tear of the popliteus muscle and tendon or of the posterior capsule (Fig. 1). Furthermore, Jadhay et al. go on to say that as the popliteus tendon passes posterolateral to the lateral meniscus, the interface between them can be seen on coronal and sagittal fluid-sensitive images as a linear hyperintensity. This may be mistaken for a lateral meniscal tear (Fig. 2).

The main weakness of the study is that it simply reviewed the incidence of patients who sustained PCL tears with a popliteus injury that

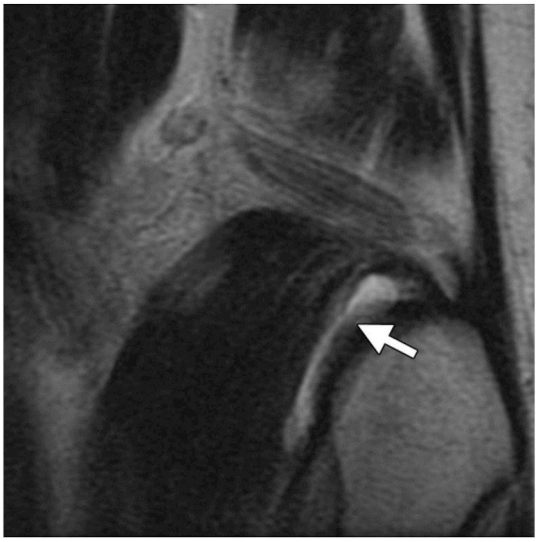


Fig. 1. Fluid extending along the popliteus bursa. Sagittal T2-weighted images show fluid in the popliteus bursa (arrow), which may be mistaken for a popliteus muscle or tendon tear. Note the presence of joint effusion and lack of edema in the popliteus muscle.

Fig. 2. Pseudotear of the lateral meniscus. Sagittal PD-weighted images show a linear hyperintense interface (arrow) between the popliteus and the posterior horn of the lateral meniscus. This may be mistaken for a lateral meniscal tear.

was missed on exam and imaging but later addressed intra-operatively. Post surgical stability was not compared with patients whose popliteus injury was not addressed. A future study should include patients with both PCL and popliteus injury and compare those with a reconstructed popliteus to those without reconstruction/repair.

5. Conclusion

In the setting of grade III PCL injury there is a high incidence of popliteus injury that is commonly missed on imaging and evaluation. The clinician must have a high suspicion for this injury pattern to ensure optimal outcomes for patients with PCL injuries. This has not been previously described in the literature, and thus further evaluation of this concomitant injury is necessary. Missing a popliteus injury could lead to sub-optimal long-term outcomes in patients that present with a PCL injury. Further prospective studies are warranted.

Author descriptions

Stephen O'Neil (oneilsr@gmail.com) is the primary author for writing the manuscript. J. Imani Dupree (Imani_Dup@msn.com) came up with the idea for the study and with the help of Ashley Nord (ashleynord1019@gmail.com) provided technical guidance for manuscript development. Matthew Pate (mjpate22@gmail.com) assisted with data analysis and authorship of the manuscript. Michelle Padley (michelle.Padley@oamichigan.com) and Lindsey Behrend provided preliminary descriptive statistical review along with editorial influence. Michael Jabara (michael.Jabara@oamichigan.com) performed the surgery and managed the patients.

Conflicts of interest

The authors of the manuscript titled Assessing the Incidence of “PCL Plus Popliteus” Injuries report NO conflicts of interest to disclose. These authors include: Stephen O'Neil, DO, Ashley Nord, MD, J. Imani Dupree, MD, Matthew Pate, BS, Michelle Padley, BS, CRC, Lindsey Behrend, BS, and Michael Jabara, MD.

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References

1. Fanelli GC, Feldmann DD. Management of combined anterior cruciate ligament/posterior cruciate ligament/posterolateral complex injuries of the knee. *Operat Tech Sports Med.* 1999;7:143–149.
2. Fanelli GC, Giannotti BF, Edson CJ. The posterior cruciate ligament arthroscopic evaluation and treatment. Current concepts review. *J Arthrosc Relat Surg.* 1994;10(6):673–688.
3. Pache S, Aman ZS, Kennedy M, et al. Posterior cruciate ligament: current concepts review. *Arch Bone Jt Surg.* 2018;6(1):8–18.
4. Fanelli GC, Edson CJ. Posterior cruciate ligament injuries in trauma patients: Part II. *Arthroscopy.* 1995;11(5):e526–e529.
5. Edwards A, Bull AM, Amis AA. The attachments of the fiber bundles of the posterior cruciate ligament: an anatomic study. *Arthroscopy.* 2007;23(3):284–290.
6. Peterson L, Pitman MI, Gold J. The active pivot shift: the role of the popliteus muscle. *Am J Sports Med.* 1984;12(4):313–317.
7. Siddharth P Jadhav, Snehal R More, Roy F Riascos, Diego F Lemos, Leonard E Swischuk. Comprehensive review of the anatomy, function, and imaging of the popliteus and associated pathologic conditions. *Radiographics.* 2014;34(2) March-April.
8. Diamantopoulos A, Tokis A, Tzurbakis M, Patsopoulos I, Georgoulis A. The posterolateral corner of the knee: evaluation under microsurgical dissection. *Arthroscopy.* 2005;21(7):826–833 (Crossref, Medline).
9. Bronstein R, Schaffer J. Physical examination of knee ligament injuries. *J AAOS.* April 2017;25(4).
10. Feltham GT, Albright JP. The diagnosis of PCL injury: literature review and introduction of two novel tests. *Iowa Orthop J.* 2001;21:36–42.
11. Houston JC, Norwood Jr LA. The Posterolateral Drawer Test and external rotation recurvatum test for posterolateral rotatory instability of the knee. *Ckin Orthop Relat Res.* 1980;147:82–87.
12. Daniel DM, Stone ML, Barnett P, Sachs R. Use of the quadriceps active test to diagnose posterior cruciate ligament disruption and measure posterior laxity of the knee. *J Bone Jt Surg Am.* 1988;70(3):386–391.
13. Rubenstein Jr RA, Shelborne KD, McCarroll JR, VanMeter CD, Rettig AC. The accuracy of the clinical examination in the setting of posterior cruciate ligament injuries. *Am J Sports.* 1994;22(4):550–557.
14. Harner CD, et al. Biomechanical analysis of a posterior cruciate ligament reconstruction. Deficiency of the posterolateral structures as a cause of graft failure. *Am J Sports Med.* 2000;28(1):32–39.
15. Krause DA, Levy BA, Shah JP, Stuart MJ, Hollman JH, Dahm DL. Reliability of the dial test using handheld inclinometer. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(5):1011–1016.