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Risk of Tunnel Convergence in Combined Anterior Cruciate Ligament and Posterolateral Corner Reconstruction

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Abstract

Purpose: To evaluate the rate of tunnel collision with combined Posterolateral Corner (PLC) and AnteriorCruciate Ligament (ACL) reconstruction and identify techniques which reduce tunnel collision.

Methods: LCL and popliteus tunnels were drilled in 64 medium and large synthetic femurs and 16 syntheticknee joints. ACL tunnels were drilled using four different techniques: trans-tibial, anteromedial with rigid pin, anteromedial with flexible pin, and outside-in. Samples without obvious tunnel collision underwent CT scan to measure distance between the tunnels.

Results: Overall frequency of tunnel collision was 24/32 in large and 32/32 for medium femurs. Obvioustunnel collision was observed in all trans-tibial and all anteromedial specimens regardless of femur size or laterality. All specimens without tunnel collision occurred in large femurs using the outside-in technique (n=8). Mean tunnel separation in samples without tunnel collision was 1.93 mm.

Conclusion: Outside-in ACL reconstruction with PLC reconstruction demonstrated the least tunnel collisionamong evaluated techniques.

Introduction

Once considered the “dark side of the knee”, recent studies have provided new light on the anatomy and biomechanical function of the Posterolateral Corner (PLC)[1,2]. Isolated injuries to the PLC of the knee are rare [3] reporting a 1.6% occurrence rate in 735 ligamentous knee injuries. Injuries to the PLC are more commonly associated with a multi-ligamentous knee injury [4] found in patients with PLC tears, 87% had concomitant injuries to the ACL, PCL, or MCL. Seventy percent of patients with posterolateral corner injuries had a concomitant Anterior Cruciate Ligament (ACL) tear. Patients with this combination of injury have substantial knee instability. Unrecognized posterolateral rotatory instability has been previously shown to be a major etiology of ACL reconstruction failure [5,6].These findings have led to an improved diagnosis of this injury pattern and increased combined reconstruction of the ACL and PLC. ACL reconstruction has been moving toward a more anatomically oriented reconstruction, either via a double bundle technique or placing a single bundle tunnel at the center of the anatomic footprint of the ACL.

These changes have led to an ACL femoral tunnel that is closer to the tunnels used for posterior lateral corner reconstruction. Bone weakening and tunnel convergence in the lateral femoral condyle has posed a significant challenge to combined ACL and PLC reconstruction. Recent studies have found a high tunnel collision rate in combined ACL and PLC reconstruction [7-9].These studies demonstrate the rate of tunnel collision could be decreased by changing the axial and coronal angulation and the tunnel depth of the PLC tunnel. However, to our knowledge no studies to date have demonstrated the comparative risk of tunnel collision among the various ACL reconstruction techniques, including: trans-tibial, anteromedial portal with rigid instruments, anteromedial portal with flexible instruments, and outside-in. The purpose of this study is to evaluate the risk of tunnel collision among multiple ACL reconstruction techniques with a combined PLC reconstruction and to identify which technique, if any, reduces the risk of tunnel collision. Our hypothesis is that anteromedial portal ACL femoral tunnel drilling, especially using a flexible guide pin, will result in a high convergence while trans-tibial drilling will produce tunnels with the lowest tunnel convergence.

Materials and Methods

Sixty-four 4th generation synthetic femurs and sixteen synthetic knee joints (Sawbones, Pacific Research Laboratories, Vashon, WA) were utilized. Two different femur sizes were used, medium (28 mm lateral condyle) and large (36 mm lateral femoral condyle), equally split between left and right lateralities, creating equal groups of sixteen samples for each of the four ACL reconstruction techniques evaluated. These synthetic femurs were mounted proximally using a c-clamp and bone clamp to an OR table. Four iterations of each of the four ACL tunnel techniques were performed. All tunnels were drilled by the same investigator.

PLC Tunnel Drilling

All samples underwent drilling of two lateral tunnels to replicate PLC reconstruction as described [10], the preferred method of PLC reconstruction at our institution. A 2.7 mm guide pin was placed at the anatomic insertion site of the lateral collateral ligament, slightly proximal and posterior to the lateral epicondyle [11]. A second 2.4 mm guide pin was then placed in the anterior one fifth of the popliteal sulcus, 18.5 mm anterior and distal to the LCL tunnel site. The LCL tunnel was then reamed using a 7mm acorn reamer (Smith and Nephew, Memphis Tennessee) over the guide pin to a depth of 50 mm. A 9mm acorn reamer was passed over the popliteal tendon tunnel to a depth of 20 mm. While no specific description of the angulation of the tunnels is stated in technique described [10], the diagram from the article suggests approximately 40-45° of coronal angulation and near neutral angulation in the axial plane. The tunnels were drilled freehand in this manner, with approximately 40° of proximal coronal angulation and neutral axial angulation. After the PLC tunnels were drilled, all samples underwent ACL tunnel drilling using one of four described techniques.

Outside-In

The Acufex pinpoint outside-in guide (Smith and Nephew, Memphis Tennessee) was used to place a 2.4 mm guide pin with the guide held at 45 degrees of posterior axial angulation from the trans-epicondylar axis, confirming visually that the tip of the guide pin was centered in the anatomic origin of the ACL (Figure 1).

A 10mm acorn reamer was then passed over the guide pin to create the femoral ACL tunnel.

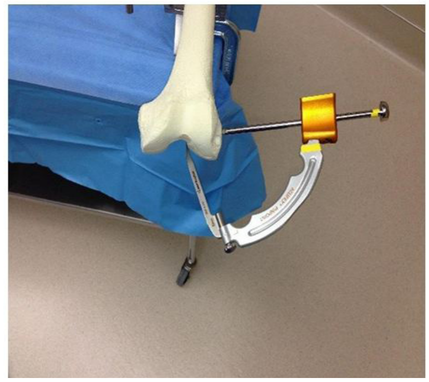

Figure 1: Outside in drilling using Acufex guide (Smith and Nephew, Memphis Tennessee).

Anteromedial Portal - Rigid and Flexible Guide Pins

A 2.7 rigid guide pin was positioned in the anatomic origin of the ACL and passed through the lateral cortex. Using data from previous studies, an exit point for the guide pin on the lateral femoral cortex was chosen to simulate the tunnel direction that could be obtained through a low anteromedial portal at 110- 120° of knee flexion[5,12,13](Figure 2).

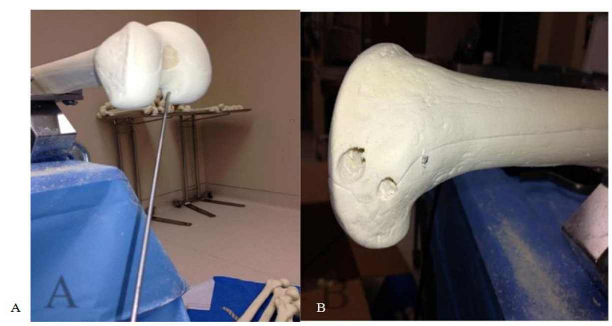

Figure 2a-2b: Anteromedial portal drilling with exit point on lateral femoral condyle.

A 10mm acorn reamer was passed over the guide pin, breaching the lateral cortex. A 2.4 flexible guide pin was used in a similar technique to drill the anteromedial flexible tunnels, following the same parameters for pin exit on the lateral femoral condyle, with over reaming using a 10mm acorn reamer.

Trans-Tibial

After mounting the femurs to the table as previously described, the tibia was held with the knee in 120°of flexion by an assistant. The tip aimer of the Acufex drill guide set at 55 degrees was placed in the anatomic footprint of the ACL insertion just posterior to the medial tibial spine. A 2.4 mm guide pin was drilled through the guide, exiting at the desired point set by the tip aimer.

The tibial tunnel was then drilled using a 10mm cannulated drill bit. An endoscopic femoral aimer, set to 7 mm offset was then positioned in the over the top position in direct contact with the lateral femoral condyle cortex. A 2.7 mm guide pin was the passed through the tibial tunnel and guide, exiting out the lateral cortex of the distal femur. A 10mm acorn reamer was then passed over the pin, breaching the lateral cortex.

Samples from all above drilling techniques without obvious tunnel collision underwent Computed Tomography (CT) scan with 2-mm slices to determine the closest distance between the tunnels or whether an occult collision existed. Samples which had obvious tunnel convergence were excluded from further radiographic evaluation. Radiographic measurements were conducted by a board-certified radiologist using the computer's straight-line measuring tool. The scans were evaluated for the slice in which the tunnels were closest, and the tangential distance (mm) from the tunnels were recorded.

Results

.Overall frequency of tunnel collision was 24/32 (75%) in large femur specimens and 32/32 (100%) for medium femur specimens. Obvious tunnel collision was observed in all trans-tibial, anteromedial with flexible instruments, and anteromedial with rigid instruments regardless of femur size or laterality. In addition, obvious tunnel collision occurred in all outside-in medium size samples, regardless or laterality. All collisions occurred between the ACL and LCL tunnels. There was no occurrence of collision between the ACL and popliteus tunnels. All specimens that had gross tunnel convergence were not radiographically evaluated, as there was no tunnel separation to measure in these specimens. All specimens without tunnel collision occurred in the large femurs from the outside-in technique group. (Figure 3).

Figure 3: Sagittal CT of outside-in sample with tunnel distance measurement.

The mean tunnel separation in these samples was 1.93 mm (range 1.06-2.54 mm) (Table 1).

Sample	Distance	Sample	Distance
OILL1	2.41 mm	OILR1	1.06 mm
OILL2	1.48 mm	OILR2	1.34 mm
OILL3	1.89 mm	OILR3	2.40 mm
OILL4	2.35 mm	OILR4	2.54 mm
		Mean	1.93 mm

Table 1: Results of tunnel distances (OILL: outside-in large femur left laterality; OILR: outside-in large femurright laterality).

Discussion

Multi-ligamentous knee injuries create a unique challenge for reconstruction. Reconstruction of the posterolateral corner requires either tunnel or screw and washer placement into the lateral condyle. Most previously described techniques use a lateral tunnel in the lateral femoral condyle. However, there is no consensus on the best technique [14] describe a tunnel drilled perpendicular to the lateral epicondyle at the isometric point [15] also described a neutral tunnel at the isometric point, parallel to the axis of the joint and perpendicular to the axis of the femur [16-19]have published techniques describing varying angles of proximal and anterior angulation of the femoral tunnel [20] described a technique that utilizes 2 femoral tunnels at the isometric points of the popliteal and LCL insertion, angled 20° and 30° proximal and anterior respectively [21]. reconstructs the PLC using a modified 2-tailed graft technique using a screw and washer. The technique preferred at our institution is the 2-tunnel technique described [9].

Combined reconstruction of the ACL and PLC using lateral femoral tunnels requires an understanding of the geometric relationship between the tunnels. Failure to understand this relationship may result in tunnel collision leading to graft failure, lateral femoral condyle weakening and fracture, and persistent instability. While various configurations of PLC tunnel have been described in varying degrees of angulation, to date there is no literature evaluating tunnel relationship with PLC tunnels and tunnels created from different ACL reconstruction techniques. Our results demonstrate a very high tunnel collision rate of 88% (56/64) in all samples. Three previous studies have previously evaluated tunnel collision using synthetic femurs with collision rates from 29- 86%[6] drilled standard ACL tunnels in 11 synthetic femurs, followed by a single LCL tunnel with varying degrees of axial and coronal angulation (0-60°). The authors concluded tunnel collision was minimized when a LCL tunnel is drilled in neutral coronal alignment with anterior axial angulation of 40° to a depth of 25 mm [7] found similar results, with no collisions in posterolateral bundle ACL tunnels and a single LCL tunnel when the

LCL tunnel was drilled in neutral coronal alignment and anterior axial angulation of 20-40°[8] reproduced the findings [6] using 18 synthetic femurs using an outside in retrograde ACL reaming technique and a single LCL tunnel. They found that optimal tunnel orientation of the LCL tunnel was 20° of proximal angulation in the coronal plane to avoid trochlear violation, and 40° of anterior angulation in the axial plane.

Conclusion

All previous studies evaluating tunnel convergence in combined ACL and PLC reconstruction varied the angulation of the LCL tunnel while keeping the ACL tunnel constant. In addition, all used a single LCL tunnel. Our study is the first to evaluate tunnel convergence with 2 constant PLC tunnels and various ACL tunnel techniques.Consistent with previous studies, we found a high rate of collision, especially in medium sized femurs. This finding is not unexpected, as the reduction in lateral femur size would naturally increase the risk of tunnel collision. In clinical situations with lateral femoral condyle widths of <28-30 mm, the surgeon should be aware of the increased risk of tunnel collision and evaluate options to reduce the risk of tunnel collision (i.e. single LCL tunnel or screw/washer fixation).

Contrary to our hypothesis, the outside-in technique was the only ACL tunnel technique without consistent convergence [22] recently found that the exit point of outside-in tunnels on the lateral femoral condyle were further away from LCL origin than the anteromedial portal ACL tunnels. This increases the distance between the ACL and LCL tunnels, and thus decreases the risk of convergence. In addition, outside-in ACL femoral tunnel drilling gives the surgeon the ability to control tunnel trajectory and to manipulate the drill guide to change the start point of the ACL tunnel on lateral condyle. Using an outside-in drill guide allows the surgeon to alter the tunnel lateral femoral location and tunnel angulation without changing the anatomic location of the tunnels opening at the ACL footprint within the joint.

While the trans-tibial samples had tunnels that were furthest away on the lateral condyle, all samples converged within the condyle (Figure 4).

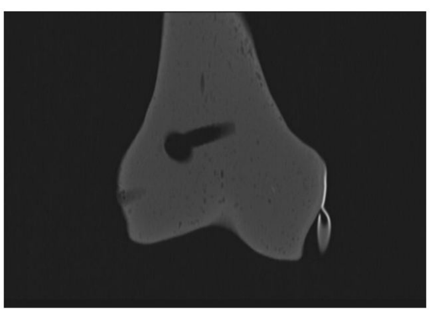

Figure 4: Coronal CT of trans-tibial sample with tunnel convergence.

This appeared to be due to the proximal angulation and depth of the LCL tunnels (50mm). Previous studies have noted increased collision with 30 mm tunnels compared to 25 mm tunnels [6-8]. The authors of this study feel that the convergence rate of trans-tibial drilling would be decreased if the PLC tunnels were drilled to a depth of 25 mm with no more than 20˚ of coronal angulation. Even still, the ability of the trans-tibial technique to reliably position the bone tunnels anatomically has been questioned [23]. Recently, there has been a great deal of interest in the anatomic placement of the ACL tunnel with evidence to suggest that tibial tunnel independent techniques produce more anatomic tunnels, lending to more stable knees and a reduction of positive pivot shift exams after reconstruction [24-29]. While previous studies on tunnel collisionhave demonstrated reduced risk of collision with anterior and proximal angulation in the axial and coronal plane with a tunnel depth of 25 mm, the aim of this study is to evaluate a constant PLC technique used by the authors with variable ACL tunnel configurations. The results of our study have provided evidence for the use of outside-in ACL reconstruction and PLC with 2 lateral femoral tunnels to decrease tunnel collision risk.

Our study has some limitations. First, the use of synthetic models limited the ability to account for the biological variability between individual human femurs. Second, the tunnels were drilled freehand by one surgeon, and does not account for any potential variability amongst surgeons. Similar studies utilized drilling jigs or goniometers to standardize all tunnel samples. However, since jigs and goniometers are not widely used intraoperatively during ligamentous reconstruction of the knee, we felt freehand drilling of the tunnels provide more realistic outcomes and would better simulate a true operative experience. Cadaveric evaluation would be helpful to support our findings. While there may be variability between surgeons, recent literature has suggested that individual surgeons are relatively consistent in their ACL tunnel placement [30]. Finally, there are no soft tissues on the synthetic bones to guide anteromedial portal drilling, which may affect ultimate tunnel placement.

Considering our findings of extremely high collisions rates, further investigation of various ACL configurations with various PLC reconstructions techniques would likely provide additional insight into an ideal combined reconstruction technique to minimize tunnel collision. Our results, however, support the use of outside-in ACL femoral tunnel drilling when combined with PLC reconstruction, as this technique has the lowest tunnel collision of the four techniques evaluated.

References

1. Andrews JR, Baker CL, Curl WW, Gidual R (1988) Surgical repair of acute and chronic lesions of the lateral capsular ligamentous complex of the knee. In: Feagin JA Jr. The crucial ligaments: diagnosis and treatment of ligamentous injuries about the knee. New York: Churchill Livingstone 1988: P425-438.
2. LaPrade RF, Ly TV, Wentorf FA, Engebretsen L (2003) The posterolateral attachments of the knee:A qualitative and quantitative morphologic analysis of the fibular collateral ligament, popliteus tendon, popliteofibular ligament, and lateral gastrocnemius tendon. Am J Sports Med 23: 854-860.
3. DeLee LC, Riley MB, Rockwood CA Jr (1983) Acute posterolateral rotatory instability of the knee. Am J Sports Med 11: 199-207.

4. LaPrade RF, Wentorf FA, Fritts H, Gundry C, Hightower CD (2007) A prospective magnetic resonance imaging study of the incidence of posterolateral and multiple ligament injuries in acute knee injuries presenting with a hemarthrosis. Arthroscopy 23: 1341-1347.

5. LaPrade RF, Resig S, Wentorf F, Lewis JL (1999) The effects of grade III posterolateral knee complex injuries in anterior cruciate ligament graft force: A biomechanical analysis. Am J Sports Med 27: 469-475.

6. O'Brien SJ, Warren RF, Pavlov H, Panariello R, Wickiewicz TL (1991) Reconstruction of the chronically insufficient anterior cruciate ligament with the central third of the patellar ligament. J Bone Joint Surg Am 73: 278-286.

7. Shuler MS, Jasper LE, Rauh PB, Mulligan ME, Moorman CT III (2006) Tunnel convergence in combined anterior cruciate ligament and posterolateral corner reconstruction. Arthroscopy 22: 193-198.

8. Camarda L, D'Arienzo M, Patera GP, Filosto L, LaPrade RF (2001) Avoiding tunnel collisions between fibular collateral ligament and ACL posterolateral bundle reconstruction. Knee Surg Sports TraumatolArthrosc 19: 598-603.

9. Narvy SJ, Hall MP, Kvitne RS, Tibone JE (2013) Tunnel intersection in combined anatomic reconstruction of the ACL and posterolateral corner. Orthopedics 36: 529-532.

10. Schechinger SJ, Levy BA, Dajani KA, Shah JP, Herrera DA, et al. (2009) Achilles tendon allograft reconstruction of the fibular collateral ligament and posterolateral corner. Artroscopy 25: 232-242.

11. LaPrade RF, Ly TV, Wentorf FA, Engebretsen L (2003) The posterolateral attachments of the of the knee: a qualitative and quantitative morphologic analysis of the fibular collateral ligament, popliteus tendon, popliteofibular ligament, and lateral gastrocnemius tendon. Am J Sports Med 31: 854-860.

12. Nakamura M, Deie M, Shiyuba H,Nakamae A, Adachi N et al. (2009) Potential risks of femoral tunnel drilling through the far anteromedial portal: A cadaveric study. Arthroscopy 25: 481-487.

13. Neven E, D'Hooghe P, Bellemans J (2008) Double bundle anterior cruciate ligament reconstruction: A cadaveric study on the posterolateral tunnel position and safety of the lateral structures. Arthroscopy 24: 436-440.

14. Kocabey Y, Nawab A, CabronDN, Nyland J (2004) Posterolateral corner reconstruction using a hamstring allograft and a bioabsorbable tenodesis screw: description of a new surgical technique. Arthroscopy 20: 159-163.

15. Verma NN, MithöferK, Battaglia M, MacGillivray J (2003) The docking technique for posterolateral corner reconstruction. Arthroscopy 19: 790-793.

16. Latimer HA, Tibone JE, ElAttrache NS, McMahon PJ (1998) Reconstruction of lateral collateral ligament of the knee with patellar tendon allograft: Report of a new technique in combined ligament injuries. Am J Sports Med 26: 656-662.

17. LaPrade RF, Johansen S, Wentorf FA, Engebretsen L, Esterberg JL, et al. (2004) An analysis of an anatomical posterolateral knee reconstruction: An in vitro biomechanical study and development of a surgical technique. Am J Sports Med 32: 1405-1414.

18. McGuire DA and Wolchok JC (2003) Posterolateral corner reconstruction. Arthroscopy 19: 790-793.

19. Seikya JK, Haemmerle MJ, Stabile KJ, Vogrin TM, Harner CD (2005) Biomechanical analysis of a combined double bundle posterior cruciate ligament and posterolateral corner reconstruction. Am J Sports Med 33: 360-369.

20. Kim SJ, Park IS, Cheon YM, Ryu SW (2004) New technique for chronic posterolateral instability of the knee: Posterolateral reconstruction using the tibialis posterior tendon allograft. Arthroscopy20:195-200.

21. Stannard JP, Brown SL, Robinson JT, McGwin G Jr, Volgas DA (2005) Reconstruction of the posterolateral corner of the knee. Arthroscopy 21: 1051-1059.

22. Gadikota HR, Sim JA, Hosseini A, Gill TJ, Li G (2012) The relationship between femoral tunnels created by the transtibial, anteromedial portal, and outside-in techniques and the anterior cruciate ligament footprint. Am J Sports Med 40:882-888.

23. Koph S, Forsythe B, Wong AK, Tashman S, Irrgang JJ, et al. (2012) Transtibial ACL reconstruction technique fails to position tunnels anatomically in vivo SD CT study. Knee Surg Sports Traumatol Arthrosc 20: 2200-2207.

24. Dargel J, Schmidt-Wiethoff R, Fischer S, Mader K, Koebke, et al. (2009) Femoral bone tunnel placement using the transtibial tunnel or the anteromedial portal in ACL reconstruction: a radiographic evaluation. Knee Surg Sports Traumatol Arthrosc 17: 220-227.

25. Alentorn-Geli E, Lajara F,Samitier G, Cugat R (2010) The transtibial versus the anteromedial portal technique in the arthroscopic bone-patellar tendon-bone anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 18: 1013-1037.

26. Tompkins M, Milewski MD, Brockmeier SF, Gaskin CM, Hart JM, et al. (2012) Anatomic femoral tunnel drilling in anterior cruciate ligament reconstruction: use of an accessory medial portal versus traditional transtibial drilling. Am J Sports Med 40: 1313-1320.

27. Shin YS, Ro KH, Lee JH, Lee DH (2013) Location of the femoral tunnel aperture in single bundle anterior cruciate ligament reconstruction: comparison of the transtibial, antermedial portal, and outside-in technique. Am J Sports Med 41: 2533-2539.

28. Franceschi F, Papalia R, Rizzello G, Del Buono A, Maffulli N, et al. (2013) Anteromedial portal versus transtibial drilling techniques in anterior cruciate ligament reconstruction: any clinical relevance? A retrospective study. Arthroscopy 29: 1330-1337.

29. Chalmers PN, Mall NA, Cole BJ, Verma NN, Bush-Joseph CA, et al. (2013) Anteromedial versus transtibial tunnel drilling in anterior cruciate ligament reconstructions: a systematic review. Arthroscopy 29: 1235-1242.

30. Wolf BR, Ramme AJ, Wright RW, Brophy RH, McCarty EC, et al. (2013) Variability in ACL tunnel placement: observational clinical study of surgeon ACL tunnel variability. Am J Sports Med 41: 1265-1273.