CASE REPORT

Case Report

Osteochondral Avulsion Fracture of the Posteromedial Bundle of the PCL in Knee Hyperflexion

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Abstract

Background Injury of the PCL of the knee in adults usually results in rupture rather than avulsion fracture and avulsions usually occur at the tibial insertion.

Case Description We report an avulsion of the PCL with a femoral origin in a 22-year-old man who was injured by hyperflexion of the knee and was treated with arthroscopy. There were two parts in the partial osteochondral avulsion fracture of the PCL posteromedial (PM) bundle. One part was fixed with polydioxanone suture through drill holes and the other was removed. The fracture healed after 3 months and the knee was stable. At 11 months postoperatively the patient had returned to full-time work without pain or restrictions. The Lysholm II knee score was 95 points. Physical examination showed a negative posterior drawer sign.

Literature Review We identified four other reported cases of PCL femoral origin avulsion fractures in adults. The subjects were 20 to 25 years old in four of five reports,

including our patient. Three of the five patients had involvement of only the lateral cortex of the medial femoral condyle whereas two other patients including our patient, had an osteochondral fracture. The mechanism of PCL avulsion seems to be similar to that of a PCL rupture. **Purposes and Clinical Relevance** The hyperflexion injury may result in injury of the PM bundle of the PCL. Our case and one other in the literature suggest such avulsions need not involve the entire PCL.

Introduction

Injury of the PCL in adults usually causes rupture rather than an avulsion fracture [2, 31, 32]. Avulsion usually occurs at the tibial insertion in adults [31, 32]. Avulsion fracture of the PCL with a femoral origin in adults has not been reported often. We performed a comprehensive literature search and found most cases of avulsion of the PCL with femoral origin were reported in adolescents [6, 14, 15, 19, 21, 27]. In contrast we found only four reported cases in adults [8, 17, 22, 24]. Three of the four reported patients had complete avulsion of the PCL and the other had partial avulsion of the anterior bundle of the PCL. We report a patient with osteochondral avulsion of the PCL limited to the posteromedial (PM) bundle from the femoral origin.

Case Report

A 22-year-old man presented with extension restriction of his left knee. He was injured 10 days before while performing warm-ups when he rapidly rotated to the right side with his knees in hyperflexion. He felt a sudden pain in his left knee and was unable to walk. The knee swelled within

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Each author certifies that his or her institution approved the reporting of this case report, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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10 minutes. The patient was sent home without undergoing clinical evaluation. After 1 week's rest the pain and swelling abated. However, he experienced repeated locking of his left knee and was unable to fully extend it. Seven days after his injury, he was seen at a local hospital where AP and lateral radiographs and MRI of the knee were performed. He was transferred to our hospital immediately thereafter. Physical examination of the knee showed an extension deficit of 15° and Grade I [16] posterior instability. Radiographs showed an osteochondral fracture in the intercondylar fossa and irregular articular surface (Fig. 1). MR images were uninformative owing to poor quality.

We performed an arthroscopy 2 weeks after the patient's injury. Routine anterolateral and anteromedial portals were used. The osteochondral avulsion fracture was attached to the PM bundle of the PCL and the anterolateral (AL) bundle of the PCL was intact. There were two parts to the avulsion fracture. The first part was approximately 1.5 cm in diameter to which was attached approximately 30% of the PCL fibers and half of the avulsed cartilage was connected to the femoral condyle (Fig. 2). The second part was approximately 0.8 cm in diameter to which was attached approximately 10% of the PCL fibers and it was locked between the PCL and medial femoral condyle. We observed no other damage. Because few fibers were connected to the PCL, the second and smaller part was excised. We treated the larger avulsion with polydioxanone suture (PDS) fixation as described below using a bone bridge suture repair technique (Fig. 3). With the left knee in 90° flexion, the fracture was clearly observed. This fracture

part was not totally avulsed from the femoral condyle and was easily reduced. We débrided the bony bed with a probe. We then drilled two holes and inserted a 2-mm K-wire toward the medial epicondyle (one from the fracture edge and another from the center of osteochondral fracture). The 2-mm K-wire then was exchanged for a 1-mm K-wire drilled through the medial skin. We then passed a straightened epidural cannula through the 1-mm K-wire into the joint and removed the K-wire. A double-stranded looped PDS was inserted into the joint through the epidural cannula. Following the same procedure, another double-stranded looped PDS was inserted into the joint. We then pulled the second PDS loop through the first PDS loop out of the anteromedial portal with a probe. Finally, we pulled the first PDS out of the medial skin and the second PDS was left for fixation. A second double-stranded PDS was inserted using the same procedure. A 3-cm-long medial incision then was made, and all PDSs were pulled into the incision, tightened, and tied on the medial condylar bone surface. After fixation, the fracture was examined. The osteochondral fracture was stable in full ROM, the articular surface was smooth, and the PCL reattachment held tension on testing.

A postoperative radiograph showed a generally normal subchondral bone (Fig. 4) compared with the preoperative radiograph. The patient wore a long leg brace locked in full extension for 4 weeks for healing of the fracture. He was instructed to use crutches and remain nonweightbearing for 3 months after the surgery. Flexion of the knee was prohibited for 4 weeks. Three months after surgery, the patient

Fig. 1A–B Preoperative (A) AP and (B) lateral radiographs of the patient's left knee show an obvious osteochondral fracture in the intercondylar fossa and an irregular articular surface (white arrows).

Fig. 2A–H Intraoperative arthroscopic photographs show the two avulsion osteochondral fracture parts and their relation with the PCL. The second avulsion part had only a small fiber connection with the PCL. **(A)** The part 1 avulsion was approximately 1.5 cm in diameter partially connected with the femoral condyle (white arrow). **(B)** The part 2 avulsion was locked between the ACL and the femoral condyle (white arrow). **(C)** The part 1 avulsion was dislocated from the femoral condyle (white arrow). **(D)** The part 2 avulsion was grasped by the forceps (white arrow). **(E)** The part 2 avulsion was approximately 0.8 cm in diameter (white arrow). **(F)** There were approximately 10% of the PCL fibers connected with the part 2 avulsion (white arrow). **(G)** The part 2 avulsion was removed (white arrow). **(H)** The anterior bundle of the PCL was intact (white arrow).

had a stable knee with no motion restriction and physical examination showed a negative posterior drawer sign. There was no pain or swelling of his left knee. A radiograph taken 3 months after surgery showed bony union (Fig. 5), and MRI performed 4 months postoperatively

showed long T2-weighted and short T1-weighted signals around the osteochondral fracture with a smooth cartilage surface (Fig. 6). At 11 months followup the patient had returned to full-time work without pain or restrictions. The Lysholm II knee score was 95 points.

Fig. 3A–H Sketches of the surgical technique and the arthroscopy photographs show the fixation technique of the avulsion part 1 through drill holes with the use of an epidural cannula and PDSs. (A) The hole was drilled with a 2-mm Kirschner wire (K-wire) toward the medial epicondyle. (B) The 2-mm K-wire then was exchanged for a 1-mm K-wire. (C) A straightened epidural cannula was passed through the 1-mm K-wire into the joint and the 1.0-mm

K-wire was removed. (D) A double-stranded looped PDS was inserted into the joint through the epidural cannula. (E) Another double-stranded looped PDS was inserted into the joint. (F) The second PDS loop was pulled through the first PDS loop out of the anteromedial portal with a probe. (G) The first PDS was pulled out of the medial skin and the second PDS was left for fixation. (H) The avulsion fracture was tightly fixed.

Fig. 4A–B Postoperative (A) AP and (B) lateral radiographs show a relatively smooth articular surface (white arrow in Illustration A) compared with that in Figure 1.

Discussion

After a comprehensive search, we found 11 cases of PCL avulsion fractures of femoral origin in adolescents in the literature [6, 14, 15, 21, 27]. In contrast, only four cases of PCL avulsions of femoral origin have been reported in adults [8, 17, 22, 23] (Table 1). Three

of these patients were between 20 to 25 years old and one was 42; our patient was 22 years old. These patients seem to be relatively younger than patients with PCL avulsion fractures from the tibia [4, 12]. Damage to the PCL by femoral avulsion has been reported in cadaveric specimens. Using a high-speed testing machine, Balasubramanian et al. [3] observed

Fig. 5A–B (A) AP and (B) lateral radiographs taken 3 months postoperatively show bone union and smooth articular surfaces (white arrow in Illustration A).

Fig. 6A–D MR images obtained 4 months postoperatively show the bone tunnel and the avulsion fracture in the correct position with smooth articular surfaces. (A) A T1-weighted proton density-weighted asymmetric turbo spin echo MR image shows the bone tunnel (white arrow) and smooth articular surfaces. (B) A T1-weighted proton density-weighted asymmetric turbo spin echo MR image shows the avulsion part fixed in the right place (white arrow). (C) A T2-weighted spectral attenuated inversion recovery MR image shows the bone tunnel (white arrow) and smooth articular surfaces. (D) A T2-weighted spectral attenuated inversion recovery MR image shows the avulsion part fixed in the right place (white arrow).

one PCL avulsion at the posterior intercondylar attachment point in a study of 14 cadaveric knees. We assume that in patients younger than 25 years the bony

insertion of the PCL might not be as strong as in older adults, but this presumption would need more confirmatory data.

Table 1. Previous reports on avulsion of the femoral origin of the PCL in adults

Study	Age (years)	Sex	PCL avulsion information	Physical examination	Combined injuries	Damage information	Time after injury (days)	Treatment of the PCL avulsion	Followup (months)	Results
O'Donoghue [22] (1950)	20	Male	PCL entirely torn off the femur	Lateral instability, drawer sign (+)	MCL and ACL avulsion	Lateral side force with the foot in external rotation	2	Reattached through drill holes with twisted silk/cotton suture by open reduction	15	Stable knee, normal motion, drawer sign (-), 10° restriction of flexion
Drucker and Wynne [8] (1975)	25	Male	Avulsion of femoral insertion with a small piece of bone	Extension and flexion deficit, drawer sign (+)	Medial meniscus avulsion, posterior capsule rupture	Hyperextension	7	Reattached through drill holes with Dexon™ suture by open reduction	NA	NA
Park and Kim [23] (2005)	42	Male	Anterior 2/3 of cortical shell and posterior 1/3 of the whole cortex avulsion	Valgus stress test (+), anterior and posterior Lachman test (+)	MCL and ACL avulsion	Lateral side force	NA	Reattached through drill holes with two Number 5 Ethibond® sutures by arthroscopy	NA	NA
Lee et al. [17] (2009)	22	Male	Partial osteochondral avulsion of the PCL AL bundle	Extension deficit of 10°, Grade I posterior instability		Anterior blow	NA	Avulsion was removed and applied with osteochondral autograft by arthroscopy	NA	Without discomfort
Current study	22	Male	Partial osteochondral avulsion of the PCL PM bundle	Extension deficit of 15°, Grade I posterior instability		Hyperflexion with the calf rotated externally	14	Reattached through drill holes with PDS by arthroscopy	11	Stable knee, no restriction of motion, drawer sign (-)

AL = anterolateral; PM = posteromedial; MCL = medial collateral ligament; NA = not applicable; PDS = polydioxanone suture.

Three of the five patients had involvement of only the lateral cortex of the medial femoral condyle and the other two had osteochondral avulsions (Table 1). Damages from PCL avulsions include medial collateral ligament avulsion [22, 23], ACL avulsion [22, 23], capsule rupture [8], and possible vascular or nerve injury [14], especially in a dislocated knee. Hesse et al. [14] reported a femoral avulsion fracture of the PCL was associated with rupture of the popliteal artery in a 9-year-old boy. However, in none of the reported adults with PCL femoral avulsions has there been any injury to major blood vessels or nerves.

The possible mechanisms of isolated PCL injury include direct anterior tibial force to a flexed knee, knee hyperflexion with a downward force on the thigh, and knee hyperextension. In addition, there are other severe combined injuries, such as varus or valgus combined injury of the knee. The etiology of the five cases included two valgus thrusts, one hyperextension thrust, one direct anterior blow, and one hyperflexion injury with the calf rotated externally. The AL bundle length reportedly increases with knee flexion and the PM bundle length decreases with increasing knee flexion angles [1, 11, 34]. We suspect that the PM bundle is relatively stretched in hyperflexion with the calf rotated externally.

The PCL most often tears in a midsubstance-type pattern during lower energy sporting-type injuries and tears in avulsion-type injury patterns during high-energy trauma [20, 29]. Schenck et al. [28] found that midsubstance tears occur at a low strain rate and avulsion “stripping” injuries from the femoral side occur at a high strain rate in hyperextension in a cadaveric knee. In several reports, avulsion of the PCL was called a “peel off lesion” that occurs through Sharpey’s fibers and can have small fragments of bone attached to the PCL [7, 10, 25]. Patients 1 through 3 (Table 1) may be considered to have massive peel off lesions. Our case is similar to that of Patient 4 [17] in that a partial osteochondral avulsion was observed and the osteochondral fragment was connected to a few fibers of the anterior portion of the PCL insertion (approximately 10% to 20% of the PCL insertion). However our case and that of Patient 4 involved different etiologies. Patient 4 had an avulsion of the AL bundle of the PCL whereas our patient had an avulsion of the PM bundle of the PCL. By analyzing the injury energy we found that a higher-energy injury can result in massive avulsion whereas a lower-energy injury can lead to partial avulsion.

The avulsion fractures of the PCL of femoral origin in adults were treated with open or arthroscopic surgeries (Table 1). All patients were treated with reduction and fixation except Patient 4. In these four patients, the bony fragment was attached to a large portion of the PCL fibers, and the patients had severe posterior instability. In one study [18], the PM bundle produced small but significant

increases in mean laxity at 0° and 10° knee flexion. In addition, the PM bundle plays a role in restraining external rotational instability in knee extension [33]. The isolated single AL bundle reconstruction does not restore normal knee mechanics and may result in residual posterior laxity [13]. Reconstruction of the AL and PM bundles is comparably important [9, 13, 24]. Harner et al. [13] found PM bundle graft forces were larger than those of the AL at all flexion angles tested. Notably, the PM bundle also played a role in reducing posterior tibial translation when the knee was in a flexed position, which further suggests both bundles are functionally important throughout the entire range of knee flexion and extension. In our patient, the osteochondral fracture was divided into two parts. The second part was relatively small and less than 10% of PCL fibers were attached to that fragment. Therefore it subsequently was excised. Removal of an avulsed PCL femoral osteochondral fracture also was reported in a 12-year-old boy [15]. In Patient 4 the avulsion site was incongruent after reduction and the fragment contained little cancellous bone. In that case the fragment also was surgically removed. However, in our patient, the other osteochondral fracture was partially connected to the femoral condyle, which seemed to be useful for weightbearing and important for maintaining PM bundle tension, so we fixed this part of the avulsion fracture. The rationale for fixation also partially relied on a study of the ACL suggesting that even reconstruction of the isolated tear of the PL bundle with integrity of the AM bundle is important [29]. An intact part of the ACL may increase the proprioception and may result in better stability and improved clinical outcome for the patient [5, 26, 30].

We report the case of a patient with avulsion of the PCL posterior bundle attached to an osteochondral fragment. This case and one other in the literature suggest such avulsions need not involve the entire PCL.

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References

1. Ahmad CS, Cohen ZA, Levine WN, Gardner TR, Ateshian GA, Mow VC. Codominance of the individual posterior cruciate ligament bundles: an analysis of bundle lengths and orientation. *Am J Sports Med.* 2003;31:221–225.
2. Amis AA, Gupte CM, Bull AM, Edwards A. Anatomy of the posterior cruciate ligament and the meniscofemoral ligaments. *Knee Surg Sports Traumatol Arthrosc.* 2006;14:257–263.
3. Balasubramanian S, Beillas P, Belwadi A, Hardy WN, Yang KH, King AI, Masuda M. Below knee impact responses using cadaveric specimens. *Stapp Car Crash J.* 2004;48:71–88.
4. Bali K, Prabhakar S, Saini U, Dhillon MS. Open reduction and internal fixation of isolated PCL fossa avulsion fractures. *Knee Surg Sports Traumatol Arthrosc.* 2012;20:315–321.

5. Chouteau J, Testa R, Viste A, Moyon B. Knee rotational laxity and proprioceptive function 2 years after partial ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2012;20:762–766.
6. Clanton TO, DeLee JC, Sanders B, Neidre A. Knee ligament injuries in children. *J Bone Joint Surg Am.* 1979;61:1195–1201.
7. Difelice GS, Lissy M, Haynes P. Surgical technique: when to arthroscopically repair the torn posterior cruciate ligament. *Clin Orthop Relat Res.* 2012;470:861–868.
8. Drucker MM, Wynne GF. Avulsion of the posterior cruciate ligament from its femoral attachment: an isolated ligamentous injury. *J Trauma.* 1975;15:616–617.
9. Fox RJ, Harner CD, Sakane M, Carlin GJ, Woo SL. Determination of the in situ forces in the human posterior cruciate ligament using robotic technology: a cadaveric study. *Am J Sports Med.* 1998;26:395–401.
10. Giordano BD, Dehaven KE, Maloney MD. Acute femoral “peel-off” tears of the posterior cruciate ligament: technique for arthroscopic anatomical repair. *Am J Orthop (Belle Mead NJ).* 2011;40:226–232.
11. Girgis FG, Marshall JL, Monajem A. The cruciate ligaments of the knee joint: anatomical, functional and experimental analysis. *Clin Orthop Relat Res.* 1975;106:216–231.
12. Griffith JF, Antonio GE, Tong CW, Ming CK. Cruciate ligament avulsion fractures. *Arthroscopy.* 2004;20:803–812.
13. Harner CD, Vogrin TM, Höher J, Ma CB, Woo SL. Biomechanical analysis of a posterior cruciate ligament reconstruction: deficiency of the posterolateral structures as a cause of graft failure. *Am J Sports Med.* 2000;28:32–39.
14. Hesse E, Bastian L, Zeichen J, Pertschy S, Bosch U, Krettek C. Femoral avulsion fracture of the posterior cruciate ligament in association with a rupture of the popliteal artery in a 9-year-old boy: a case report. *Knee Surg Sports Traumatol Arthrosc.* 2006;14:335–339.
15. Itokazu M, Yamane T, Shoen S. Incomplete avulsion of the femoral attachment of the posterior cruciate ligament with an osteochondral fragment in a twelve-year-old boy. *Arch Orthop Trauma Surg.* 1990;110:55–57.
16. Janousek AT, Jones DG, Clatworthy M, Higgins LD, Fu FH. Posterior cruciate ligament injuries of the knee joint. *Sports Med.* 1999;28:429–441.
17. Lee YS, Ahn JH, Park JH, Park JW, Yoon JY, Kum DH. Partial femoral avulsion of the posterior cruciate ligament presenting as an osteochondral defect. *J Knee Surg.* 2009;22:369–371.
18. Markolf KL, Feeley BT, Tejwani SG, Martin DE, McAllister DR. Changes in knee laxity and ligament force after sectioning the posteromedial bundle of the posterior cruciate ligament. *Arthroscopy.* 2006;22:1100–1106.
19. Mayer PJ, Micheli LJ. Avulsion of the femoral attachment of the posterior cruciate ligament in an eleven-year-old boy: case report. *J Bone Joint Surg Am.* 1979;61:431–432.
20. Meyers MH, Moore TM, Harvey JP Jr. Traumatic dislocation of the knee joint. *J Bone Joint Surg Am.* 1975;57:430–433.
21. Mirzatołoei F. [Posterior dislocation of the hip and posterior cruciate ligament avulsion in an 8-year-old boy] [in Turkish]. *Acta Orthop Traumatol Turc.* 2009;43:532–534.
22. O'Donoghue DH. Surgical treatment of fresh injuries to the major ligaments of the knee. *J Bone Joint Surg Am.* 1950;32:721–738.
23. Park IS, Kim SJ. Arthroscopic fixation of avulsion of the posterior cruciate ligament from femoral insertion. *Arthroscopy.* 2005;21:1397.
24. Race A, Amis AA. PCL reconstruction: in vitro biomechanical comparison of ‘isometric’ versus single and double-bundled ‘anatomic’ grafts. *J Bone Joint Surg Br.* 1998;80:173–179.
25. Ross G, Driscoll J, McDevitt E, Scheller A Jr. Arthroscopic posterior cruciate ligament repair for acute femoral “peel off” tears. *Arthroscopy.* 2003;19:431–435.
26. Safran MR, Allen AA, Lephart SM, Borsa PA, Fu FH, Harner CD. Proprioception in the posterior cruciate ligament deficient knee. *Knee Surg Sports Traumatol Arthrosc.* 1999;7:310–317.
27. Sanders WE, Wilkins KE, Neidre A. Acute insufficiency of the posterior cruciate ligament in children: two case reports. *J Bone Joint Surg Am.* 1980;62:129–131.
28. Schenck RC Jr, Kovach IS, Agarwal A, Brummett R, Ward RA, Lanctot D, Athanasiou KA. Cruciate injury patterns in knee hyperextension: a cadaveric model. *Arthroscopy.* 1999;15:489–495.
29. Shelbourne KD, Porter DA, Clingman JA, McCarroll JR, Rettig AC. Low-velocity knee dislocations. *Orthop Rev.* 1991;20:995–1004.
30. Siebold R, Fu FH. Assessment and augmentation of symptomatic anteromedial or posterolateral bundle tears of the anterior cruciate ligament. *Arthroscopy.* 2008;24:1289–1298.
31. Sonin AH, Fitzgerald SW, Friedman H, Hoff FL, Hendrix RW, Rogers LF. Posterior cruciate ligament injury: MR imaging diagnosis and patterns of injury. *Radiology.* 1994;190:455–458.
32. Takahashi N, Niitsu M, Itai Y, Sato M, Kujiraoka Y, Ikeda K, Kanamori A. [MR imaging of posterior cruciate ligament injuries] [Article in Japanese]. *Nihon Igaku Hoshasen Gakkai Zasshi.* 2001;61:421–426.
33. Tsukada H, Ishibashi Y, Tsuda E, Fukuda A, Yamamoto Y, Toh S. Biomechanical evaluation of an anatomic double-bundle posterior cruciate ligament reconstruction. *Arthroscopy.* 2012;28:264–271.
34. Van Dommelen BA, Fowler PJ. Anatomy of the posterior cruciate ligament: a review. *Am J Sports Med.* 1989;17:24–29.