Distal Femoral Condylar Fracture Through a Femoral Tunnel 11 years after Anterior Cruciate Ligament Reconstruction, A Case Report

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INTRODUCTION

Anterior cruciate ligament (ACL) reconstructive surgery is a recognized treatment for patients with ACL insufficiency. ACL reconstructive surgery is among the most commonly performed orthopedic procedures in the United States with over 100,000 cases each year.[1] Associated complications rates for ACL reconstructions range between 1.8% and 24%.[2] It is widely accepted that the most common complication is joint stiffness. However, infection, reflex sympathetic dystrophy, and hardware failure are also known to occur. Fracture after ACL surgery has been reported as a complication. Fractures of the patella are the most common fracture variant in the post-operative period, but supracondylar and tibial fractures may also occur. Fracture through the femoral tunnel is a rare but increasingly documented complication of arthroscopic knee surgery.[2,3,4,5] A number of reports have cited interference screws and multiple trocar pin insertions acting as stress risers facilitating femur fractures.[3] Additionally, fractures through screw hole augmentation devices have been reported.[2,4,5] Finally, there are two cases in recent literature of supracondylar stress fractures in professional athletes that may have returned to competitive sports too early at 22 and 12 weeks after surgery.[3,5] We report on a distal femoral condylar fracture through the cross-pin tunnel of an ACL reconstruction performed 11 years prior. The previous cases of post ACL reconstruction femur fractures have all been through femoral tunnel sites. To our knowledge there are no cases in the literature reporting a femur fracture through a screw post site in a non-competitive athlete at such an extended post-operative interval.

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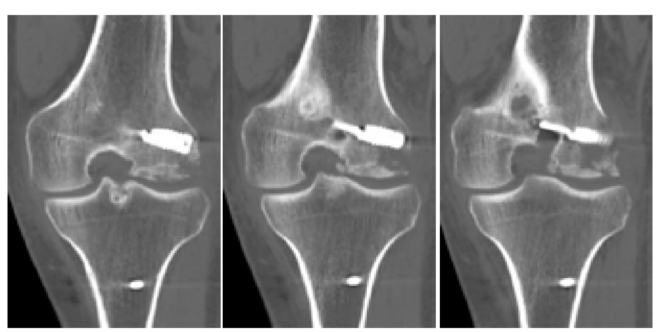
CASE REPORT

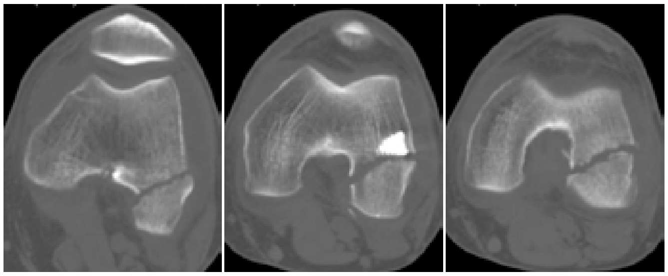
Our patient is a 29-year old recreational male athlete who presented to our institution after sustaining an injury to his left knee during a kickball game in 2006. He exercised occasionally, had no significant medical history, and had no history of metabolic, oncologic, or prior musculoskeletal disease. His surgical history was significant for a left ACL reconstruction with medial and lateral partial menisectomies in 1995. Reports indicate that prior to the index procedure in 1995, the patient had a positive Lachman test and a positive pivot shift maneuver. A review of the operative reports from 1995 revealed that he underwent an ACL reconstruction with an autologous quadrupled hamstring graft measuring 8mm in diameter without complication. A notchplasty was performed with removal of 6-7mm of the intercondylar roof. The tibial tunnel was positioned and reamed to 8mm in diameter. The femoral tunnel was drilled transtibially to a depth of 25mm and a diameter of 8mm. The cross-pin guide was placed and an 8mm cross-pin tunnel was drilled. Femoral graft fixation was performed with a 10.5mm x 30mm Arthrotek bone mulch screw. Screw and washer fixation was used for tibial graft fixation and consisted of a 42mm Linvatec cortical screw and a 20mm Linvatec spiked washer. The patient had no complications from his ACL reconstruction and eventually returned to full activity without symptoms.

In the summer of 2006, the patient was playing kickball and reported landing on his left leg, twisting his knee and hearing a tearing sound. On presentation, he was noted to have an antalgic gait, a significant left knee effusion, and limited knee range of motion. There was marked tenderness on the lateral aspect of his left knee. His distal neurovascular exam was intact with palpable pulses. Radiographic examination showed a coronal fracture. A computed tomography scan, which was



1a 1b 1c

Figures 1a, 1b and 1c. Coronal computed tomography scans of the distal femur prior to surgery. There is an extension of a coronal fracture line from lateral to medial along the lateral femoral condyle. The fracture line appears to propagate along the line of the bone mulch screw.



2a 2b 2c

Figures 2a, 2b and 2c. Axial computed tomography scans of the distal femur prior to surgery. There is an extension of a coronal fracture line from lateral to medial along the lateral femoral condyle. The fracture line appears to propagate along the line of the bone mulch screw.

obtained to better characterize the bony injury, revealed that the fracture had approximately 7-8 mm of displacement with an additional 3mm step-off of the weight-bearing surface of the lateral femoral condyle (Figures 1 and 2). An MRI revealed a coronal fracture through the posterior aspect of the lateral femoral condyle with an intact ACL graft. Open reduction and internal fixation of the femoral condyle was recommended.

The patient was brought to the operating room where the fracture was reduced and repaired via a lateral open exposure. The final reduction was confirmed by inspection and dynamic fluoroscopy. Examination under anesthesia demonstrated the knee to be stable with full range of motion and laxity testing. The patient was discharged from the hospital on postoperative day three. He was instructed to be non-weightbearing and received outpatient physical therapy as well as a CPM machine. The patient did well and had an uneventful post-operative course. On subsequent visits over the following six months, fracture healing was evident and the patient had full restoration of range of motion. At two years from his fixation, he had returned to work but had not fully regained his pre-injury level of athletic activity. Plain films showed a healed distal femur with non-prominent internal fixation in place (Figure 3). On physical exam there was a grade 1A Lachman maneuver, a negative pivot shift, and mild quadriceps atrophy. Although he denied any instability, he was reluctant to return to his pre-injury level of athletic activity due to his two prior surgeries. He was encouraged to resume recreational activities and athletics as tolerated and was then discharged from further care.

3a 3b

Figures 3a and 3b. AP and lateral films status post open reduction and internal fixation at 2 years post-operative. Both views show clear evidence of bone healing and restoration of anatomical alignment.

DISCUSSION

Current techniques for ACL reconstruction include the use of allograft soft tissue grafts and soft tissue grafts such as hamstring (semitendinosus and gracilis) autografts. Fixation options for the femoral side include interference screws, button fixation, and cross-pin fixation techniques. Initial graft fixation stability following reconstruction has been the primary factor driving both the choice of graft type and method of fixation. Historically, bone-tendon-bone (BTB) was preferred due to better initial fixation techniques and outcomes.[6,7] As increased concerns developed regarding anterior knee pain, extensor mechanism dysfunction, and post-operative limitations in range of motion, alternate methods became prevalent, particularly hamstring tendon grafts.[8]

With increasing acceptance of decreased donor site morbidity and favorable biomechanical properties, hamstring and soft-tissue allografts have become increasingly used in ACL reconstruction. [9,10] Various techniques for graft fixation exist including interference screws, button techniques, and cross-pin fixation. Cadaveric studies have shown cross-pinning to be superior to other techniques with respect to pullout stiffness, pullout strength, and slippage.[7,9,1011,12,13,14,1,5,16] These advantages have helped promote the use of cross-pinning and hamstring grafts in ACL reconstructive surgery.

A more recent concern following ACL reconstruction is the incidence of supracondylar femur fractures. This is growing a concern for surgeries performed with tunneling into the femur, the use of bone mulch screw or cross-pinning devices.[4,17,18,19,20] Wiener et al. described a distal femoral shaft fracture resulting from gradual fatigue and overuse seven months following a endoscopic ACL surgery with a patellar tendon autograft.[2] The authors concluded that the multiple cortical holes at the fracture site were stress risers resulting from trocar holes used during the ACL surgery. This was supported by sclerosis at the trocar holes which were hypothesized to be caused by thermal necrosis.[2] In our patient, multiple trocar sites were not apparent, but considering the extended interval from the index surgery, they may have healed to the extent that they were not visible radiologically.

The concept of stress risers and bone weakening via cortical disruption has been gaining more support in the literature. Using a canine model, Brooks et al. determined that diaphyseal drill holes with a diameter greater than 20% of the bone decrease the torsional energy absorbing capacity of bone by 55%.[21,22] In a later study in rabbits, it was found that bending strength was reduced by 30% when the holes on the tension side of the cortex are less than 30% of the bone diameter.[21,22,23] Our patient was subject to large-diameter drill holes during his index procedure which we believe compromised bone strength. First, a 25mm deep, 8mm wide trans-osseous femoral tunnel was drilled through the distal femur, followed by an 8mm wide tunnel for the bone mulch screw from the lateral femoral condyle propagating medially. Finally, a 10.5mm x 30mm bone mulch screw was placed in this tunnel. The use of these large tunnels could have predisposed our patient to a fracture due to cortical weakening. Newer techniques include the use of two smaller diameter titanium cross pins as a substitute for the larger, single screw.

In a recent report, Mithofer et al. illustrated the importance of surgical technique as it is related to optimal femoral tunnel placement during reconstruction.[24] The authors noted optimal placement of the tunnel is as far posterior as possible without compromising the posterior cortex. When considered in light of the findings of Burstein and Brooks, suboptimal screw placement with posterior cortical disruption can be a nidus for bone weakening and eventual stress risers leading to fractures.[21,22] This is significant as it relates the number of drill holes and trocar passes to the likelihood of potential future complications. However, to our knowledge, there are no studies demonstrating the relationship between drill hole size, number, screw placement, and the incidence of fractures.

Although the geometry of the distal femur is complex, the weakest area is believed to be the posterior aspect of the distal femur.[24] Although stress fractures are recognized in orthopedic literature, little research has been devoted to describing this in cadaveric models, which can then be applied to humans. To date, all the case reports have described fractures resulting from stress risers originating in the femoral tunnel. This has typically yielded the characteristic fracture pattern extending from the intraosseous tunnel created for the ACL graft superolaterally. Typically, these are oblique fractures in the coronal plane extending from the tunnel site or interference screw site.[2,12,17,24] Mithoefer described a different fracture, resulting from disruption of the posterior cortex. In that pattern, the initial stress riser is still the femoral tunnel or interference screw tunnel. However, axial cuts on CT reveal that disruption of the posterior wall are more likely to lead to a split of the lateral femoral condyle instead of the bicondylar split extending into the metaphysis. Our fracture pattern is unique in that in the coronal sectioning on CT, it is a shearing fracture not through the femoral tunnel, but instead through the lateral bone mulch screw hole. On axial cuts, the fracture is from medial to lateral, as opposed to the posterior to anterior orientation of fractures through the femoral tunnel. We believe that the bone mulch tunnel acted as a stress riser in our patient. This is important as the size of the lateral drill hole or cross-pins as well as their position with respect to the posterior cortex needs to be better defined to decrease the likelihood of this being a stress riser.

Another factor which may have played a role in the development of the fracture seen in our patient is bone tunnel enlargement. Reported to occur in up to 68% of cases, bone tunnel enlargement places patients at a risk for post-operative fractures.[26] The precise etiology of this has yet to be determined. It was initially thought to be an immune-mediated phenomenon, but research showed no difference in the incidence of tunnel enlargement with allograft and autograft.[27] It is now thought that tunnel lysis is a complex imbalance of osteoclastic, osteblastic, immune, and non-specific biological factors. The tunnel enlargement at both the transosseous femoral and the bone mulch screw sites may have additionally weakened the bone to the point where the fracture in our patient could have occurred.

There are potential weaknesses of this case report, limiting the ability to draw widespread conclusions. Firstly, the index operation was performed at a different hospital then ours, where the patient was subsequently treated and had initial follow-up. Continuity of care was adequate, but having the patient and all records under one system might have allowed for more standardized physical examination testing over time. When reviewing the reports of the physical exam, many of the surgeons quantified the ACL pathology with the Lachman maneuver. Although the reliability of the Lachman test is quite high, no standard assessments by devices such as the KT-1000 or other devices were performed. There has been growing support for the pivot shift as a better indicator of knee stability.[28] The pivot shift test was not serially performed which could have provided additional information to the Lachman regarding rotational stability of the knee.

Our case illustrates that the risk of fracture from the stress riser effect of a bone mulch screw may persist many years after the initial repair and perhaps indefinitely. Patients should be informed of the risk of post-operative fractures and educated that a fracture may occur even many years after a repair. Proper technique and minimizing the size of any cortical defect should be emphasized. Further avenues of research include the relationship between drill hole size, number, screw placement, and the incidence of fractures, as well as the relationship between optimal screw diameter and cross-pin stress risers in cadaveric models.

References

1. **Owings MF, Kozak LJ.** Ambulatory and inpatient procedures in the United States, 1996. *Vital Health Stat* 1998; 139: 1-119.
2. **Wiener D, Siliski J.** Distal femoral shaft fracture: A complication of endoscopic anterior cruciate ligament reconstruction. *Am J. of Sports Medicine* 1996; 24(2): 244-247.
3. **Wilson TC, Rosenblum WJ, Johnson DL.** Fracture of the femoral tunnel after an anterior cruciate ligament reconstruction. *J Arthroscopic and Related Surg* 2004; 20(5) e45-47.
4. **Radler C, Wozasek G, Helmut S, Vecsei V.** Distal femoral fracture through the screw hole of a ligament augmentation device. *Arthroscopy* 2000; 16(7): 737-739.
5. **Arriaza R, Senaris J, Couceiro G, Aizpurua J.** Stress fractures of the femur after ACL repair with transfemoral fixation. *Knee Surg Sports Traumatol Arthosc* 2006;14: 1148-1150
6. **Zantop T, Ruemmler M, Welbers B, Langer M, Weimann A, Peterson W.** Cyclic loading comparison between biodegradable interference screw fixation and biodegradable double cross-pin fixation of human bone patellar tendon bone grafts. *Arthroscopy* 2005; 21(8): 934-941.
7. **Zantop T, Weimann A, Wolle K, Musal, V, Langer M, Peterson W.** Initial and 6 weeks postoperative structural properties of soft tissue anterior cruciate ligament reconstructions with cross-pin or interference screw fixation: An in vivo study in sheep. *Arthroscopy* 2007; 23(1): 14-20.
8. **Aglietti, P, Buzzi R, D'Andria S, et al:** Patellofemoral problems after anterior cruciate ligament reconstruction. *Clin Orthop* 1993; 288: 1294-1297.
9. **Howell SM, Taylor MA.** Brace-free rehabilitation, with early return to activity, for knee reconstructed with double-looped semitendinosus and gracilis graft. *J Bone Joint Surgery Am* 1996; 78: 814-825.
10. **Lawhorn, KW, Howell SM.** Scientific justification and technique for anterior cruciate ligament reconstruction using autogenous and allogenic soft-tissue grafts. *Orthop Clin of North America* 2003; 34:1.
11. **Weiler A, Hoffman RFG, Stahelin AC et al.** Hamstring tendon fixation using interference screws: A biomechanical study in calf tibial bone. Arthroscopy 1998; 14:29-37.
12. **Miller CM, Tibore JE, Hewitt M et al.** Interference screw divergence in femoral tunnel fixation during endoscopic anterior cruciate ligament reconstruction using hamstring grafts. Arthroscopy 2002;18:510-514.
13. **Ha KI, Kim SH, Ahn JH.** The HAKI technique of femoral interference screw insertion. Arthoscopy 1999; 15:110-114.
14. **Sanchis-Alfonso V, Tinto-Pedrerol T.** Femoral interference screw divergence after anterior cruciate ligament reconstruction provoking severe anterior knee pain. *Arthroscopy* 2004;20 (5)528-531.
15. **Clark R, Olsen RE, Larson BJ, Goble EM Farrer RP.** Cross-pin femoral fixation: A new technique for hamstring anterior cruciate ligament reconstruction of the knee. *Arthroscopy* 1998; 14: 258-267.
16. **Ahmad CS, Gardner TR, Groh M, Arnouk J, Levine WN.** Mechanical properties of soft tissue femoral fixation devices for anterior cruciate ligament reconstruction. *Am J of Sports Med 2004*; 32: 635-640.
17. **Berg EE.** Lateral femoral condyle fracture after endoscopic anterior cruciate ligament reconstruction. *Arthroscopy* 1994;10:693-695.
18. **Manktelow AR, Haddad FS, Goddard NJ.** Late femoral condyle fracture after anterior cruciate ligament reconstruction: A case report. *Am J Sports Med* 1998;26:587-590.
19. **Noah J, Sherman OH, Roberts C.** Fracture of the supracondylar femur after anterior cruciate ligament reconstruction using patellar tendon and iliotibial band tenodesis: A case report. *Am J Sports Med* 1992;20:615-618.
20. **Ternes JP, Blaiser RB, Alexander AH.** Fracture of the femur after anterior cruciate ligament reconstruction with Gore-Tex prosthetic graft: A case report. *Am J Sports Med* 1993; 21:147-149.
21. **Burstein AH, Currey J, Frankel VH, et al.** Bone strength: The effect of screw holes. *J Bone Joint Surg Am* 1972;54:1143-1156.
22. **Brooks DB, Burnstein AH, Frankel VH.** The biomechanics of torsional fractures: The stress concentration effect of a drill hole. *J Bone Joint Surg Am* 1970;52: 507-514
23. **Rosson J, Egan J, Shearer J et al.** Bone weakness after the removal of plates and screws: Cortical atrophy of screw holes. *J bone Joint Surg Br* 1991;73: 283-286.
24. **Mithoefer K, Gill TJ, Vrahas MS.** Supracondylar femoral fracture after arthroscopic reconstruction of the anterior cruciate ligament. *J Bone Joint Surg Am* 2005; 87:1591-1596.
25. **Guy P, Krettek C, Mannss J, Whitall KP, Schandelmaier P, Tcherne H.** CT-based analysis of the geometry of the distal femur. *Injury* 1998;29 Suppl3:C16-21.
26. **Webster KE, Feller JA, Hameister KA.** Bone tunnerl enlargement following anterior cruciate ligament reconstruction: a randomized comparison of hamstring and patellar tendon grafts with 2-year follow-up. *Knee Surg Sports Traumatol Arthros*. 2001;9:86-91
27. **Hoer J, Moller HD, Fu FH.** Bone tunnel enlargement after anterior cruciate ligament reconstruction: fact or fiction? *Knee Surg Sports Traumatol Arthros*. 1998;6(4):231-40.
28. **Lane CG, Warren R, Pearle AD.** The Pivot Shift. *JAAOS* 2008:16 (12) 679-688.