

Insufficiency fracture of the tibial plateau after anterior cruciate ligament reconstructive surgery: a case report and review of the literature

Jessica J. Wong¹, BSc, DC, FCCS(C)
Brad Muir², HBSc (Kin), DC, FRCCSS(C)

Peri-articular fractures after anterior cruciate ligament (ACL) reconstructive surgery are rare. To our knowledge, this case documents the first insufficiency fracture of the tibial plateau after ACL reconstruction, which presented three weeks after the procedure. A 25-year-old female recreational soccer player suffered an insufficiency fracture of the tibial plateau, extending 1.5 mm into the anterior wall of tibial tunnel and medial compartment under the anterior horn of medial meniscus, which presented as a diagnostic challenge. Clinically, the fracture mimicked a low-grade infection of the surgical site, while radiographically, the fracture resembled an avulsion fracture, later confirmed as a tibial tunnel fracture with computed tomography. With the ACL graft integrity not in jeopardy, four weeks of non-weightbearing and a delayed post-operative rehabilitation program was effective in allowing the fracture to heal. Good functional outcome was achieved after conservative management, with minimal loss of terminal knee extension and minimal pain at 22-month follow-up.

KEY WORDS: tibial plateau, fracture, ACL reconstruction, complication, conservative management

Les fractures péri-articulaires après une chirurgie reconstructive du ligament croisé antérieur (LCA) sont rares. À notre connaissance, ce cas représente la première fracture par insuffisance du plateau tibial après une chirurgie reconstructive du LCA, qui s'est présentée trois semaines après la procédure. Une joueuse amateur de soccer de 25 ans a subi une fracture par insuffisance du plateau tibial, se prolongeant 1,5 mm dans la paroi antérieure du tunnel tibial et dans le compartiment médian sous la corne antérieure du ménisque interne, ce qui présentait une difficulté de diagnostic. Du point de vue clinique, la fracture ressemblait à une infection légère du foyer opératoire, alors que d'un point de vue radiographique, cela ressemblait plus à une fracture par avulsion. Plus tard, la tomographie par ordinateur a confirmé une fracture du tunnel tibial. L'intégrité de la greffe n'étant pas en danger, quatre semaines sans porter aucune charge et un programme différé de réhabilitation postopératoire ont permis la guérison de la fracture. De bons résultats fonctionnels ont été atteints après la gestion conservatrice, avec une perte minimale de l'extension du genou terminal, et une douleur minimale après 22 mois de suivi.

MOTS CLÉS : plateau tibial, chirurgie reconstructive du LCA, complication, gestion conservatrice

¹ Graduate Student, Clinical Sciences, Canadian Memorial Chiropractic College, Toronto, Ontario, Canada

² Assistant Professor, Division of Undergraduate Studies, Canadian Memorial Chiropractic College, Toronto, Ontario, Canada

Corresponding author: Jessica J. Wong, Graduate Student, Clinical Sciences, Canadian Memorial Chiropractic College, 6100 Leslie Street, Toronto, Ontario M2H 3J1. Phone: (416) 482-2340. Email: jes.wong@utoronto.ca.

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Introduction

Injuries to the anterior cruciate ligament (ACL) are common in athletic populations, particularly in female athletes participating in soccer. The incidence of ACL injury ranges from 0.06-3.7 per 1000 hours of training and participation in soccer, and accounts for thousands of ACL tears annually.^{1,2} Female soccer players have up to 6-times greater risk of an ACL tear than male counterparts.³ In light of this, between 50,000 and 100,000 ACL reconstructive surgeries are performed annually in the United States⁴, while the rate of revision ACL reconstruction in Denmark is 4.1% after five years⁵. Post-surgical complications after ACL reconstruction vary widely and include stiffness, wound complications, infection, graft failure, deep venous thrombosis, pulmonary embolism, osteonecrosis and peri-articular fracture.⁶⁻⁸ Peri-articular fractures involving the tibia plateau are rare, as only a few case reports describe this specific complication.⁹⁻¹⁹

Post-surgical complications related to ACL reconstruction have important clinical implications. In a retrospective hospital database review from 1997-2006, it was found that of 70,547 ACL reconstructive surgeries performed, 6.5% of cases had subsequent surgery on either knee within one year.⁵ Predictors of subsequent knee surgery included female gender, concomitant knee surgery, and operation by lower-volume surgeons, while predictors of subsequent ACL reconstruction included age of less than 40 years, concomitant meniscectomy or other knee surgery, and surgery in lower-volume hospitals.⁵ This suggests that while ACL reconstruction is a relatively safe procedure, there remains a noted risk of subsequent operation on either knee, which is increased by a number of predictors, including those who are younger and female. It is therefore important to conduct timely assessment of those presenting with knee complaints after ACL reconstruction surgery to facilitate appropriate management, in aims to minimize the need for subsequent operation.

To our best knowledge, this case report details the first published case of an insufficiency fracture of the tibial plateau presenting three weeks after ACL reconstructive surgery. It was a diagnostic challenge, as its clinical presentation mimicked that of an infection or septic arthritis, but appropriate and timely imaging and investigative procedures detected the fracture. The early detection may have also mitigated its severity and allowed for uncomplicated non-invasive management of the fracture. Discus-

sion will surround the incidence, pathogenesis, clinical presentation, imaging and management of this post-surgical complication.

Case Report

A 25 year-old female recreational soccer player sustained a left knee injury while playing soccer. During the game, she received an impact from another player to the medial aspect of her knee as her foot was planted, taking a varus force to the left knee. There was no audible pop or click during this injury, though she was unable to weightbear immediately after and had to use crutches to ambulate. She also reported noticeable swelling at the left knee. The patient did not report any previous injuries to this knee and did not experience any numbness or tingling into the lower extremity. She was otherwise healthy with no known medical conditions. Past medical history was remarkable for a wrist fracture fifteen years ago and a fracture of the right lateral malleolus ten years ago. She was taking oral contraceptive pills and doxycycline for acne, was a social drinker and did not smoke.

The patient immediately followed RICE principles and went to a chiropractic clinic two days after the injury for an assessment. Based on history and physical examination findings, the initial diagnosis was a left lateral collateral ligament (LCL) sprain with a suspected lateral meniscal tear and the patient was referred to a family physician for an MRI. The subsequent MRI found a full thickness ACL tear and suspected partial LCL tear in the left knee and the patient was referred to an orthopedic surgeon for consultation. Prior to the surgical consultation, the patient was treated with tolerable rehabilitation exercises and laser therapy at the chiropractic clinic twice a week for four weeks in aims to minimize muscle atrophy.

At her surgical consultation four weeks later, the patient was able to ambulate with a cane, but experienced recurrent mild dull pain at the anteromedial knee and episodes of instability when the left knee was in extension. Physical examination by the orthopedic surgeon revealed no swelling or effusion within the knee and no tenderness along the joint line. Left knee range of motion was passively full, but mildly lacked terminal flexion with active motion and lacked 5 degrees of genu recurvatum when compared to the right knee. It was difficult to perform ligamentous testing due to patient apprehension, though varus and valgus stability appeared intact. There was a

grade 1 positive Lachman test and a grade 1 positive pivot shift test with soft end feel. Anterior drawer test, dial testing, examination of other ligaments and lower limb neurovascular examination were unremarkable. While clinical examination did not show prominent laxity, the patient's left knee ACL deficiency was deemed symptomatic and confirmed on MRI. Due to the patient's desire to return to sport and her good candidacy for ACL reconstruction using a hamstring autograft, surgery was agreed upon. After ACL reconstruction, the patient had an uncomplicated recovery, and was discharged home by the orthopedic surgeon with pain medication, rehabilitation protocol and a follow-up appointment in 3-5 weeks' time.

At three weeks post-surgery, the patient began experiencing tenderness at the surgical site, with redness, swelling, warmth and decreased knee range of motion due to pain. There was no preceding trauma, and the patient had not yet returned to sport. She was also closely adhering to her rehabilitation protocol of daily open chain range of motion and light strengthening exercises of the knee within pain tolerance. At the chiropractic clinic, knee radiographs were ordered, which found moderate joint effusion and soft tissue swelling at the medial joint space, and suggestion of cortical offset at the medial tibial epiphysis (Figures 1a and 1b).

Upon further review, these radiographs showed a small



FIGURE 1a. AP Knee View

Significant soft tissue swelling is observed at the medial aspect of the left knee, near the pes anserine attachment. There is evidence of ACL reconstruction with a tibial tunnel (triangle) at the medial tibial plateau and a ligament anchor (Endobutton device) at the lateral femoral condyle (arrowhead). A cortical offset at the medial tibial epiphysis is suggested at the entrance of the tunnel (arrow).

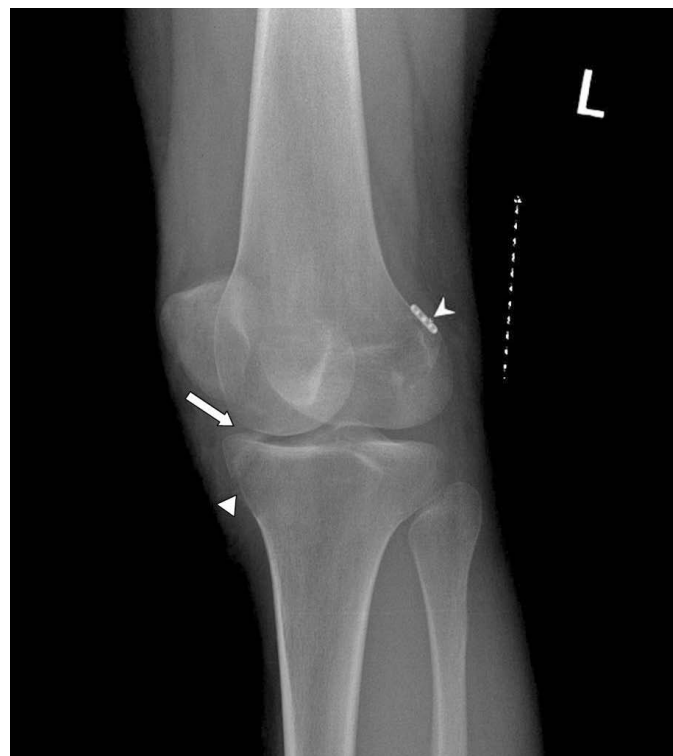


FIGURE 1b: Lateral Oblique Knee View

Moderate joint effusion is detected in the left knee with fullness of the suprapatellar recess and blurring of the posterior portion of the Hoffa's fat pad. A cortical defect at the proximal tibia (arrow), the tibial tunnel (triangle), and a ligament anchor (Endobutton device) at the lateral femoral condyle are noted (arrowhead).

triangular shaped fracture fragment well margined posteriorly and laterally by an oblique lucent line traversing the anteromedial aspect of the tibial plateau. This resulted in the cortical offset noted at the articular surface of the medial tibial plateau. The oblique lucent line is just superomedial to the tibial tunnel created by the orthopaedic surgeon to fix the reconstructed ACL.

Due to the amount of soft tissue swelling and joint effusion noted in radiographs, possible low-grade infection or septic arthritis could not be ruled out at the time, so she was sent to the emergency department for blood tests, which were unremarkable. A follow-up appointment with the orthopaedic surgeon was advised.

At her follow-up appointment with the orthopaedic surgeon five weeks post-surgery, the patient continued to report pain and persistent warmth around the surgical

site. On examination, the patient walked with slightly flexed knee gait, though passively she could extend her knee fully and flex to within 10 degrees of the other side. While she had a moderate-sized effusion at the left knee, her wounds were well healed and she was afebrile. Her quadriceps femoris were contracting but moderately inhibited, and there was noted tenderness proximal to the tibial wound. Lachman test and pivot shift of her left knee were negative.

Computed tomography (CT) of her left knee revealed a 1.5 mm cortical defect into the anterior portion of the medial compartment, underneath the anterior horn of the medial meniscus, with mild joint effusion present (Figures 2a and 2b). The CT images, read by a medical radiologist, confirmed the presence of a subacute, undisplaced intra-articular fracture involving the anteromedial corner



FIGURE 2a: CT Knee – Sagittal Slice
A cortical defect is noted at the anterior portion of the medial compartment, underneath the anterior horn of the medial meniscus, confirming the presence of an intra-articular fracture (arrow). Mild joint effusion is present.



FIGURE 2b: CT Knee – Axial Slice
The cortical defect is shown extending into the tibial tunnel by 1.5 mm without displacement (arrow).

of the medial tibial plateau and extending into the tibial tunnel by 1.5 mm. Joint effusion was also noted and the ACL graft was intact.

With the ACL graft integrity intact, non-weightbearing for four weeks with use of crutches, with a delay in the rehabilitation protocol, was prescribed to see if the fracture would heal. A follow-up appointment was given in four weeks' time. At follow-up, physical examination of her left knee found no swelling or pain on palpation, with only minimal loss of terminal knee extension. A repeat CT scan of the left knee revealed that the tibial plateau fracture was healed, and the patient was allowed to resume her rehabilitation protocol.

At 13 months post-surgical follow-up, the patient reported minimal pain of 1/10 intensity localized to the fracture site at the medial-anterior tibial. On palpation, a small bony abnormality is noted at the fracture site. Full knee range of motion was noted, with the exception of a 5 degree loss of genu recurvatum with the injured knee. The orthopaedic surgeon suspected that the surgical screw was slightly protruding from the tibial tunnel and leading to the residual pain. A lidocaine injection into the medial joint line of the knee was effective in eliminating the pain temporarily. At this point, the patient opted to tolerate the minor degree of pain without pursuing further interventions, and was able to return to certain sports (volleyball and basketball) on a regular basis.

At 22 months post-surgical follow-up, the minimal pain of 1/10 intensity at the fracture site remained, with aggravation of pain only after prolonged sitting (2 hours or more), or long distance running (5 km or more), where the intensity would increase to 3/10. The patient deemed this pain tolerable and continued with her recreational sports without difficulty.

Discussion

Incidence:

Tibial plateau fracture presenting as a complication following ACL reconstruction surgery is rare, with only ten English-language case reports documenting this occurrence.⁹⁻¹⁸ Thietje et al described a tibial fracture after ACL reconstruction surgery, but as the article was written in German, details could not be obtained.¹⁹ Although rare, it is important to be aware of this post-operative complication, as most cases required surgical fixation

of the fracture.^{10-12,15,16} This warrants an in-depth understanding of the pathogenesis and clinical presentation of this post-surgical complication to aid in recognition and management.

Pathogenesis:

Although its pathogenesis is not completely understood, there are contributing factors that predominantly relate to bone strength, tibial tunnel and graft harvest site. It has been proposed that in young healthy individuals with ACL reconstruction, the loss of trabecular cancellous bone is greater than cortical bone loss after the operative procedure. Even though trabecular cancellous bone constitutes only 20% of bone mass, there is a decreased transosseous bone strength as a result of the normal surgical procedure.²⁰⁻²² While there are no studies that specifically measure bone strength of the tibia following graft harvest or tibial tunnel drilling, biomechanical studies have found that bone defects, such as screw holes, can concentrate stress and decrease bone strength to torsional loading.^{23,24} For instance, diaphyseal drill holes with a diameter greater than 20% of the bone have been shown to reduce bone strength by 55-90%.^{23,25-27}

This can be further complicated by additional factors. Authors have also suggested that other biomechanical factors, such as motion of the graft within the tunnel and fixation methods/devices, and biological factors, such as graft swelling and use of allograft tissue, may also contribute to tunnel enlargement.^{28,29} Further, with patellar tendon grafts, authors suggest that the tibial harvest site, combined with the tibial tunnel, may synergistically act as stress-risers to reduce proximal tibial bone strength.^{9-11,14} In four of the cases of tibial fractures after ACL reconstruction, the patellar tendon autografts were involved.^{9-11,14,16,18} In our case, the patient suffered a tibial plateau fracture with a gracilis-semitendonosis autograft, which was similar to two other cases found in the literature.^{13,15} This may suggest that the tibial tunnel plays a larger role as a stress-riser when compared to the harvest graft site.

Clinical Presentation:

The details of previous relevant case reports on tibial plateau fractures after ACL reconstruction are outlined in Table 1. Cases had an age range of 20-61 years, with 4 cases involving females and 8 cases in males. Most cases

Table 1:
Published Case Reports on Tibial Plateau Fractures after ACL Reconstruction

Author(s), Year	Age, gender, type of fracture, graft	Presentation, trauma, onset after ACL surgery	Imaging confirming fracture	Outcome, follow-up
El-Hage et al., 1998 ¹²	20 year-old male, intra-articular tibial plateau fracture extending into tibial tunnel, allograft	Pain, swelling after road traffic accident, 18 months	CT	Open reduction and internal fixation of fracture, full recovery at 7 months
Moen et al., 1998 ¹⁴	29 year-old female, tibial fracture at graft harvest site, patellar tendon	Pain, swelling, inability to weightbear after minor fall, 6 weeks	X-rays	Protected weightbearing with cast and crutches, outcome not reported
Morgan and Steensen, 1998 ⁹	30 year-old male, minimally displaced tibial plateau fracture extending into tibial tunnel, patellar tendon	Pain, swelling after direct trauma from baseball bat, 7 months	X-rays	Non-weightbearing for 4 weeks, full recovery at 4 weeks
Delcogliano et al., 2001 ¹⁰	27 year-old male, displaced tibial plateau fracture extending into tibial tunnel, patellar tendon	Pain, swelling after motorcycle accident, 7 months	X-rays	Open reduction and internal fixation of fracture, mild quadriceps weakness at 1 year, early knee degeneration at 2 years
Mithofer et al., 2004 ¹¹	61 year-old female, bicondylar tibial plateau fracture extending into tibial tunnel, patellar tendon	Pain, swelling, inability to weightbear, crepitation after falling down stairs, 7 months	X-rays and CT	Minimally invasive surgical fixation, mild decrease in motion at 3 months
Sundaram et al., 2005 ¹³	40 year-old female, undisplaced tibial plateau fracture extending into tibial tunnel, gracilis-semitendinosis	Pain, swelling, hemarthrosis after falling onto knee when walking, 12 months	MRI (not detected with x-rays)	6-week non-weightbearing cast and 6-week weightbearing knee brace, mild decrease in motion at 3 months
Thaunat et al., 2006 ¹⁸	24 year-old male, fracture at tibial fixation site, patellar tendon	Pain, inability to weightbear, hemarthrosis after 4-ft fall, 4 years	CT	6-week non-weightbearing cast and 2-week weightbearing knee brace, full recovery at 7 months
Voos et al., 2007 ¹⁶	43 year-old female, oblique metaphyseal tibial fracture extending into donor site, patellar tendon	Pain, swelling after falling while jogging on treadmill, 4 years	X-rays and CT	Open reduction and internal fixation of fracture, full recovery at 12 months
Polyzois et al., 2009 ¹⁵	43 year-old male, distal femoral and tibial plateau fracture, gracilis-semitendinosis	Pain, swelling after road traffic accident, 2 weeks	X-rays	Open reduction and internal fixation of fracture, full recovery at 12 months
Gobbi et al., 2011 ¹⁷	41 year-old male, tibial plateau fracture involving medial condyle and extending into tibial tunnel, semitendinosis	Pain, swelling, giving way after running backwards in soccer game, 4.5 years	X-rays and CT	Open reduction and internal fixation of fracture, full recovery at 12 months

used patellar tendon autograft^{9,11,14,16,18}, with two cases using gracilis-semitendinosis autograft^{13,15}, one case using double strand semitendinosis graft¹⁷ and one case using a freeze-dried Achilles tendon allograft¹². Most fractures involved either the tibial tunnel^{9-13,17}, tibial fixation site^{14,18} or graft harvest/donor site^{14,16}. The case described by Polyzois et al had femoral and tibial fractures in the opposite direction of the ACL femoral and tibial tunnels, but it should be noted that the injury was preceded by high energy trauma from a road traffic accident, with the patient suffering multiple fractures.¹⁵ All cases presented

with knee pain and a degree of swelling, and were preceded by some form of trauma, namely falls or motor vehicle accidents. One case was preceded by minimal trauma of running backwards during soccer, though it cannot be determined whether the onset of fracture occurred before or after the minimal trauma.¹⁷ Three cases involved patients who could not weightbear after the incident.^{11,14,18}

In our case, the patient also presented with pain and swelling, though there was no preceding trauma. To our best knowledge, this is the first published insufficiency fracture of the tibial plateau after ACL reconstruction

surgery, presenting only three weeks after the surgical procedure. Other authors have noted that it is important to rule out more sinister causes of swelling, including wound complications⁸ and septic arthritis^{30,31}. In a prospective consecutive cohort of subjects with primary ACL reconstruction in England from 2008-2010, it was found that a small percentage subsequently suffered from symptomatic deep venous thrombosis (0.30%), pulmonary thromboembolism (0.18%) or wound complication (0.75%).⁸ Our patient was sent to the emergency department by the chiropractor to undergo blood tests and investigate the possibility of an infection or septic arthritis. This suggests that pain at the surgical site with persistent swelling should heighten the clinician's suspicion for a post-surgical complication, such as septic arthritis or peri-articular fracture, regardless of whether there was preceding trauma.

Imaging:

A brief review of the ACL reconstruction surgery is warranted to further understand the imaging findings on radiographs and advanced imaging. One of the primary ACL reconstruction procedures is the autologous doubled semitendinosis and gracilis tendon graft (also known as four-strand hamstring graft). This procedure involves a femoral tunnel positioned at the lateral femoral condyle and a tibial tunnel positioned through the medial tibial plateau. Various methods are used to secure the graft within the tunnels until bony union occurs, including interference screws and the distal femoral Endobutton device.³²

Some of the previous case reports describing tibial plateau fractures were detected on knee radiographs^{10,11,14-17} though other cases used solely computed tomography^{12,18}. In cases where the fracture was found on CT, it was not reported whether knee radiographs had initially detected the fracture. Sundaram et al noted that their subject's undisplaced tibial plateau fracture was not detected with knee AP or lateral oblique radiographs and was only found on subsequent MRI.¹³ Thus, it was recommended that all acutely painful and swollen knees from trauma, following ACL reconstruction, should undergo an MRI when knee radiographs are read as normal.¹³ MRI has been shown to be a sensitive instrument to exclude occult fractures not detected on plain radiographs.^{33,34} In our case, while the initial radiographs detected a cortical defect at the medial tibial plateau, CT was required to determine the precise

location and extent of the fracture. This supports the role of advanced imaging in cases where post-surgical fracture is suspected based on clinical presentation.

Management:

Treatment of tibial plateau fractures after ACL reconstruction has been variable.

In previous reports, five cases were surgically managed with open reduction and internal fixation^{10,12,15-17}, one case was surgically managed with minimally invasive surgical fixation¹¹, and four cases were managed with 4-6 weeks of non-weightbearing^{9,13,14,18}. The surgical cases tended to be associated with moderate-to-high degrees of trauma and more severe fractures, such as displaced fractures. Mithofer et al successfully used minimally-invasive fracture fixation of an intra-articular tibial plateau fracture, which involved the use of indirect fracture reduction and new plate designs, and no ACL revision was necessary.¹¹ The distinct characteristic of our case is the early and insufficiency fracture onset. In all previous cases, the subjects were examined in a tertiary care setting, underscoring the importance of referring suspected cases of peri-articular fractures after ACL reconstruction to orthopedic specialists by primary contact providers.

In our patient's case, early detection of this fracture may have minimized the need for invasive treatment. The patient had pain and swelling only three weeks after her ACL reconstruction, and was assessed at a chiropractic clinic. Prompt investigations ordered by the chiropractor included knee radiographs, which detected a possible infection or septic arthritis, and facilitated an immediate referral to the emergency department. Delayed assessment and diagnosis of the tibial plateau fracture may have led to further progression of the fracture and possible indication for more invasive management, such as surgical fixation of the fracture or ACL revision if the graft was in jeopardy. An appropriate index of suspicion for post-surgical complications is important, particularly in primary care providers focused on post-surgical rehabilitation. For instance, a recent case report describes active post-operative ACL reconstruction rehabilitation combined with soft tissue therapy in a chiropractic clinic that facilitated successful recovery and return to function.³⁵ Authors emphasized the need to be up-to-date on the most recent evidence in post-surgical ACL rehabilitation, including early active exercise.^{35,36} As highlighted in our patient's

case, effective management of post-surgical rehabilitation should not only include evidence-based rehabilitation protocols, but should also include an understanding of potential post-surgical complications, including tibial plateau fractures. This facilitates detection and appropriate management in both orthopedic surgeons and primary care providers, including chiropractors.

Summary:

This case report described the occurrence of a tibial plateau fracture presenting three weeks after ACL reconstruction, without any preceding trauma. Discussion surrounded the role of bony defects caused by transosseous tibial tunnels from ACL reconstruction that may have contributed to the post-operative tibial plateau fracture. In this case, early detection allowed for conservative management in the form of four weeks of non-weightbearing and delayed rehabilitation protocol to allow the fracture to heal, avoiding the need for surgical fixation of the fracture. This suggests that all acutely painful knees with persistent swelling, whether preceded by trauma or not, should be carefully investigated by both primary care and tertiary care providers to determine the underlying pathology and rule out peri-articular fractures.

References

1. Bjordal JM, Arnoy F, Hannestad B, Strand T. Epidemiology of anterior cruciate ligament injuries in soccer. *Am J Sports Med.* 1997; 25:341-345.
2. Fauno P, Wulff Jakobsen B. Mechanism of ACL injuries in soccer. *Int J Sports Med.* 2006; 27:75-79.
3. Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature. *Am J Sports Med.* 1995; 23:694-701.
4. Fineberg MS, Zarins B, Sherman OH. Practical considerations in anterior cruciate ligament replacement surgery. *Arthroscopy.* 2000; 16: 715-724.
5. Lind M, Mehnert F, Pedersen AB. Incidence and outcome after revision anterior cruciate ligament reconstruction: results from the Danish registry for knee ligament reconstructions. *Am J Sports Med.* 2012; May 4 [Epub ahead of print].
6. Allum R. Complications of arthroscopic reconstruction of the anterior cruciate ligament. *J Bone Joint Surg Br.* 2003; 85:12-16.
7. Sekiya JK, Ong BC, Bradley JP. Complications in anterior cruciate ligament surgery. *Orthop Clin North Am.* 2003; 34:99-105.
8. Jameson SS, Downen D, James P, Serrano-Pedraza I, Reed MR, Deehan D. Complications following anterior cruciate ligament reconstruction in the English NHS. *Knee.* 2011, DOI:10.1016/j.knee.2010.11.011
9. Morgan E, Steensen RN. Traumatic proximal tibial fracture following anterior cruciate ligament reconstruction. *Am J Knee Surg.* 1998; 11:193-4.
10. Delcogliano A, Chiossi S, Caporaso A, Franzese S, Menghi A. Tibial plateau fracture after arthroscopic cruciate ligament reconstruction. *Arthroscopy.* 2001; 17:E16.
11. Mithofer K, Gill TJ, Vrahas M. Tibial plateau fracture following anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2004; 12:325-8.
12. El-Hage ZM, Mohammed A, Griffiths D, Richardson JB. Tibial plateau fracture following allograft anterior cruciate ligament (ACL) reconstruction. *Injury.* 1998; 29:73-4.
13. Sundaram RO, Cohen D, Barton-Hanson N. Tibial plateau fracture following gracilis-semitendinosus anterior cruciate ligament reconstruction: the tibial tunnel stress-riser. *Knee.* 2006; 13:238-240.
14. Moen KY, Boynton MD, Raasch WG. Fracture of the proximal tibia after anterior cruciate ligament reconstruction: a case report. *AM J Orthop.* 1998; 27:629-630.
15. Polyzois I, Manidakis N, Graham S, Tsiridis E. An unusual periarticular fracture following ipsilateral anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2009; 17:503-507.
16. Voos JE, Drakos MC, Lorich DG, Fealy S. Proximal tibia fracture after anterior cruciate ligament reconstruction using bone-patellar tendon-bone autograft: a case report. *HSSJ.* 2008; 4: 20-24.
17. Gobbi A, Mahajan V, Karnatzikos G. Tibial plateau fracture after primary anatomic double-bundle anterior cruciate ligament reconstruction: a case report. *Arthroscopy.* 2011; 27(5):735-40.
18. Thauat M, Nourissat G, Gaudin P, Beaufile P. Tibial plateau fracture after anterior cruciate ligament reconstruction: role of the interference screw resorption in the stress riser effect. *Knee.* 2006; 13(3): 241-3.
19. Theitje R, Faschingbauer M, Nurnberg HJ. Spontaneous fracture of the tibia after replacement of the anterior cruciate ligament with absorbable interference screws: a case report and review of the literature. *Unfallchirurg.* 2000; 103: 594-596.
20. Kartus J, Stener S, Nilsen R, Nilsson U, Eriksson BI, Karlsson J. Bone mineral assessments in calcaneus after anterior cruciate ligament injury: an investigation of 92 male patients before and two years after reconstruction or revision surgery. *Scan J Med Sci.* 1998;8:449-455.
21. Ejerhed L, Kartus J, Nilsen R, Nilsson U, Kullenberg R, Karlsson J. The effect of anterior cruciate ligament surgery on bone mineral in the calcaneus: a prospective study with

- a 2-year follow-up evaluation. *Arthroscopy*. 2004; 20: 352-359.
22. Nyland J, Fisher B, Brand E, Krupp R, Caborn DNM. Osseous deficits after anterior cruciate ligament injury and reconstruction: a systematic literature review with suggestions to improve osseous homeostasis. *Arthroscopy*. 2010; 26(9): 1248-1257.
 23. Burstein AH, Currey J, Frankel VH et al. Bone strength: the effect of screw holes. *J Bone Joint Surg AM*. 1972; 54: 1143-1156.
 24. Uthoff HK. Mechanical factors influencing the holding power of screws in compact bone. *J Bone Joint Surg Br*. 1973; 55(3): 633-9.
 25. Brooks DB, Burstein 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.
 26. Johnson BA, Fallat LM. The effect of screw holes on bone strength. *J Foot Ankle Surg*. 1997; 36:446-451.
 27. Rosson J, Egan J, Shearer J, Monro P. Bone weakness after the removal of plates and screws. Cortical atrophy or screw holes? *J Bone Joint Surg Br*. 1991; 73(2): 283-6.
 28. Konan S, Haddad FS. Femoral fracture following knee ligament reconstruction surgery due to an unpredictable complication of bioabsorbable screw fixation: a case report and review of literature. *J Orthop Traumatol*. 2010; 11(1): 51-5.
 29. Wilson TC, Kantaras A, Atay A, Johnson DL. Tunnel enlargement after anterior cruciate ligament surgery. *Am J Sports Med*. 2004; 32(2): 543-9.
 30. Mouzopoulos G, Fotopoulos VC, Tzurbakis M. Septic knee arthritis following ACL reconstruction: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2009; 17:1033-1042.
 31. Wang C, Ao Y, Wang J, Hu Y, Cui G, Yu J. Septic arthritis after arthroscopic anterior cruciate ligament reconstruction : a retrospective analysis of incidence, presentation, treatment and cause. *Arthroscopy*. 2009; 25(3): 243-249.
 32. Meyers AB, Haims AH, Menn K, Moukaddam H. Imaging of the anterior cruciate ligament repair and its complications. *AJR*. 2010; 194: 476-484.
 33. Remplik P, Stabler A, Merl T, Roemer F, Bohndorf K. Diagnosis of acute fractures of the extremities: comparison of low-field MRI and conventional radiography. *Eur Radiol*. 2004; 14(4): 625-30.
 34. Oka M, Monu JU. Prevalence and patterns of occult hip fractures and mimics revealed by MRI. *Am J Roentgenol*. 2004; 182(2): 283-8.
 35. Solecki TJ, Herbst EM. Chiropractic management of a postoperative complete anterior cruciate ligament rupture using a multimodal approach: a case report. *J Chiropr Med*. 2011; 10(1): 47-53.
 36. Beynon BD, Uh BS, Johnson RJ, et al. Rehabilitation after anterior cruciate ligament reconstruction: a prospective, randomized, double-blind comparison of programs administered over 2 different time intervals. *Am J Sports Med*. 2005;33:347-59.