5 Anterior Cruciate Ligament Injury and Reconstruction

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5.1 Introduction

Anterior cruciate ligament (ACL) tears are a common knee injury, especially in young and physically active individuals. The ACL has been perhaps the most studied ligament in the human body in the last decade. Its importance to knee function has been demonstrated by the substantial functional impairment and decreased performance experienced after ACL injury [1]. This is especially true in the high-level athlete performing cutting, pivoting, and kicking activities [2]. The ACL confers stability to the knee by resisting both rotational and translational forces, thereby facilitating the normal kinematics of the knee [3–5]. Anatomic, hormonal, environmental, and biomechanical factors appear to influence the incidence of ACL injuries with females having a four- to sixfold increase in rate of ACL injury compared to men [3].

The clinical diagnosis of an ACL injury can be challenging, and concomitant pathology is important to recognize. The classic history for an ACL tear is a noncontact pivoting injury resulting in immediate swelling after hearing a "pop." The patient is typically unable to return to play because of pain and difficulty with pivoting and cutting. The key physical examination maneuver to diagnose an ACL injury is the Lachman, performed in 20–30° of knee flexion. Perceived side-to-side difference should be assessed, and determination of an "end point" of translation noted. The pivot shift is also helpful, but the maneuver is sometimes difficult to perform in the clinic because of guarding by the patient. Least reliable is the anterior drawer, performed at 90° knee flexion, as hamstring spasticity and difficulty with motion can mask an injury.

Plain radiography is often the first study ordered to rule out other abnormalities and may demonstrate a Segond fracture, which is pathognomonic for ACL injury. Magnetic resonance imaging (MRI) remains the imaging technique of choice for patients with suspected ACL tear where the diagnosis is in question. MRI is also useful in identifying concomitant knee pathology. Arthroscopy remains the gold standard for diagnosing ACL rupture and meniscal tear in a patient with persistent symptoms.

ACL reconstruction has evolved considerably over the past 30 years. Advances have largely centered on an understanding of the anatomy of footprint of the ACL. Multiple studies have identified the importance of anatomic ACL reconstruction to restore the ACL to its native dimensions, insertion sites, and collagen orientation to confer ideal rotational and translational stability as misplaced tunnels can lead to graft failure [2, 6–8]. The anatomy of the ACL consists of two distinct bundles: the anteromedial and posterolateral, representing intracapsular structures supplied predominately by the middle geniculate artery.

Treatment for ACL injuries includes operative reconstruction or nonoperative rehabilitation. The age and level of activity of the patient must be considered prior to making any recommendations. The primary candidates for ACL reconstruction are active patients with functional instability. Current evidence suggests that ACL deficiency can lead to chondral damage as well as meniscal tears and that reconstruction leads to long-term functional and cost benefits in the right patient though some studies suggest increased arthrosis on later follow-up [5, 9].

Standard management protocol includes early active range of motion to regain full knee range of motion with closed chain weight-bearing exercises prior to surgical reconstruction. After the pathology is characterized by diagnostic arthroscopy, treatment options depend upon the patient, injury, and surgeon preferences. Concomitant pathology, including meniscal tears, chondral defects, or other ligamentous injuries, can be addressed in the same setting.

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This chapter will utilize a case-based format to demonstrate the correlation between MRI and arthroscopy for pathology and review the diagnosis and techniques for management of each patient.

5.2 Case 1: ACL Rupture

5.2.1 History/Exam

An 18-year-old rugby player presented to orthopedic clinic 1 week following a tackling injury where another player's head collided with his knee during play. A patella dislocation was reduced on the field, and a large effusion was evident immediately. One week later, he reported a resolving effusion as well as feeling of instability with attempted return to play. He had sought advice from his athletic trainer and team physical therapist concerning his symptoms and presented to our orthopedic clinic for further evaluation.

On physical examination, the patient was found to have a moderate effusion with obvious lack of end point with Lachman examination. Lateral joint line tenderness was notable with a positive McMurray's. A pivot shift was noticeably positive in the office. No varus or valgus opening or asymmetry with the contralateral knee was noted on examination. The patient was otherwise neurovascularly intact and without symptoms in his contralateral knee. He had pain and difficulty with straight leg raise without a palpable patella tendon defect. Given the patient's examination and desire to return to competitive play, advanced imaging was obtained to evaluate for additional pathology.

5.2.2 Imaging

Plain radiographs were obtained demonstrating no bony avulsions or other associated injuries. There was no evidence of arthritic changes or areas of significant cartilage loss. Magnetic resonance imaging was obtained to further evaluate the patient's ACL, menisci, and other soft tissue structures, given his persistent symptoms. A complete sequence of images was obtained, including coronal fat-saturated T1 and T2 sequences, sagittal T1 and fat-saturated T2, and axial T1 and T2 sequences. Sagittal T2-weighted images are demonstrated in Fig. 5.1a, and coronal T2-weighted images are demonstrated in Fig. 5.1b.

A complete midsubstance ACL tear was present as shown in Fig. 5.2a, b. Acute hemarthrosis was present with a typical

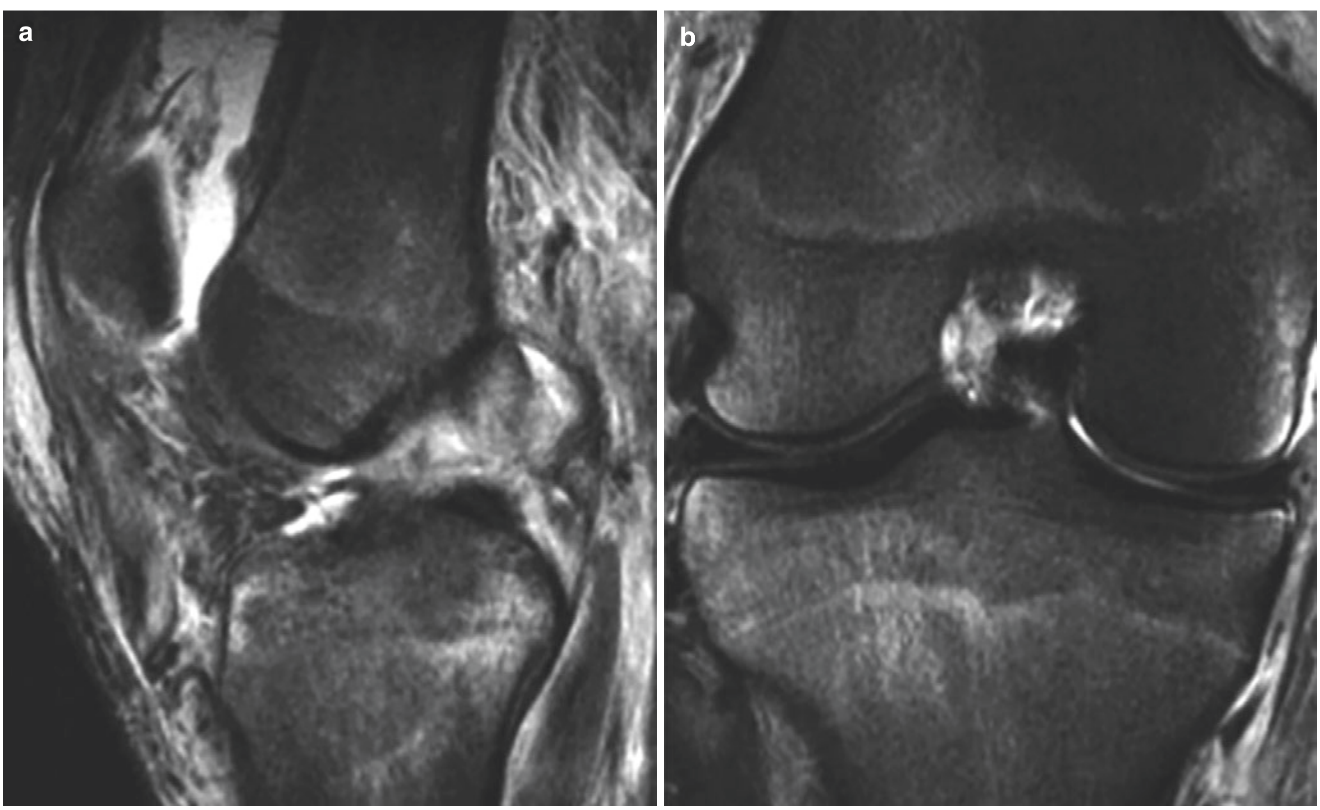

Fig. 5.1 (**a**, **b**) T2 sagittal image is shown demonstrating absence of the ACL as well as the typical bone bruise pattern. Coronal T2-weighted image demonstrates the "empty notch sign"

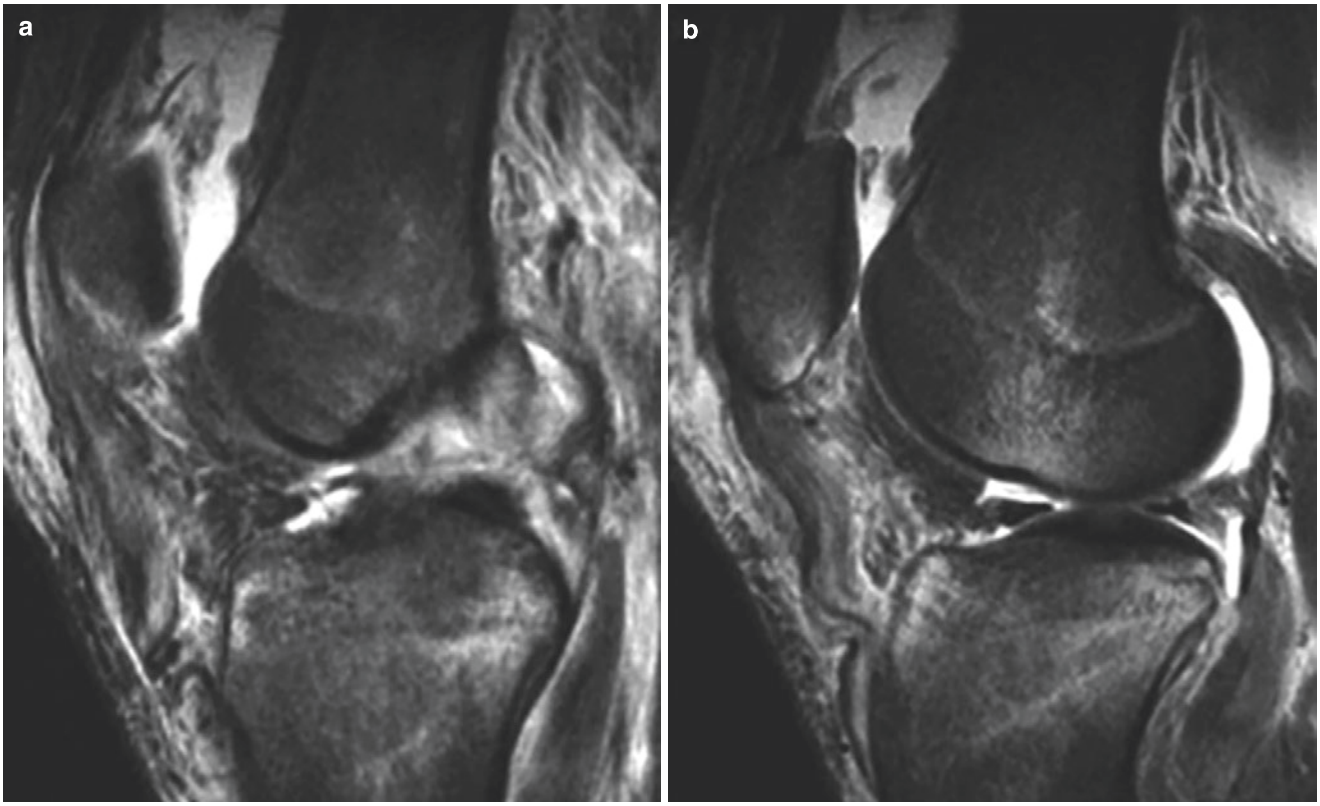

Fig. 5.2 T2 sagittal imaging demonstrates edema within the substance of the ACL with complete disruption (**a**). Partial tearing of the patella tendon is seen at this level (**b**)

bone contusion pattern present as shown in Fig. 5.3. The ACL is seen as an edematous mass without the typically taught fibers. The lateral meniscus visualized best on the sagittal T2-weighted image (Fig. 5.3) showed no meniscal tear. The medial meniscus was intact as was the MCL. No posterior cruciate ligament or articular cartilage pathology was present. The patella tendon was partially disrupted with a wavy appearance to a portion of its fibers (Fig. 5.2b).

MRI allowed for confirmation of ACL tear as well as diagnosis of a patella tendon disruption of uncertain severity. This was consistent with the patient's clinical examination; therefore, risks and benefits of operative intervention were discussed with the patient. He elected to proceed with possible patella tendon repair and planned reconstruction of the ACL given his age and hopes to continue to compete at a collegiate level.

5.2.3 Arthroscopy

The patient was taken to the operating room and placed supine with a post placed in the appropriate position. The hamstring tendon graft was harvested utilizing a tendon stripper as pictured below Fig. 5.4a. The graft was prepared on the back table by doubling semitendinosus and gracilis tendons over to make a four-stranded graft using an endobut-

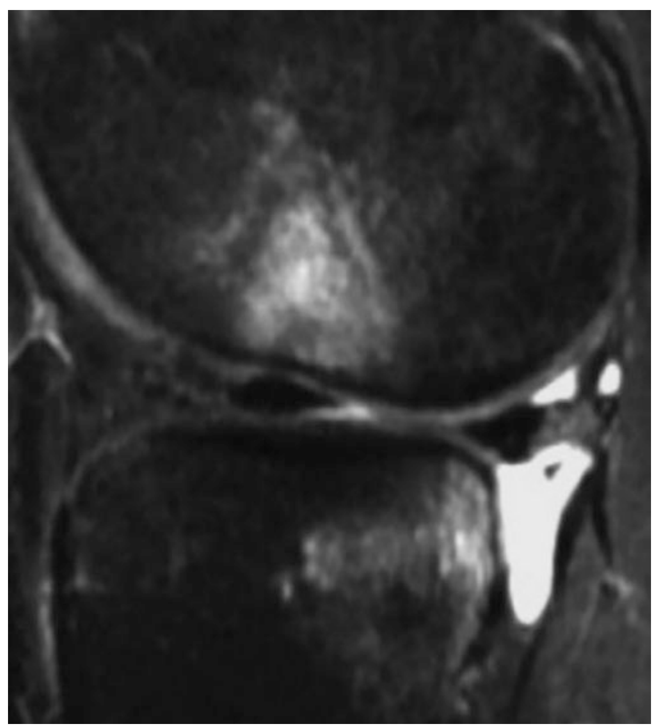

Fig. 5.3 The typical bone bruise pattern is shown on T2-weighted imaging about the lateral femoral condyle and posterolateral tibial plateau. Additionally, the tibia is noted to be translated forward relative to the posterior aspect of the distal femur producing an "anterior drawer" on imaging

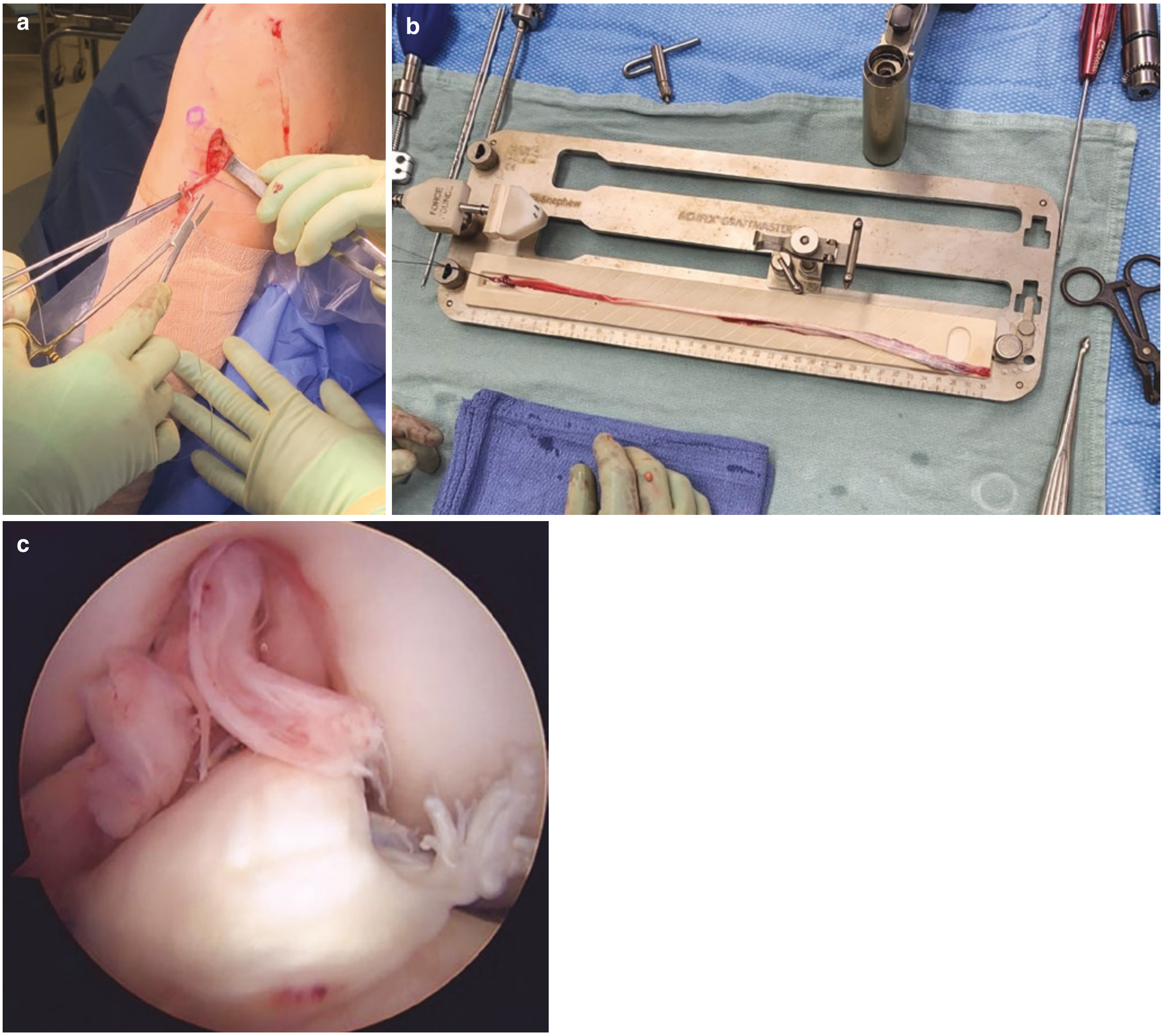

Fig. 5.4 Tendon harvest (**a**). Hamstring graft after preparation (**b**). Arthroscopic visualization of the intercondylar notch reveals a complete tear of the ACL with fibrous proliferation and remaining stump on the tibial side (**c**)

ton loop for suspensory femoral fixation and whip stitches in the free limbs of the graft. A standard diagnostic arthroscopy of the knee was completed. The ACL was completely absent with a remaining stump seen demonstrated in Fig. 5.4c with no intact fibers remaining. The articular cartilage and medial meniscus were found to be intact. This correlated well with the findings on MRI.

Following diagnostic arthroscopy, the tibial footprint and ACL over the top position in the back of the notch were debrided using a shaver. Next, the appropriate position off the back of the posterolateral notch was chosen for guide pin placement (Fig. 5.5a). An offset guide can be used here to retain 1–2 mm of posterior wall following drilling. We like to use an accessory medial (AM) portal for separate femoral tunnel drilling to allow more anatomic femoral tunnel drilling with the knee in hyperflexion (Fig. 5.5b) [8].

Once the femoral tunnel was drilled to the appropriate depth, a commercially available tibial guide is used to place a guide wire for the tibial tunnel using intra-articular landmarks. Once the tibial tunnel was prepared, a Beath needle was used to pass the graft utilizing suture (Fig. 5.5c), and it was fixed on the femoral side by deploying the endobutton on the lateral femoral cortex. Back pressure tension on the graft assures appropriate deployment of the button. Fluoroscopy can be used for confirmation if needed. Once the femoral side is fixed, the knee was cycled through the complete ROM, and the graft was tensioned and secured on the tibial side with a interference screw. The final graft was

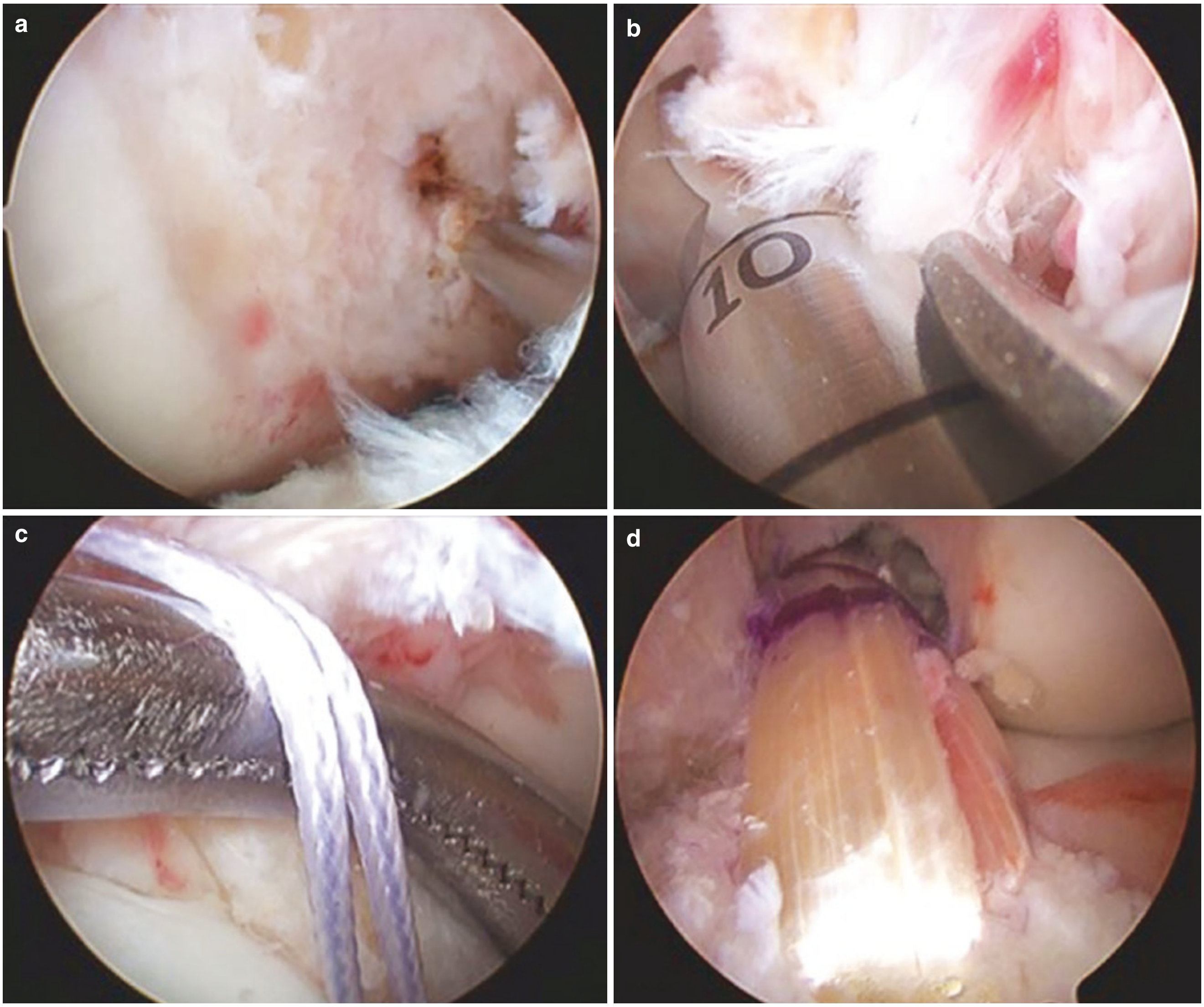

Fig. 5.5 ACL reconstruction steps are shown with placement of a guide pin in the anatomic position utilizing an accessory inferomedial portal (AM portal) (**a**). Femoral tunnel drilling is performed with a skid in place in hyperflexion to protect the femoral condyle (**b**). Both needle and suture are passed through the tunnel to allow for graft shuttling (**c**). The autograft is fixed with interference screw fixation (**d**)

inspected and noted to have excellent tension in Fig. 5.5d. Finally, the patella tendon was repaired using a Krackow suture technique as shown in Fig. 5.6a, b.

5.2.4 Discussion

MRI demonstrated a complete ACL tear. Several direct MRI signs suggest complete disruption of the ACL in this case. The ACL is discontinuous and does not have the turgor of a normal ACL (Fig. 5.1a). This is best examined on MRI in the sagittal plane where the fibers seen on the T2-weighted image as no longer taught. In the acute setting, the ACL appears as an edematous mass, producing the so-called empty notch sign where fluid rather than ACL fills the intercondylar notch (Fig. 5.1b).

The indirect signs of an ACL injury on MRI are also seen here including the typical hemarthrosis, though this is a largely nonspecific finding. Additionally, the characteristic bone bruise pattern is noted about the lateral femoral condyle and posterolateral tibial plateau due to the prior pivoting event (Fig. 5.3). Often an anterior drawer can be seen where the tibia sits slightly more anterior to a line drawn parallel to the posterior aspect of the distal femur (Fig. 5.3). A Segond fracture which is noticeable on X-ray can also be seen on MRI as shown in the T1 image in Fig. 5.7. The PCL may also appear buckled in some cases.

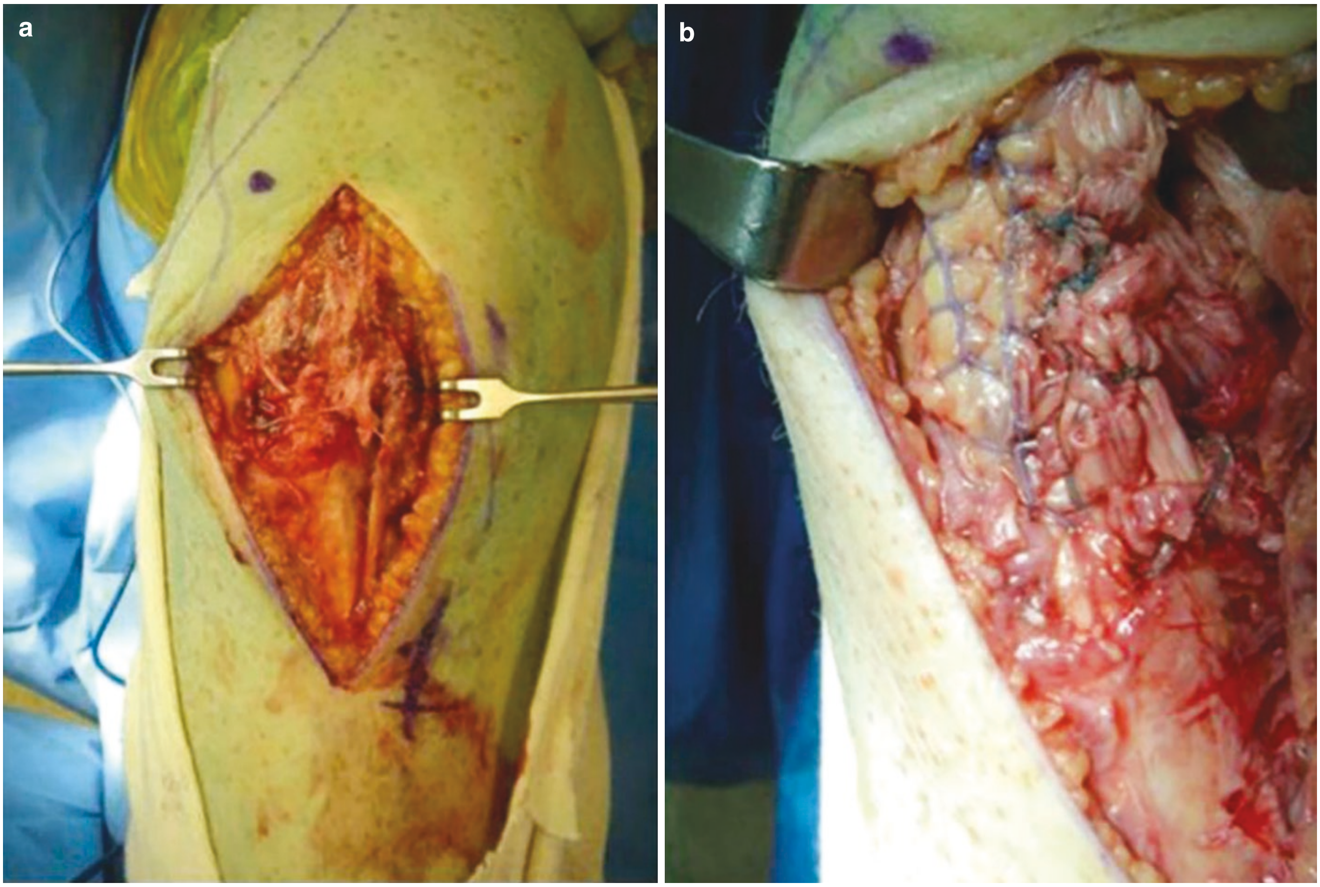

Fig. 5.6 Intraoperative photo demonstrates a partial patella tendon rupture (**a**). This is repaired primarily utilizing Krackow suture technique (**b**)

Fig. 5.7 T1-weighted coronal image demonstrates a Segond fracture

5.3 Case 2: ACL Reconstruction with Patellar Tendon Autograft

5.3.1 History/Exam

An 18-year-old female basketball player sustained a noncontact injury to her left knee during play. She was seen in sports medicine clinic 2 weeks later after noticing continued instability episodes with attempted return to sport where she was noted to have a sizeable effusion and limited knee range of motion. She was referred to our orthopedic clinic.

Physical examination of the knee demonstrated no opening with varus or valgus stress. A pivot shift was not possible in the office due to her pain and swelling. She did however have a 2+ Lachman's on her symptomatic side as compared to her asymptomatic side. Patellar apprehension testing was negative, but McMurray's provocative maneuvers were positive. Radiographs as well as advanced imaging were obtained to confirm suspected ACL injury and evaluate for additional meniscal pathology.

5.3.2 Imaging

Initial plain radiographs were unremarkable for any bony abnormality. Given the persistent symptoms, concerning examination and effusion, MRI without contrast was obtained. A complete sequence of images was obtained, including sagittal gradient, STIR, proton density, coronal gradient and fat-saturated T2, and axial fat-saturated T2 without contrast. Coronal T2-weighted images and sagittal images are demonstrated in Fig. 5.8a, b.

The MRI images demonstrated ACL tear as well as complex posterior horn medial meniscus tear (Figs. 5.8a–c). The PCL, LCL, and MCL were all intact with no focal abnormalities.

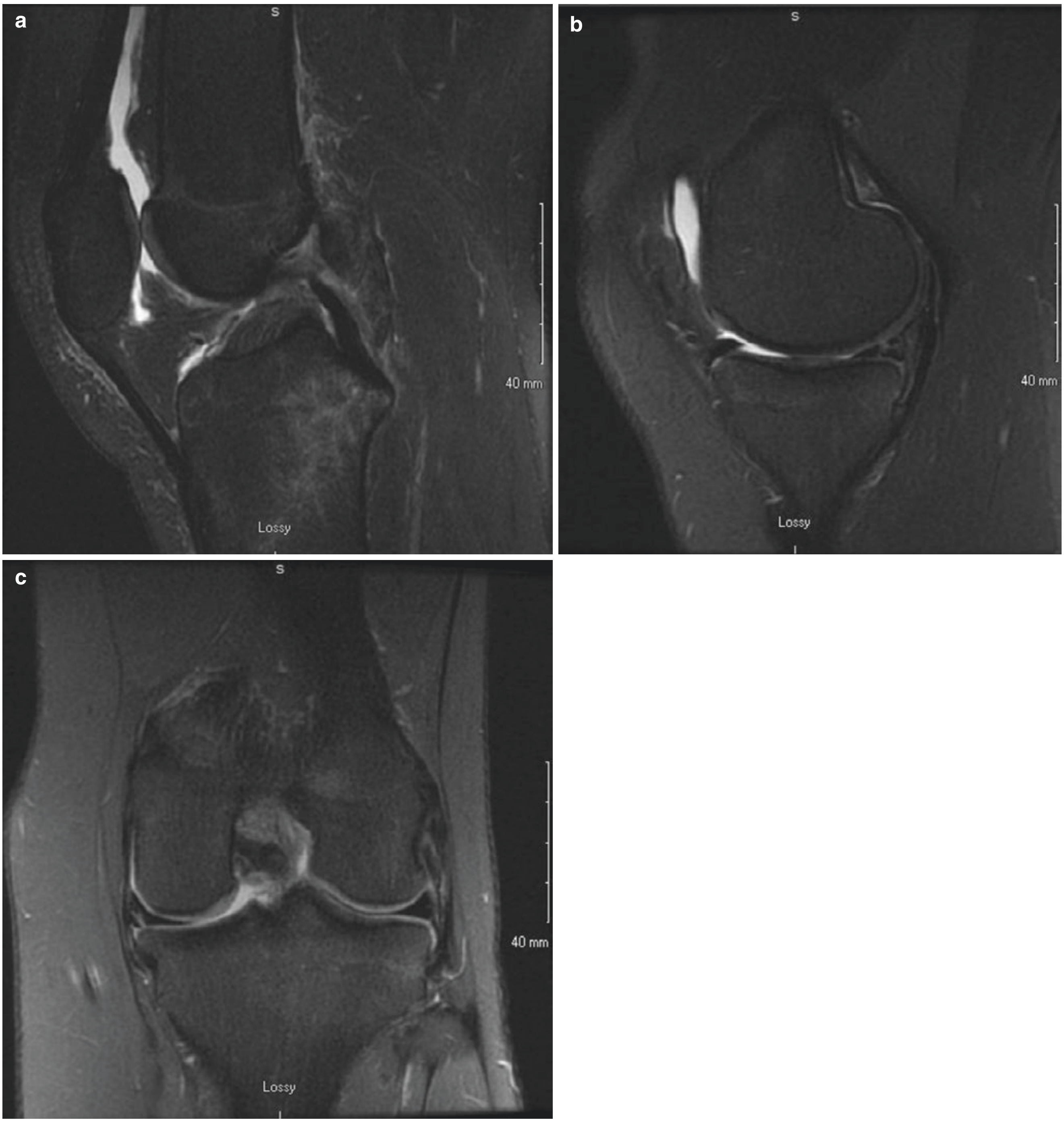

Fig. 5.8 Sagittal MRI demonstrates ACL tear (**a**). Sagittal and coronal images demonstrate posterior horn medial meniscus tear (**b, c**)

The patient's history, physical exam, and MRI were consistent with an ACL tear and posterior horn medial meniscus tear. A lengthy discussion was had with the patient and her family regarding management of ACL tear as well as medial meniscus tear, specifically the differences in rehab protocol for meniscus repair vs meniscectomy. They elected to undergo arthroscopy with ACL reconstruction with a plan to repair her medical meniscus if amenable.

5.3.3 Arthroscopy

On the day of surgery following a preoperative nerve block, the patient was taken to the operating room and placed supine upon the operating room table and positioned for ACL reconstruction. Examination under anesthesia was performed as previously described which demonstrated positive pivot shift and Lachman tests. Standard inferolateral and inferomedial portals were made, and a diagnostic arthroscopy completed which confirmed ACL tear as well as posterior horn medial meniscus tear as expected (Fig. 5.9).

Given the patient's expectations preoperatively, her young age, and her current activity as a basketball player, the decision was made to perform arthroscopic-assisted ACL reconstruction as well as medial meniscus repair (Fig. 5.10).

Although several graft options are available, autograft is the gold standard graft option and has been demonstrated to lead to lower failure rates than allograft options in young patients [10]. In this case, bone patella bone autograft was selected for this young, female athlete. A central 1/3 bone-patellar tendon-bone graft was harvested. The graft is typically 10mm wide. Bone blocks of 20–25 mm are typically harvested from both the tibia and patella. Bone blocks are prepared for 10mm tunnel size with the tibial block trimmed to 20mm while the patellar block may remain at 25mm. The ACL footprint was debrided with a shaver. After debriding the ruptured ACL fibers, we first prepare our tibial tunnel placing our drill guide in the central medial

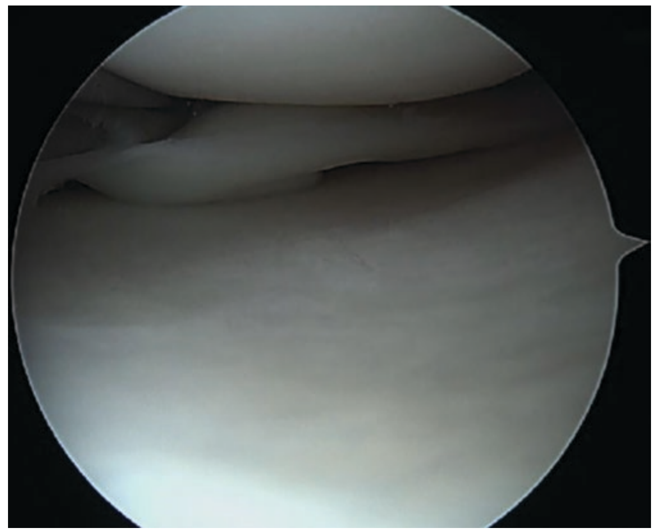

Fig. 5.9 Medial meniscus tear demonstrated on arthroscopy

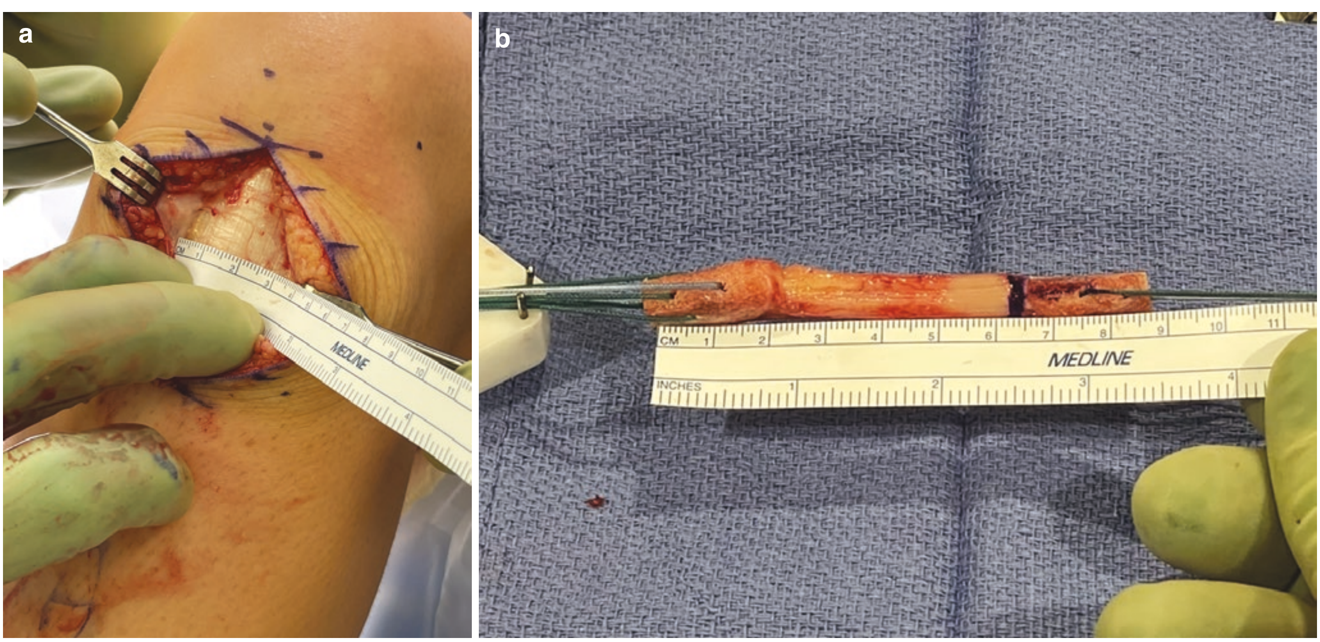

Fig. 5.10 Patellar tendon graft harvest (**a**) and preparation (**b**)

aspect of the ACL footprint. Position of the guidewire is confirmed on lateral fluoroscopic views to assure appropriate location. Following tibial tunnel preparation, the femoral tunnel is prepared using a targeting guide (from an accessory inferomedial portal) allowing independent drilling to obtain anatomic graft orientation. We leave a 1–2mm back wall (depending upon knee size) to allow interference screw fixation (Fig. 5.11a–d). The accessory inferomedial portal is approximately 3 cm medial to the patellar tendon. ACL reconstruction was performed using an anatomic single-bundle technique [7, 8] (Fig. 5.11d), double-bundle techniques and individual-bundle techniques are described though they have not been widely adopted by most surgeons [11, 12].

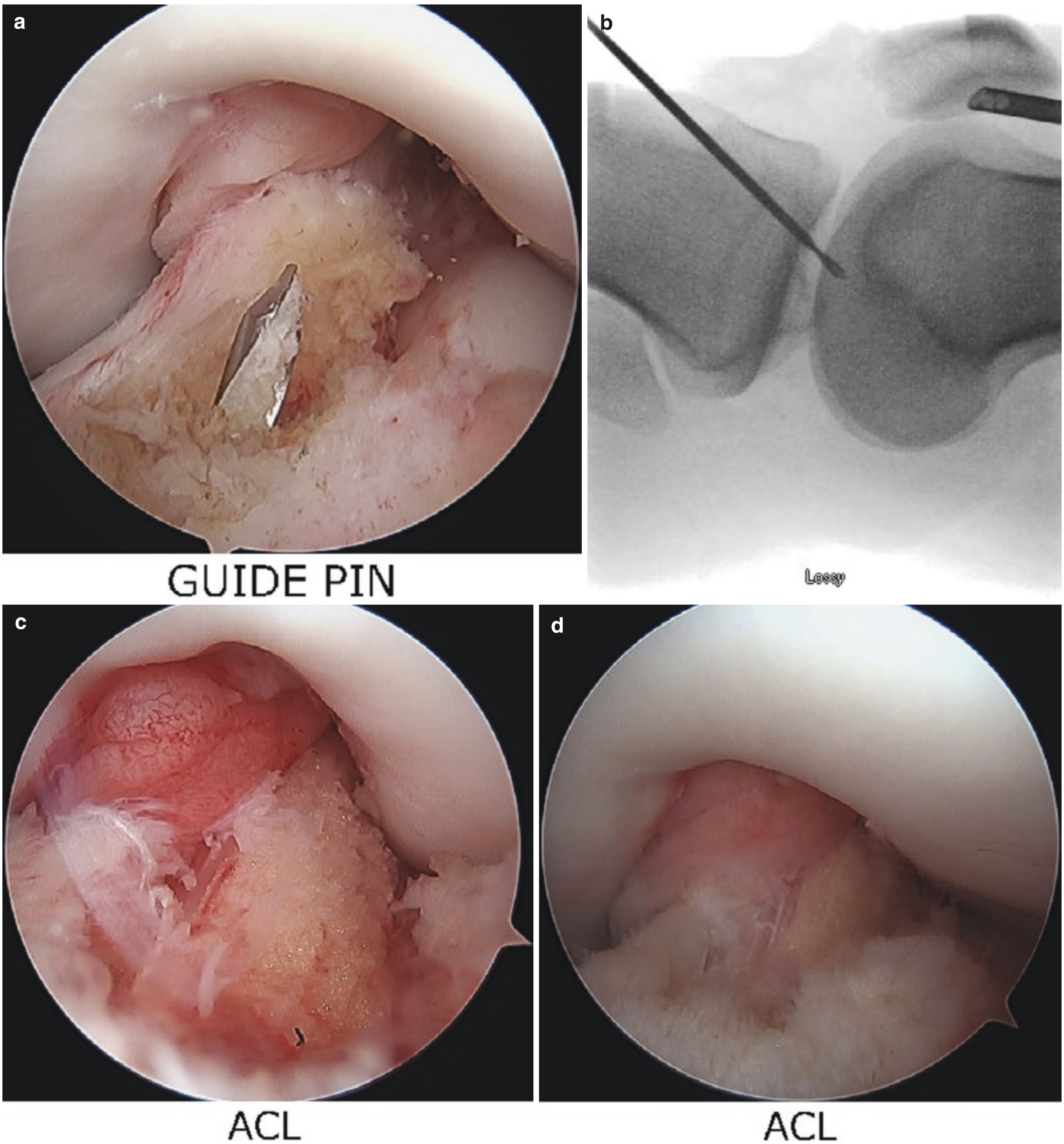

Fig. 5.11 Following complete debridement of the remaining ACL, a guide pin is placed through an accessory AM portal on the femoral side and later the tibial side (**a**). Intra-operative fluoroscopy is used to confirm correct tibial guide pin position in the AP plane utilizing Blumensaat's line as anatomic reference point (**b**). Final graft is taught and well fixed (**c**, **d**). Medial meniscus repair (**e**)

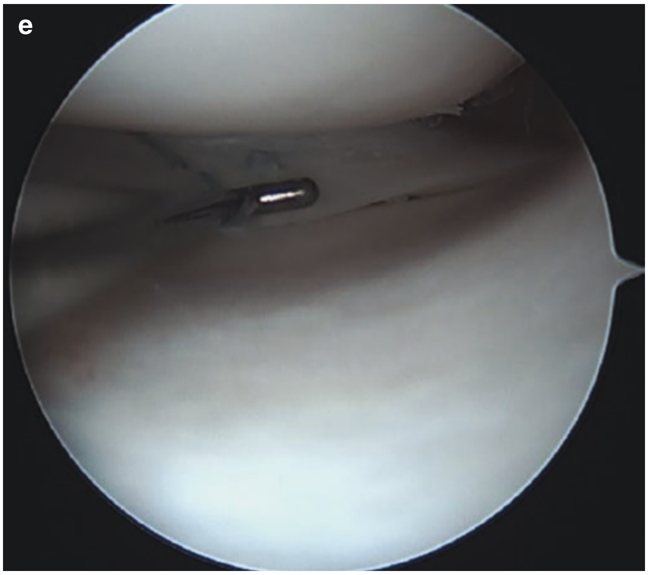

Fig. 5.11 (continued)

5.3.4 Discussion

Comparative studies looking at hamstring and patella tendon autograft have yielded equivalent results historically [10]. Bone patellar tendon bone grafts offer the advantage of faster healing/graft incorporation of bony plugs as well as less graft laxity [13] although have higher rates of postoperative anterior knee pain, and these grafts are a fixed length given the bony plugs making graft tunnel mismatch a possibility in certain individuals. Hamstring tenon grafts offer less anterior knee pain, but are more likely to stretch as compared to patellar tendon grafts [13], thus tend to be avoided in young female athletes or hyperlax individuals at our institution. Athletes can often return to play within 1 year postoperatively accounting for known graft biologics and successfully passing rehabilitation goals.

Current evidence supports meniscus repair in appropriate patients when the tear is located in a vascular zone and amenable to repair [14], and this can be done at the time of ACL reconstruction when there is concomanant pathology with evidence supporting increased rartes of meniscal healing with concomanant ACL reconstruction [14].

5.4 Case 3: ACL Reconstruction with Quadriceps Tendon Autograft

5.4.1 History/Exam

A 27-year-old female sustained a right knee injury in a skiing accident. She attempted conservative management, but ultimately presented to sports medicine clinic 8 weeks later after noticing continued instability events and pain. She was referred to the orthopedic clinic after MRI was obtained.

Physical examination of the knee demonstrated no opening with varus or valgus stress. 2+ Lachman's was present on her symptomatic side as compared to her asymptomatic side. Patellar apprehension and McMurry testing were both negative.

5.4.2 Imaging

Initial plain radiography was unremarkable for any bony abnormality. MRI without contrast had previously been obtained, demonstrating ACL rupture (Fig. 5.12).

The patient's history, physical exam, and MRI were consistent with an ACL tear. Given that the patient was quite active and failing conservative treatment, they elected to undergo arthroscopy with ACL reconstruction.

5.4.3 Arthroscopy

On the day of surgery following a preoperative nerve block, the patient was taken to the operating room and placed supine upon the operating room table and positioned for ACL reconstruction. Examination under anesthesia was performed as previously described which demonstrated positive pivot shift and Lachman tests. Standard lateral and medial portals were made, and a diagnostic arthroscopy completed which confirmed ACL rupture.

As mentioned previously, autograft is the gold standard graft option and has been demonstrated to lead to lower failure rates than allograft options in young patients [10]. Quadriceps tendon autograft was utilized in this case. ACL footprint was debrided and tunnels prepared as described above. Quadriceps tendon graft was harvested through a midline incision made from the superior pole of the patella to about 7 cm proximally. It was carried down through subcutaneous tissue and then through the quad tendon sheath. A 10-mm-wide graft was harvested from the center of the quad tendon, utilizing a dual-blade knife, with a 25 mm bone plug from the proximal pole of the patella. This was prepared on the back table by passing #2 FiberWire and #2 Ethibond suture through drill holes in the bone plug and a combination of whip stitched orthocord suture and #2 FiberWire in a Krakow fashion on the soft tissue end. Simple, interrupted, inverted vicryl suture was used to close the quadriceps tendon graft site (Fig. 5.13). Tunnel drilling was completed as above with 10mm tunnel sizes. The bone block is placed into the femoral socket and secured with an interference screw. The soft-tissue side of the graft is secured over a post screw and washer on the tibial side.

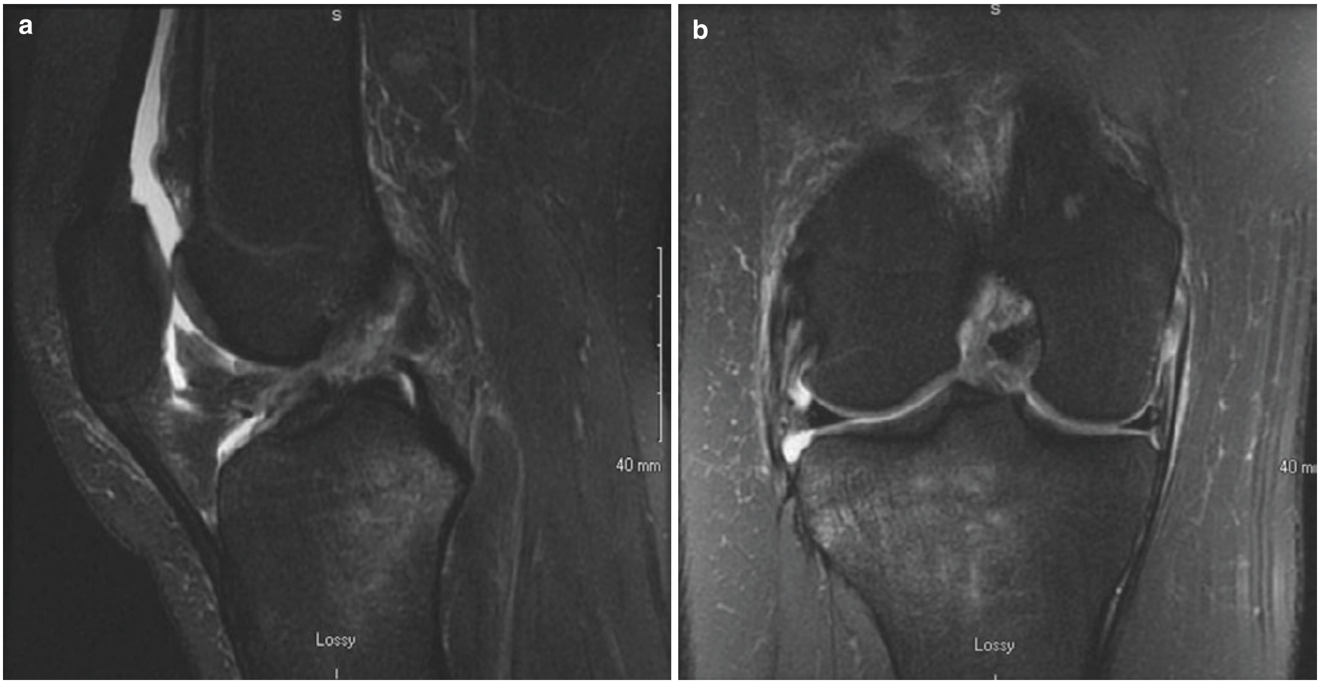

Fig. 5.12 Sagittal (**a**) and coronal (**b**) MRI demonstrating ACL tear

5.4.4 Discussion

Quadriceps tendon autograft has been recently gaining in popularity, though it has been a discussed autograft option since 1979 when it was advocated by Marshall and later in 1984 by Blauth [15]. Biomechanically, the quadriceps tendon autograft with bone plug has a higher load to failure and thickness than equal width patellar tendon [16]. There are multiple techniques and variations in quadriceps tendon ACL reconstruction that include mini-open versus arthroscopic assisted harvest and all soft tissue versus bone plug inclusion [16–18].

The quadriceps tendon autograft has been shown to have similar stability compared to the BPTB and hamstring autografts with about 23.7% side-to-side difference greater than 3mmm, versus 21% for BPTB and 26.2% for hamstrings [19]. Comparative studies of quadriceps tendon compared to BPTB show less anterior knee pain with a risk ratio of 0.25 and similar anterior knee pain as hamstring autograft [19]. Donor site morbidity at the extensor mechanism though first thought to be detrimental has been shown to recover similar muscle strength as other ACL autografts [19]. At 10-year follow-up, the quadriceps tendon ACL reconstruction has been shown to have comparable stability and return to sport as the BPTB [18].

5.5 Case 4: Bony ACL Avulsion

5.5.1 History/Exam

A 35-year-old male presented to our sports medicine clinic with pain in his left knee that began approximately 4 days prior. The patient reported that while coaching his daughter's basketball team, his knee gave way when he was running down the court. He had immediate pain and swelling and was able to bear weight but unable to continue coaching that day. He was seen at a local clinic where he was given crutches and a soft brace. An aspiration performed by the clinic improved his pain tremendously. Prior to this injury, he had one prior knee arthroscopy of which he does not remember the details. He had tried nonsteroidal anti-inflammatories, muscle relaxants, physical therapy, and stretching prior to presentation without relief.

On physical examination, he was noted to have pain with range of motion and a moderate effusion. Range of motion was noted to be limited compared to the contralateral side. He lacked approximately 10° extension, with flexion up to 90° with significant effort. Additionally, lateral joint line tenderness was present, and McMurray's exam was positive in the clinic. Lachman's was grossly positive with no firm end point and a pivot shift was reproducible. There was no opening with varus or valgus stress and a negative posterior drawer.

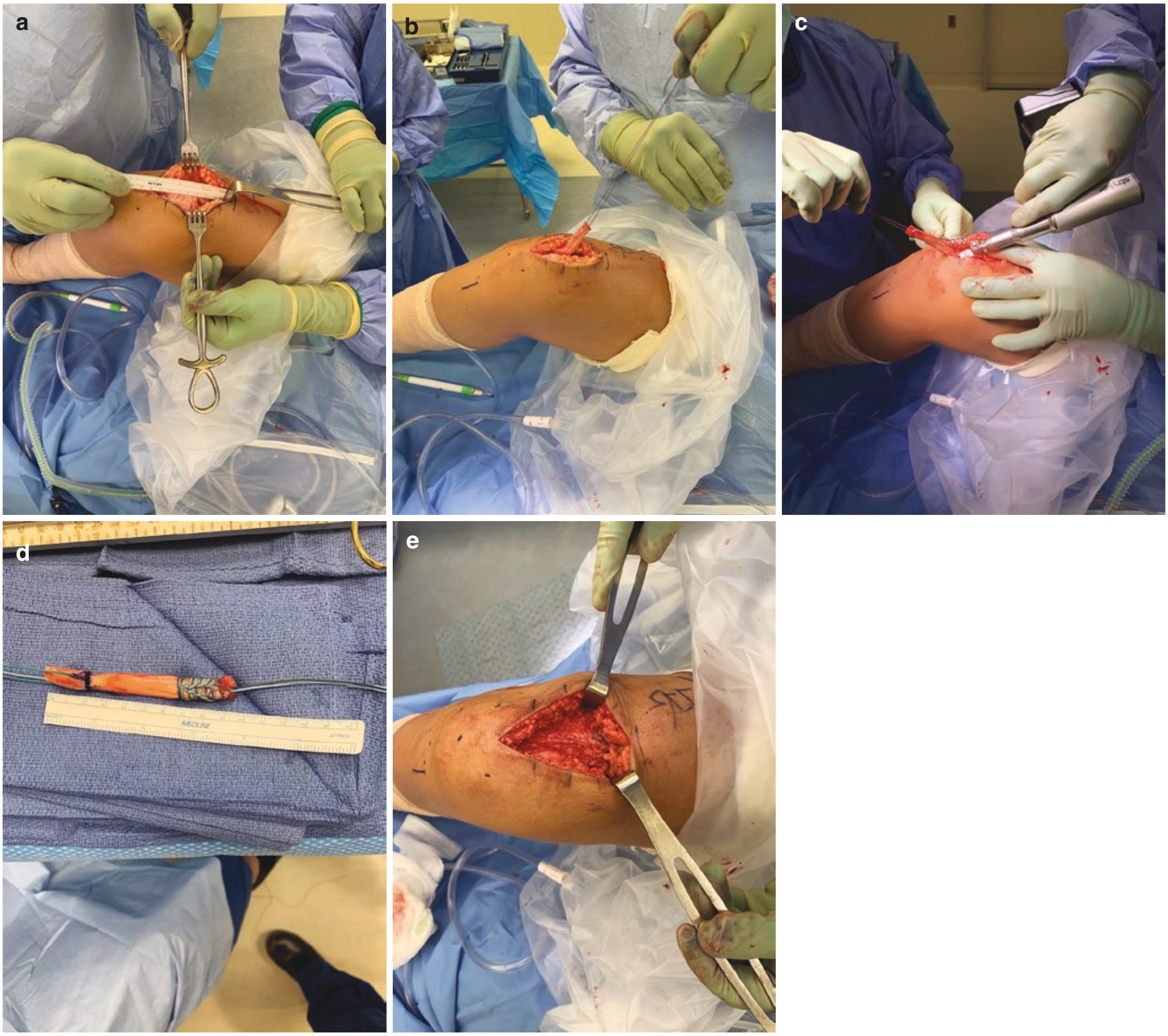

Fig. 5.13 Quad tendon harvest (**a**, **b**, **c**), preparation (**d**), and closure (**e**)

Given the acute nature of his injury as well as difficulty with range of motion, decision was made to evaluate further with MRI. Additionally, the brace was discontinued at this time with instructions to work on aggressive range of motion with formal physical therapy. The initial radiographs obtained at the outside clinic revealed a bony abnormality not fully appreciated about the tibial spine.

5.5.2 Imaging

Radiographs obtained at the outside hospital suggested a possible injury about the tibial spine. There was no evidence of arthritic changes in the medial and lateral compartments. MRI without contrast was obtained to further evaluate the patient's soft tissue anatomy. A complete sequence of images was obtained, including sagittal gradient, STIR, proton density, coronal gradient and fat-saturated T2, and axial fat-saturated T2 without contrast. Coronal fat-saturated T2-weighted images are demonstrated in Fig. 5.14a, b, and sagittal stir images are demonstrated in Fig. 5.15a, b.

The sagittal images (Fig. 5.15a, b) demonstrate normal medial meniscus with an anterior horn root insertion of the lateral meniscus avulsed with a bone fragment along with the adjacent ACL. A focal radial tear of the posterior horn of the lateral meniscus can be seen on the sagittal STIR image as well. Increased signal is evident within the substance of the ACL with avulsion of the anterior tibial spine noted in coronal T2-weighted image (Fig. 5.14a, b). The PCL, LCL, and MCL were all intact with no focal abnormalities. Mild focal

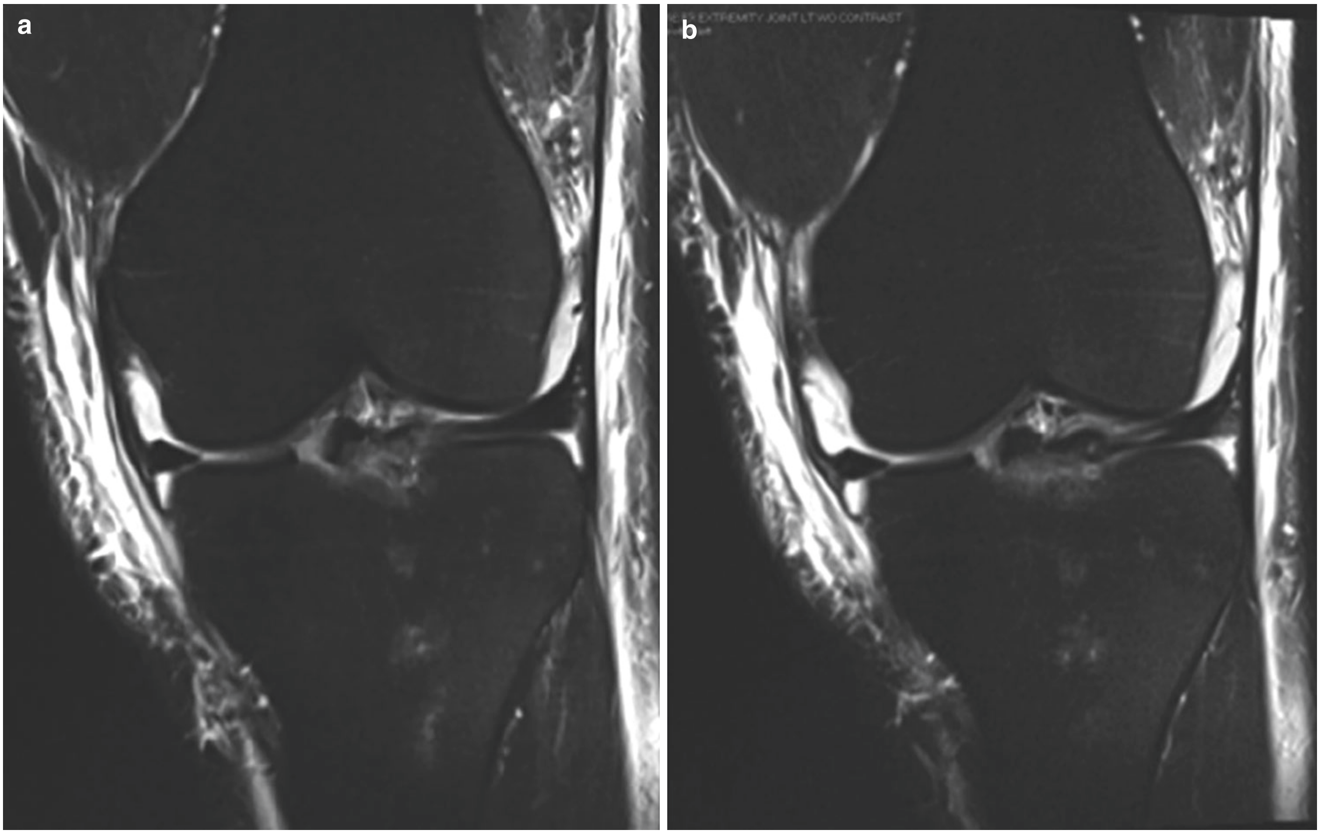

Fig. 5.14 Coronal MRI STIR imaging reveals increased signal in the proximal tibial eminence at the ACL attachment (**a**, **b**)

thickening and edema are present within the patella tendon possibly from chronic patella tendinitis.

In addition to the bony avulsion of the ACL and the anterior horn of the lateral meniscus, a very minimally depressed lateral tibial plateau fracture is seen at the posterior aspect of the plateau. Typical lipohemarthrosis is seen within the joint. The patient's history, physical exam, and MRI were consistent with an ACL tear. His symptoms were persistent with consistent sense of instability with any activity and stair climbing. Surgical intervention was offered, with a plan to address his ACL with either fixation depending on the size of the bony fragment or ACL reconstruction with hamstring autograft. Additionally, arthroscopy would allow for evaluation of his lateral meniscus.

5.5.3 Arthroscopy

The patient was taken to the operating room and placed supine upon the operating room table with a post placed in the appropriate position as well as the leg holder appropriately positioned. Once the patient was asleep, an exam under anesthesia was performed as we always do prior to any knee arthroscopy. A pivot shift was reproducible in the operating room. Both extremities were prepped in as we typically do when considering hamstring reconstruction to allow for contralateral harvest if needed to supplement a small graft. A tourniquet was placed nonsterile around the operative extremity. Standard inferolateral and inferomedial portals were made, and a diagnostic arthroscopy completed. Of note, arthroscopy was performed first in this situation given the uncharacteristic findings on MRI.

Following evacuation of bloody effusion, we were able to visualize the joint, which had no evidence of chondromalacia. No loose bodies were noted on arthroscopy. The camera was brought into the notch where the ACL was seen to be intact throughout its midsubstance (Fig. 5.16a). However, when the scope was brought more anterior and inferior, the entire tibial eminence of the ACL was noted to have pulled off with an associated bleeding bony bed (Fig. 5.16a, b). This bed was covered with a layer of fibrous tissue deposited over the previous weeks leading up to surgery. Examination of the medial compartment revealed no medial meniscus tear. The knee was then brought into the figure-of-four position, and the arthroscope was brought into the lateral compartment where the anterior horn of the lateral meniscus was displaced and attached to the bony tibial eminence piece.

The bony bed of the meniscus and ACL tibial attachment was prepared using an arthroscopic shaver to remove the underlying fibrinous material. A burr was utilized to aid in

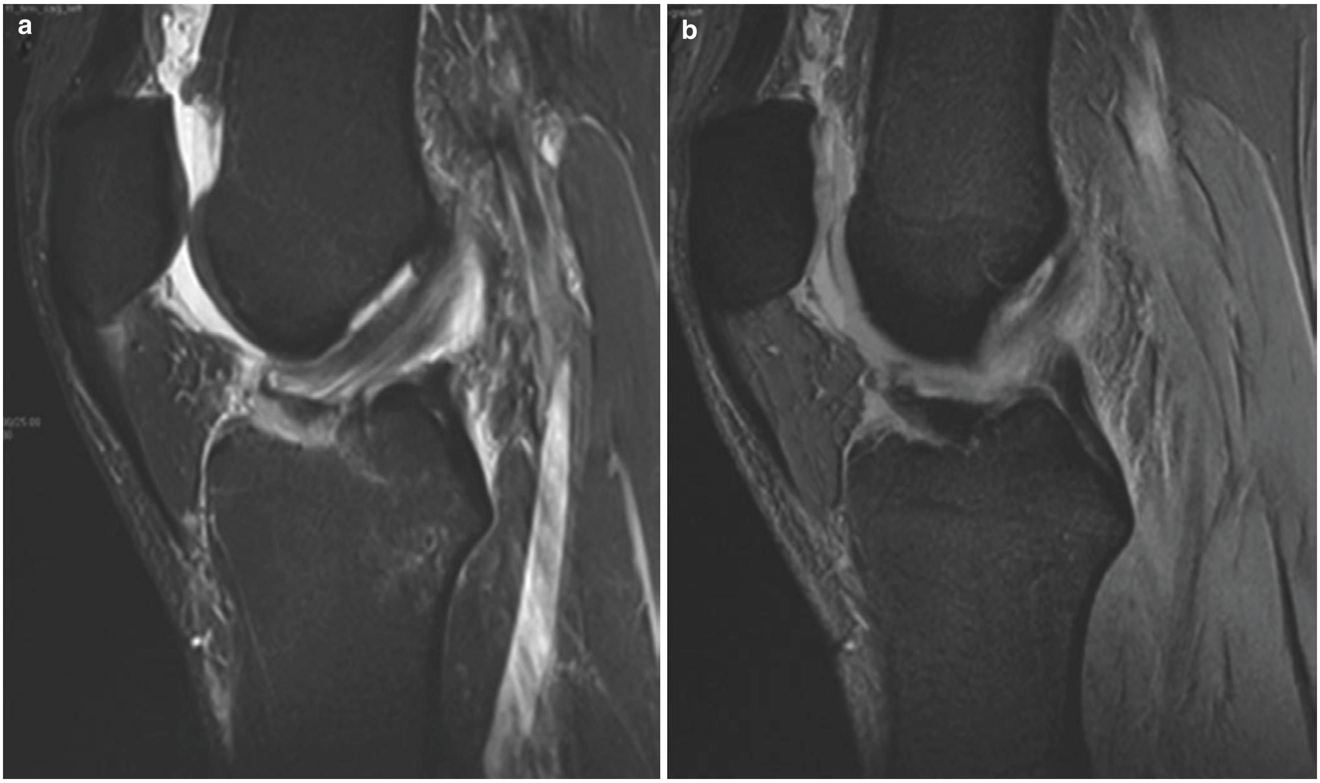

Fig. 5.15 ACL fibers appear taught attached to the elevated tibial eminence (**a**). The bony attachment of the ACL is elevated anteriorly with little remaining posterior cortical attachment (**b**)

the reduction of the bony fragment (Fig. 5.16b, c) to allow for slight recession of the fragment. The ACL fully attached to the bony fragment was then reduced to its native position with an arthroscopic probe. Guide pins for screw fixation were placed medial and lateral to the patella tendon in a converging fashion (Fig. 5.16d). We confirmed this reduction under fluoroscopy and direct visualization. We were pleased with the length of our pins and subsequently predrilled and tapped. Two partially threaded 6.5 mm screws and washers were placed over guide wire (Fig. 5.17a–d) with excellent reduction confirmed under arthroscopy and fluoroscopy with final radiographs taken postoperatively (Fig. 5.18a, b).

Following fixation, the ACL was once again examined and was taught. The lateral meniscus was once again examined, and the posterior lateral meniscus tear was found to have healed needing no further intervention. The arthroscope was removed, and a Lachman test was performed with a firm end point noted. The patient was placed in an IROM set from 0 to 90 to begin range of motion immediately with protected weight bearing for 2 weeks.

5.5.4 Discussion

MRI is the imaging of choice for possible ACL avulsion injuries. While CT may help with establishing the amount of bone avulsed off the tibial eminence, MRI allows for simultaneous diagnosis of other concomitant knee pathology, which in this case included lateral meniscal pathology. MRI is estimated to have a sensitivity and specificity over 90% for detecting ACL injury in the setting of bony avulsion injury [20]. MRI is the preferred modality for evaluating the other soft tissue structures of the knee that may be causing symptoms.

Tibial eminence fractures are well described in the orthopedic literature [14]. Anatomically, they represent avulsion injuries to the insertion of the anterior cruciate ligament (ACL) on the tibia and are considered the childhood equivalent of an ACL tear. Tibial avulsion injuries of the ACL are less common in the adult patient though they do occur [21]. Management of these injuries can include nonsurgical or surgical options. Nonoperative modalities include therapy, range of motion, and strengthening programs with appropriate utilization of nonsteroidal anti-inflammatory agents (NSAIDS). Surgical options include ACL reconstruction with allograft or autograft or fixation in the setting of a large bony fragment [22].

Meyers and McKeever described a classification of these injuries dividing them into three types [23]. Type I describes a nondisplaced or minimally displaced eminence fracture, which can be treated nonoperatively. In type II, the anterior third is displaced proximally with up to one half of the attachment off though the posterior attachment is still present. Type III fractures represent complete displacement. Immobilization in extension can be pursued for type I and

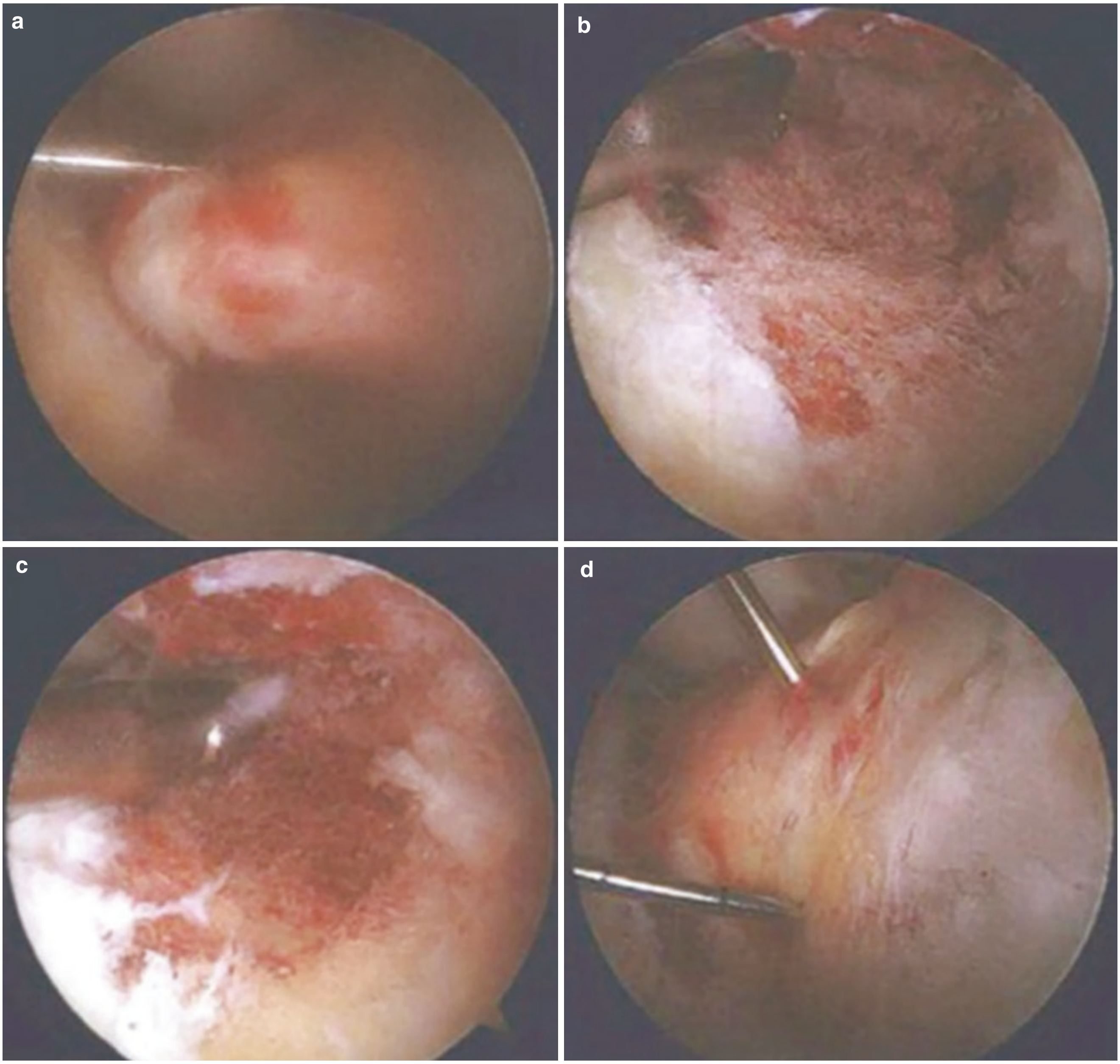

Fig. 5.16 Bloody effusion is noted on arthroscopy due to the acuity of the fracture. The ACL remains completely attached to a large tibial eminence avulsion and is being pulled down with an arthroscopic probe with attached anterior horn of the lateral meniscus (**a**). The bed beneath the elevated ACL is covered with fibrous tissue (**b**). An arthroscopic burr is used to debride the overlying tissue and recess the bony bed (**c**). Once reduction is achieved, two guide wires are placed medial and lateral to the patella tendon to hold the reduction (**d**)

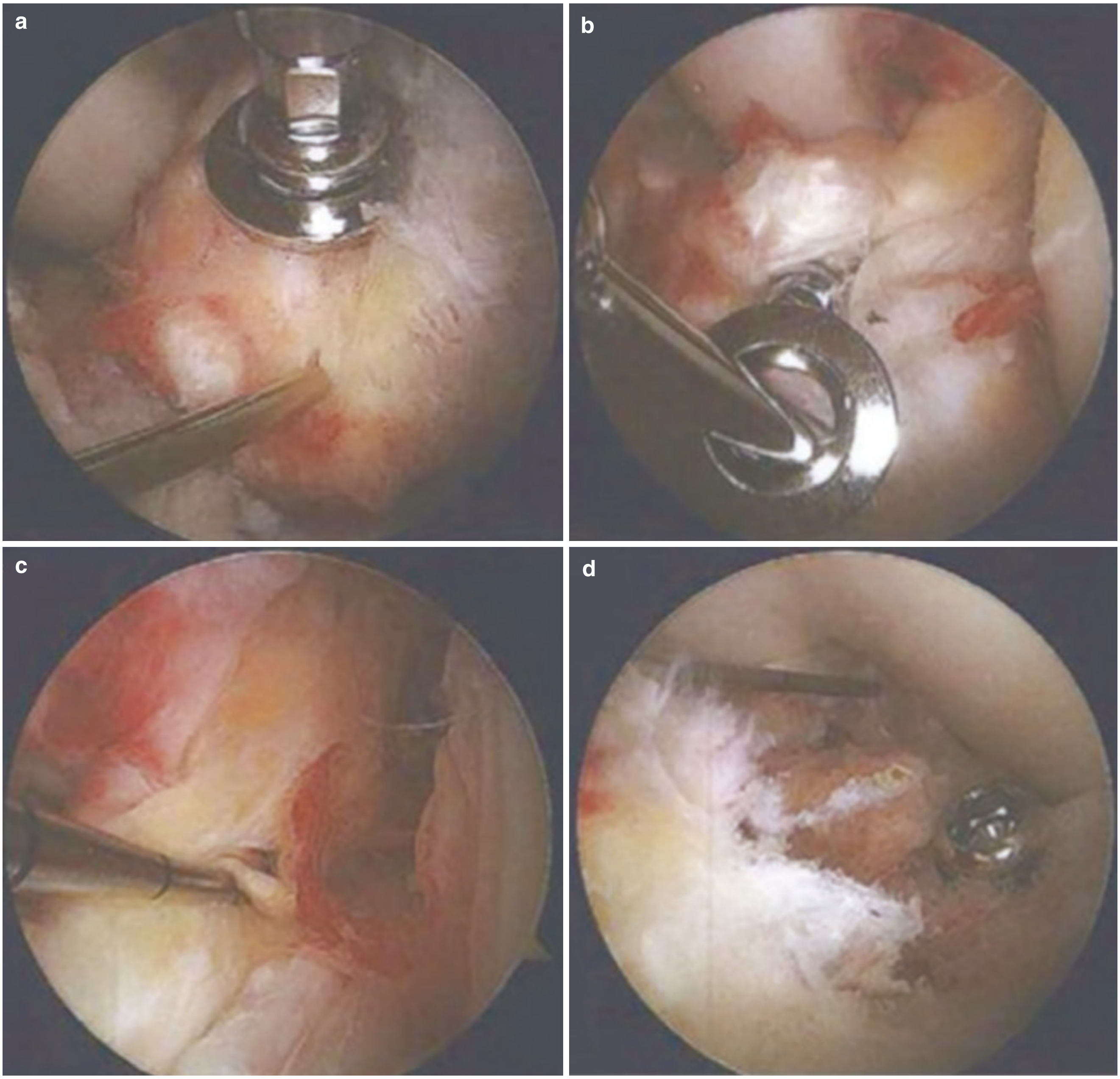

Fig. 5.17 Two partially threaded 6.5 mm screws are placed over guide wire along with washers (**a, b, c**). Excellent reduction is achieved with no notch impingement noted on full extension (**d**)

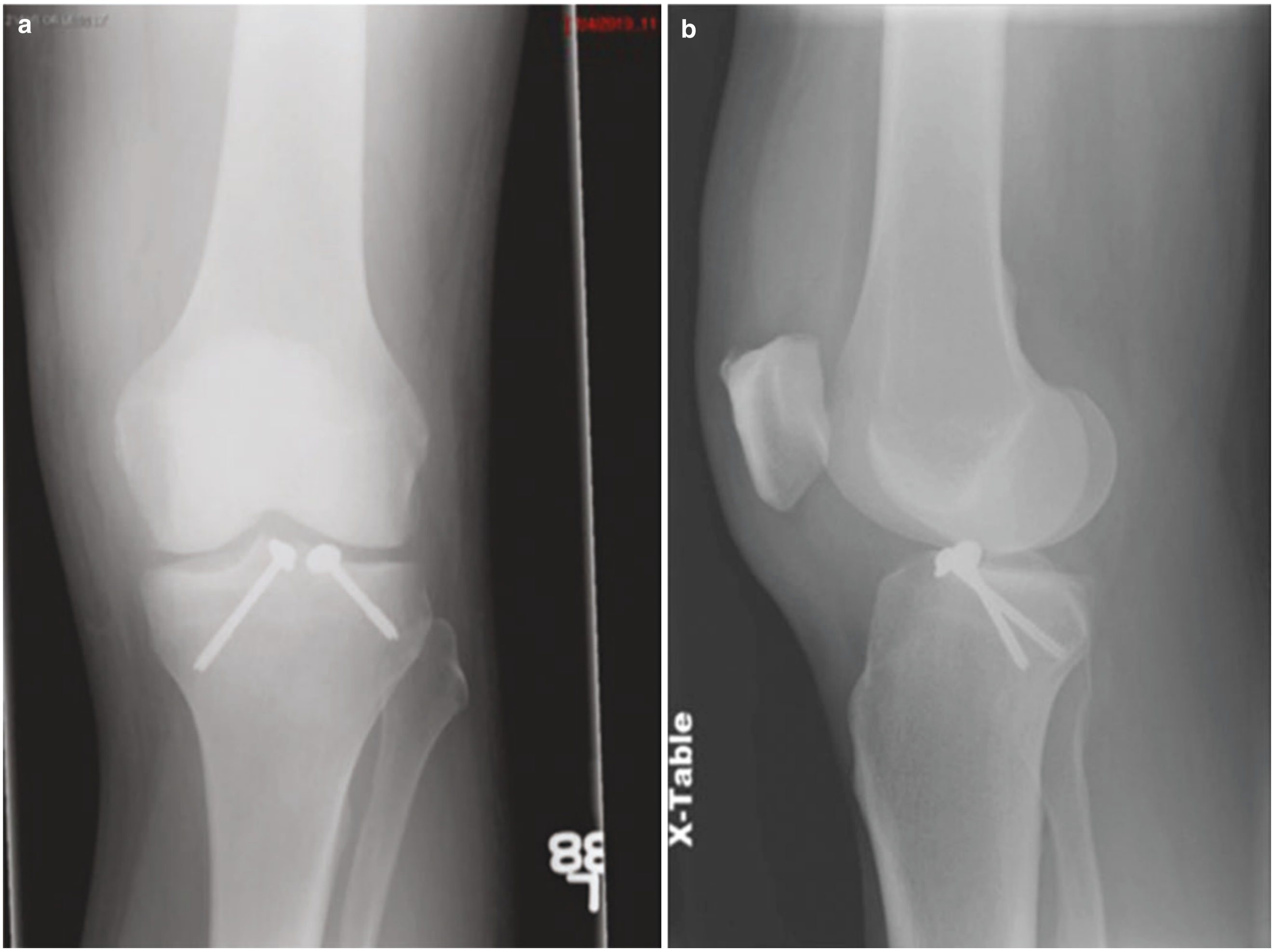

Fig. 5.18 Postoperative radiographs demonstrate divergent screw fixation with reduction of the tibial eminence (**a**, **b**)

some type II injuries with most type III injuries requiring fixation. Regardless of the treatment method, residual laxity may be present after tibial eminence avulsion injuries. Arthroscopy and MRI for damage to other attached soft tissue structures allow for accurate reduction and treatment of these injuries [24]. Fixation can be achieved with sutures or hardware [24–29]. Outcomes for different fixation methods do not appear to differ [27].

5.6 Conclusions

ACL injuries are a common reason for knee surgery in young and healthy patients. The clinical diagnosis of ACL tear is straightforward, though coexistent pathology is frequently present and must be recognized for surgical and rehabilitation planning. A careful history, physical examination including provocative maneuvers and imaging as dictated from the exam are key in establishing an appropriate diagnosis. Magnetic resonance imaging (MRI) remains the imaging technique of choice for patients with suspected ACL tear. MRI is also useful in identifying concomitant knee pathology that may change staging of intervention. Surgical intervention can be pursued in the carefully chosen active patient, and the approach must be individualized. Lower demand patients may be better managed with nonoperative care. Autograft has become the standard of care, especially in young, active patients. Autograft options include patellar tendon, hamstring, and quad tendon. The most recent literature demonstrates similar performance between quad tendon and patellar tendon grafts which may have a slight advantages over hamstring grafts [13, 15, 16, 30]. Techniques for improving ACL reconstruction are under constant analysis and development.

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