4 Chondral Lesions

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4.1 Introduction

Articular cartilage damage is a common cause of disability in the knee. Damage to the articular cartilage can span from isolated chondral defects to diffuse cartilage loss and osteoarthritis. Articular cartilage is composed of type II (hyaline) cartilage. Cartilage is relatively avascular and lacks ability to heal on its own, instead gathering nutrients from the joint space itself via diffusion. Chondral disruption through the subchondral plate can stimulate bleeding, infiltration of marrow cells, and a fibrocartilaginous healing response. However, this fibrocartilage is predominately type I collagen and has inferior wear characteristics to organized type II hyaline cartilage [1]. Lesions that do not penetrate to subchondral plate lack a healing response unless something is done to stimulate healing [2].

Patients with articular cartilage lesions often present with activity-related pain and recurrent effusions. This pain is typically isolated to a compartment of the knee, and they may also have mechanical symptoms. They may walk with an antalgic gait and have an effusion. Tenderness along the joint line or in the affected compartment is typically present. Concomitant malalignment of the limb and ligamentous instability may also be present and must be addressed if present [2]. Patellar instability is a common cause of patellar articular cartilage injury, typically at the medial and/or central surfaces. Patellar stabilization and alignment are typically addressed at the time of the cartilaginous procedures.

Imaging of the knee should include anteroposterior weight-bearing, Rosenberg (45° flexion posteroanterior), lateral, and axial view of the patella (Merchant or Skyline). Full-length standing hip-to-ankle images should be acquired to quantify malalignment [2]. Advanced imaging with magnetic resonance imaging (MRI) should be done to evaluate the articular cartilage and subchondral bone and to assess for concomitant meniscus and ligamentous injuries or deficiencies. However, the accuracy of MRI in predicting the size of the lesion has been questioned and has been found to underestimate the size of the lesion [3, 4].

Nonoperative treatment options for articular cartilage defects in the knee include weight loss, physical therapy, exercise, bracing, injections (corticosteroid and viscosupplementation), activity modification, and anti-inflammatories. In young, active individuals with unstable lesions, surgeons should exercise caution in prescribing nonoperative management as first-line therapy, particularly in acute injuries.

Operative treatment for focal cartilage defects is considered if nonoperative treatment measures fail. Techniques can be divided into conventional and advanced techniques. Conventional techniques include debridement (chondroplasty) and marrow-stimulating techniques. Marrow-stimulating techniques include abrasion chondroplasty, drilling, and microfracture. These techniques penetrate the subchondral plate and invoke a bleeding response and extravasation of bone marrow elements to form a clot in the defect. This clot remodels to a fibrocartilaginous tissue which has inferior wear characteristics to normal type II hyaline cartilage [2, 5].

The most commonly used classification system for articular cartilage injury is the Outerbridge classification. While originally described for patellar lesions [6], it has over time become the most common means of describing cartilaginous lesions. Grade 0 is normal cartilage. Grade I is softening and swelling of the cartilage. Grade II is partial-thickness defect with fissures that do not extend to subchondral bone. Grade III lesions display fissures that extend to subchondral bone. Grade IV is exposed subchondral bone.

Advanced cartilage repair techniques can be divided into cartilage restoration procedures and cartilage replacement. Cartilage restoration procedures include autologous chondrocyte implantation (ACI), matrix-associated ACI (MACI®), and juvenile allogeneic cartilage (DeNovo). These techniques adequately replace the cartilage surface but lack bony support underlying the cartilage lesions. Cartilage

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B. C. Werner (ed.), *MRI-Arthroscopy Correlations*, https://doi.org/10.1007/978-3-030-94789-7_4

replacement techniques typically include a region of subchondral bone and include osteochondral autograft transfer and osteochondral allograft transfer. The type of cartilage procedure chosen depends on many factors including the size of the lesion, condition of the underlying bone, location of the lesion, prior procedures performed, and expectations of the patient.

This chapter will utilize a case-based format to demonstrate the correlation between MRI and arthroscopy for articular cartilage lesions of the knee. Diagnosis and management of each patient will be discussed for each case of the following seven cases.

4.2 Case 1: Grade II and IV Femoral Condyle Lesion Treated with Microfracture

4.2.1 History/Exam

A 19-year-old male collegiate football player reported to the orthopedic clinic reporting a 1-week history of right knee pain and swelling. The pain was located along the medial and lateral joint line. He did not recall any specific traumatic events. His symptoms worsened as the season progressed, as did the swelling. He reported occasional clicking in association with the pain. He denied any catching, locking, or instability.

On physical examination the right knee was found to have intact skin without any erythema or warmth. There was a moderate-sized effusion. There was tenderness along the medial and lateral joint line. McMurray test was positive for pain but not for catching. The knee was stable to varus and valgus stress. Lachman's, anterior drawer, and posterior drawer revealed stable endpoints.

4.2.2 Imaging

Magnetic resonance imaging was obtained to further evaluate the meniscus and chondral surfaces. A full complement of images was obtained. The technique used included fat-suppressed, fast T2-weighted images acquired axially, sagittally, and coronally, as well as T1-weighted sagittal images.

A full-thickness chondral defect measuring 8 mm involving the posterior weight-bearing aspect of the lateral femoral condyle was identified. There was mild bone marrow edema associated with the chondral defect, demonstrated in Fig. 4.1a–c. The medial meniscus and lateral meniscus were intact. All ligamentous structures were intact. Of note, the medial femoral condyle had increased signal on T2 images. However, the chondral surfaces of the medial compartment were intact.

The patient had continued symptoms at the end of the season, particularly lateral joint line pain and swelling. Given the MRI findings of a full-thickness chondral defect involving the lateral femoral condyle, surgical treatment was discussed. After reviewing the risks and benefits, the patient elected to pursue a diagnostic arthroscopy and likely microfracture of the chondral defect.

4.2.3 Arthroscopy

The patient was taken to the operating room and placed in the supine position. A standard diagnostic arthroscopy of the right knee was performed. Multiple small chondral loose bodies were identified, measuring <2 mm, demonstrated in Fig. 4.2a, b. A small, focal grade IV chondral defect was identified involving the lateral femoral condyle. It measured 4 mm in size and was surrounded by an approximate 4 mm rim of mild grade II chondral changes, seen in Fig. 4.2c. Finally, there was a small horizontal cleavage tear involving the lateral meniscus, which was flipped into the femoral notch, demonstrated in Fig. 4.3a, b. These arthroscopic findings of the chondral defect correlated with the MRI findings.

The small chondral loose bodies were removed with a 4.0 mm arthroscopic shaver without difficulty. The horizontal cleavage tear involving the lateral meniscus was addressed with a partial meniscectomy using the arthroscopic biters and shaver, shown in Fig. 4.3c. Finally, the chondral defect of the lateral femoral condyle was addressed. The cartilage defect was debrided down to the subchondral bone. Care was taken to maintain stable edges circumferentially around the defect. A microfracture awl was then used to penetrate the subchondral bone. The arthroscopic fluid flow was turned off, and bleeding from the microfracture holes was confirmed, seen in Fig. 4.4a, b.

4.3 Case 2: Grade IV Femoral Condyle Lesion Treated with Osteochondral Autograft Transplantation (OATS)/Mosaicplasty

4.3.1 History/Exam

A 33-year-old male presented with a 6-month history of waxing and waning left knee pain. He initially experienced pain when he hyperextended his knee while removing an engine block from an automobile. He felt a pop in his knee and developed laterally based pain and an effusion within hours of the injury. He treated the knee conservatively and had a resolution of his pain and effusion. However, as these symptoms resolved, he began to develop a sense of instabil-

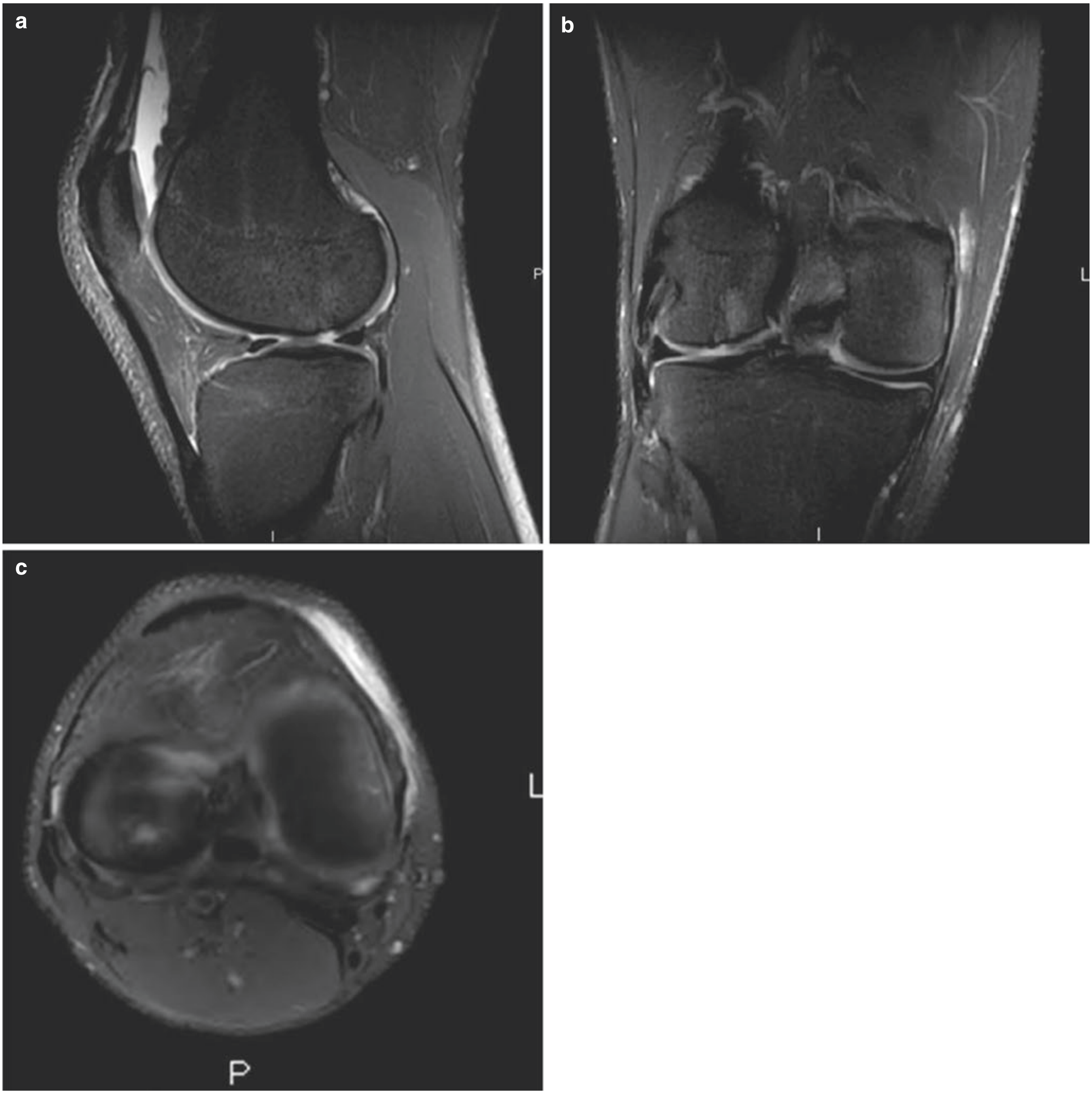

Fig. 4.1 (**a**–**c**) Select sagittal, coronal, and axial T2 images from a 3-T MRI of the right knee without contrast. A contained grade IV lesion measuring approximately 8 mm involving the lateral femoral condyle. There is a small amount of signal within the underlying bone without any cyst formation or bone loss

ity. One instability event leads to another hyperextension event with sharp lateral pain and effusion development. His lateral pain, effusions, and instability have continued since the second hyperextension injury.

On physical examination the left knee was found to have intact skin with no erythema or warmth. There was a moderate-sized effusion. The knee was tender along the lateral joint line. Active range of motion was noted to be 15°–90° of flexion. Passively, the knee's range of motion improved to 10°–100°. Pain was recreated laterally with deep flexion. McMurray testing produced a lateral catch and pain. The knee was stable to varus and valgus stress. The Lachman's, anterior drawer, and posterior drawer were negative. The remainder of the extremity was neurovascularly intact.

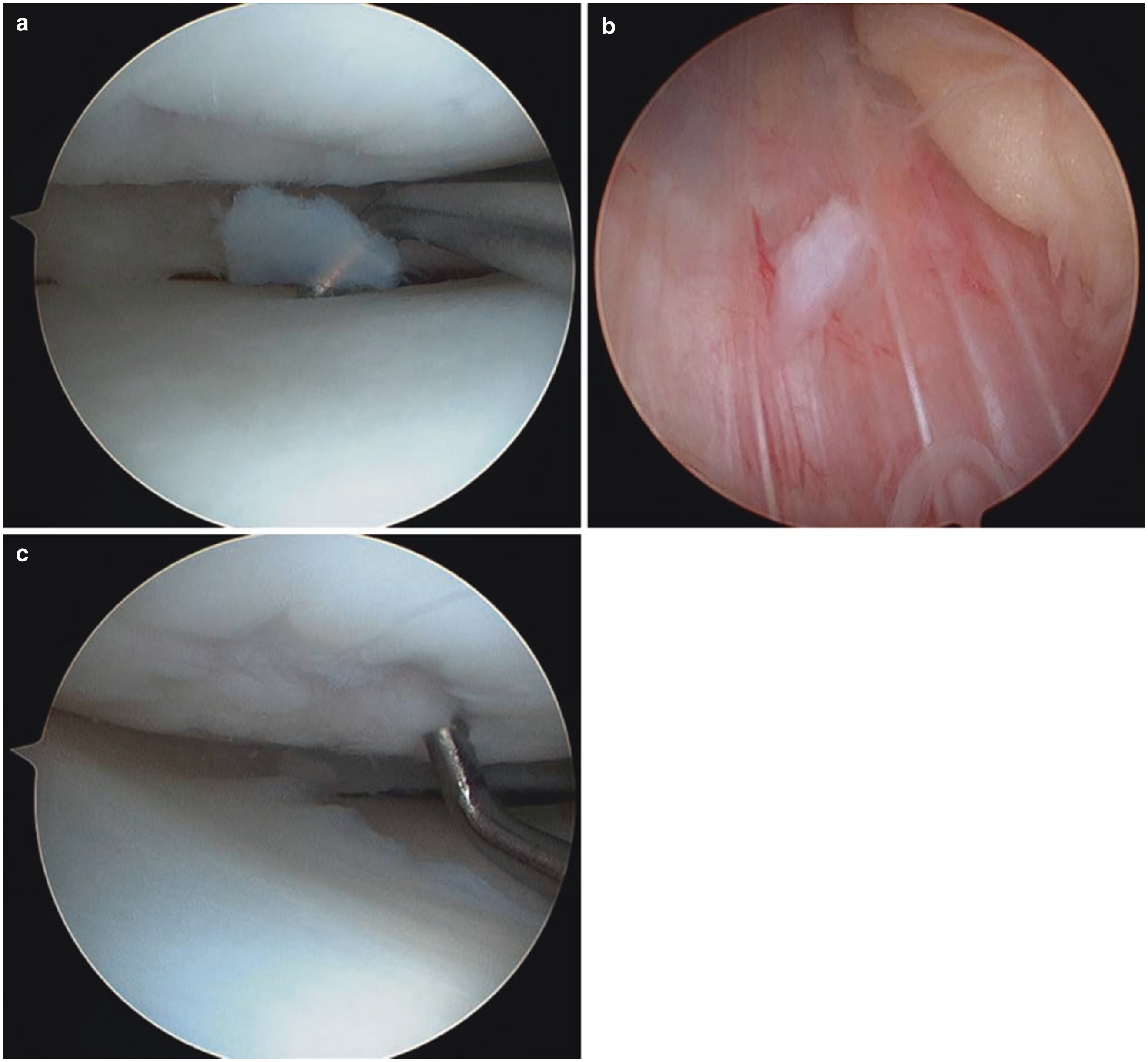

Fig. 4.2 (**a**–**c**) Two arthroscopic views demonstrating loose chondral pieces measuring 2–4 mm. A chondral defect involving the lateral femoral condyle measuring approximately 8 mm was identified

4.3.2 Imaging

Plain radiographs of the left knee demonstrated well-maintained joint spaces on the AP and Rosenberg views. No lucencies were identified on AP or lateral views, as shown in Fig. 4.5a, b.

Magnetic resonance imaging was obtained to further evaluate the meniscus and chondral surfaces. A full complement of images was obtained. The technique used included fat-suppressed, fast T2-weighted images acquired axially, sagittally, and coronally, as well as T1-weighted sagittal images.

The MRI demonstrated bone marrow edema involving the posterolateral femoral condyle. The cartilage overlying this area of bony edema had a notable signal abnormality on T2 images. There was a linear band of signal intensity at the interface between the cartilage and subchondral bone, which was suggestive of a delamination or flap. The area of delamination measured approximately 1.4 cm in the anterior to posterior dimension. A small joint effusion was present, demonstrated in Fig. 4.6a, b. The remainder of the MRI was normal.

Given the patient's continued lateral pain and effusion, arthroscopy and possible cartilage procedure were discussed.

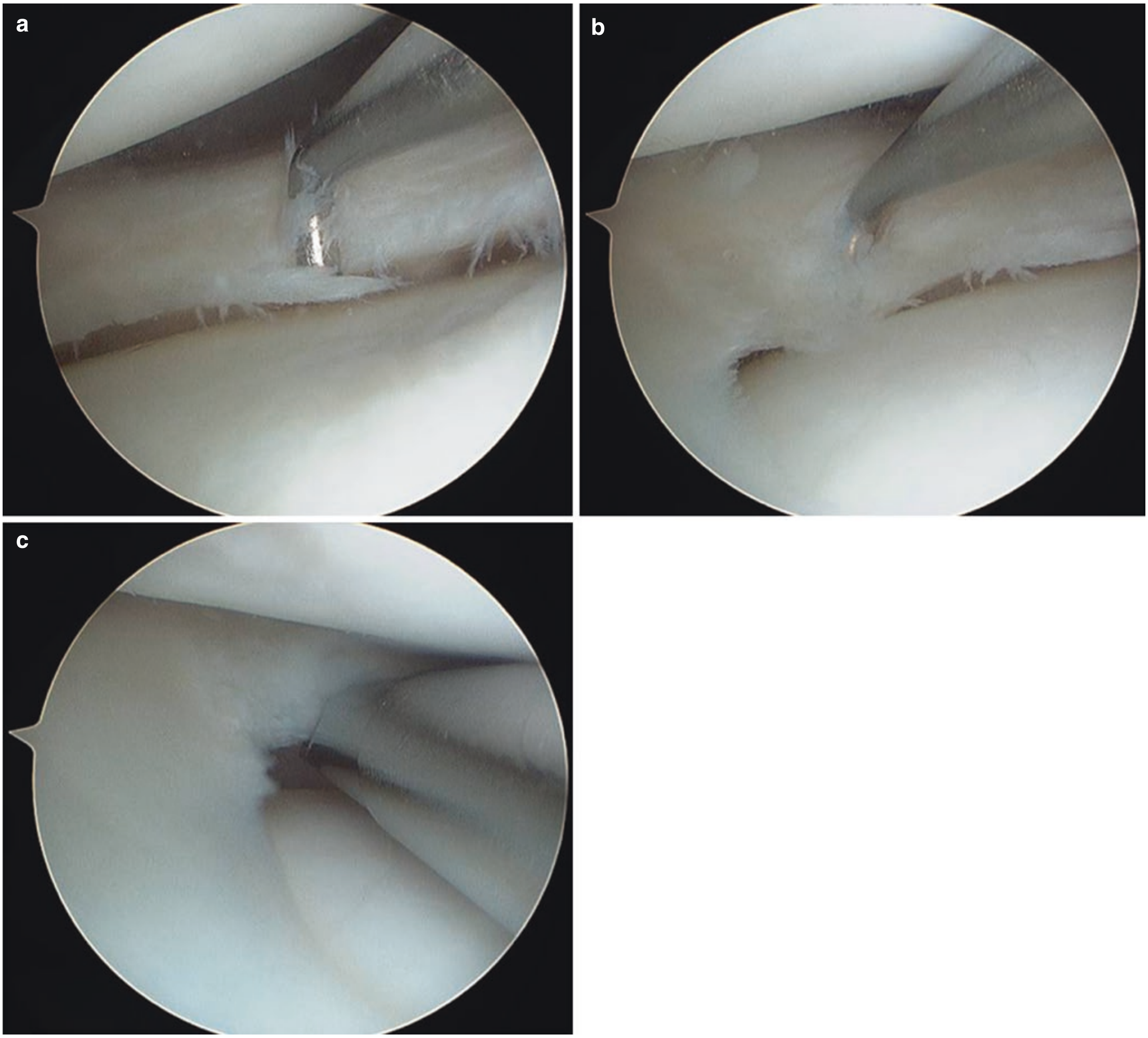

Fig. 4.3 (**a**–**c**) Two arthroscopic views depicting the horizontal cleavage tear involving the lateral meniscus. There was an unstable flap component that could be displaced into the joint with an arthroscopic probe. The tear was debrided with a 4.0 mm arthroscopic shaver

After reviewing the risks and benefits of surgery, the patient decided to proceed with surgery.

4.3.3 Arthroscopy

The patient was taken to the operating room and placed in the supine position. A standard diagnostic arthroscopy of the right knee was performed. A grade IV chondral defect with an overlying flap of cartilage was found involving the lateral femoral condyle with the knee flexed to 45°. It measured 9 mm in the medial to lateral dimension and 15 mm in the anterior to posterior dimension. It was slightly narrower at its most anterior portion, demonstrated in Fig. 4.7a, b. This correlated to the MRI images.

The defect was debrided down to the subchondral bone with an arthroscopic shaver and sized with the osteochondral autograft transplantation system, as shown in Fig. 4.8a–c. It was decided to use the superomedial aspect of the trochlea as the donor sight for the osteochondral autograft. Two donor plugs were harvested from this region, measuring 10 × 14 mm and 6 × 14 mm, respectively. The transplant site was then prepared by removing a 10 × 12 mm and 6 × 12 mm core of bone. The 10 × 4 mm donor plug was then placed into the corresponding hole followed by the 6 × 14 mm donor plug, demonstrated in Fig. 4.9a–c.

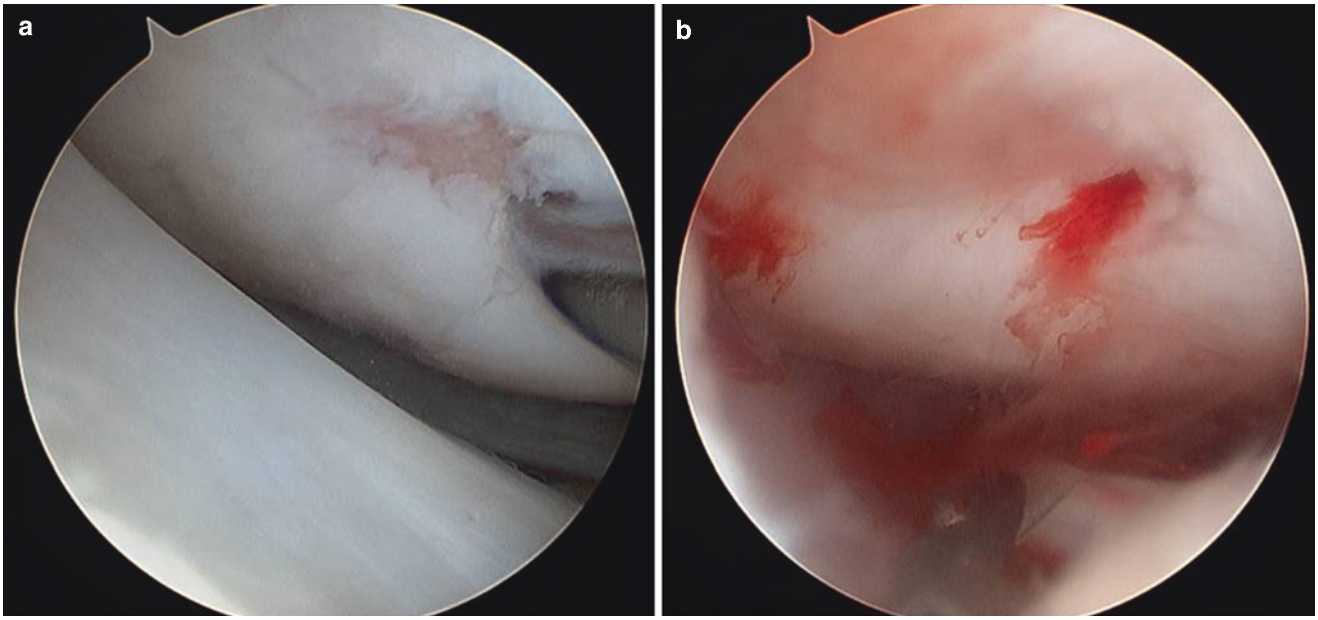

Fig. 4.4 (**a**, **b**) Arthroscopic views of the chondral lesion after debridement to stable shoulders showed that the area of grade IV changes was 4 mm with a surrounding 4 mm ring of grade II changes. An arthroscopic awl was used to perform a microfracture. When flow was turned off, there was bleeding from the microfracture holes

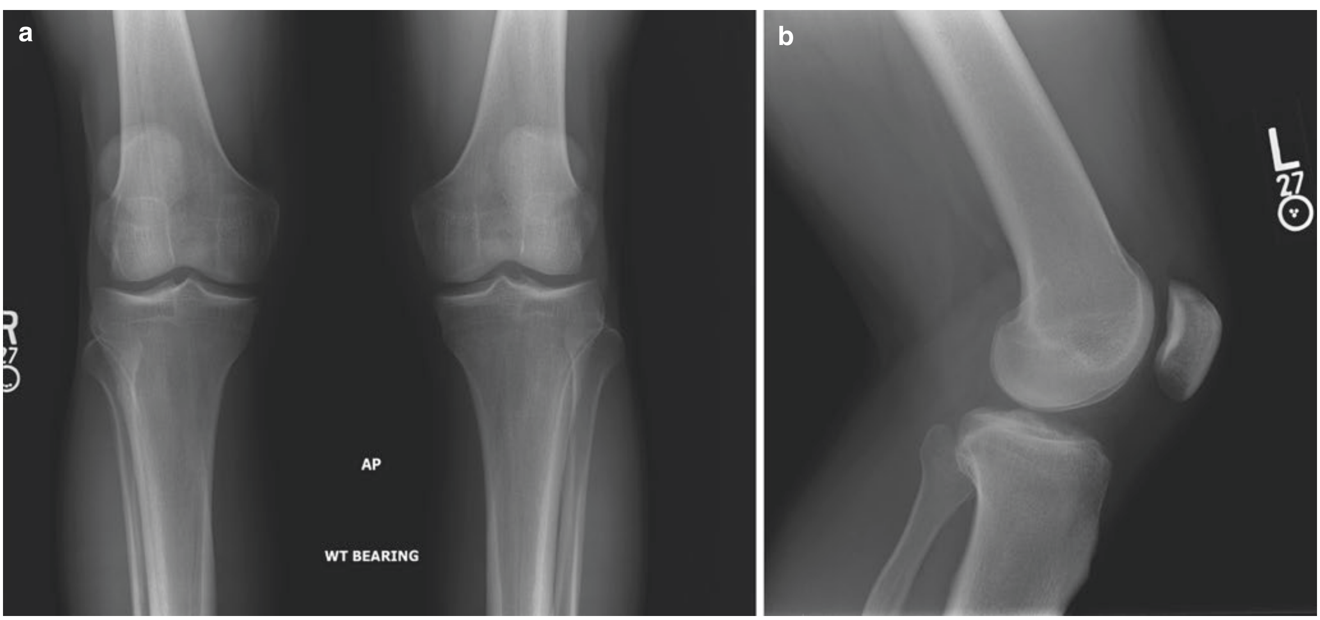

Fig. 4.5 (**a**, **b**) AP and lateral views of the left knee showing well-maintained joint spaces with no lucencies

4.3.4 Discussion for Microfracture and OATS/Mosaicplasty

Cartilage lesions are evident on both T1 and T2 MR sequencing. These lesions can appear as cartilage thinning, fissuring, or full-thickness defects. The full-thickness defects are easily identified on T2 imaging, as the defect will fill with joint fluid. This shows up as a bright white signal within the cartilage defect extending to the black layer of the subchondral bone. Unstable lesions reveal synovial fluid between the cartilage fragment and the subchondral bone. Depending on how long the defect has been present, its size, and the overall limb alignment, the underlying bone may have increased signal within it on T2-weighted images signifying bony edema.

During arthroscopy, cartilage lesions can have a variable presentation. The Outerbridge classification helps to define the severity of these defects. Grade I chondral changes present as cartilage softening and/or blistering. Grade II chondral changes appear as mild thinning of the cartilage and possible

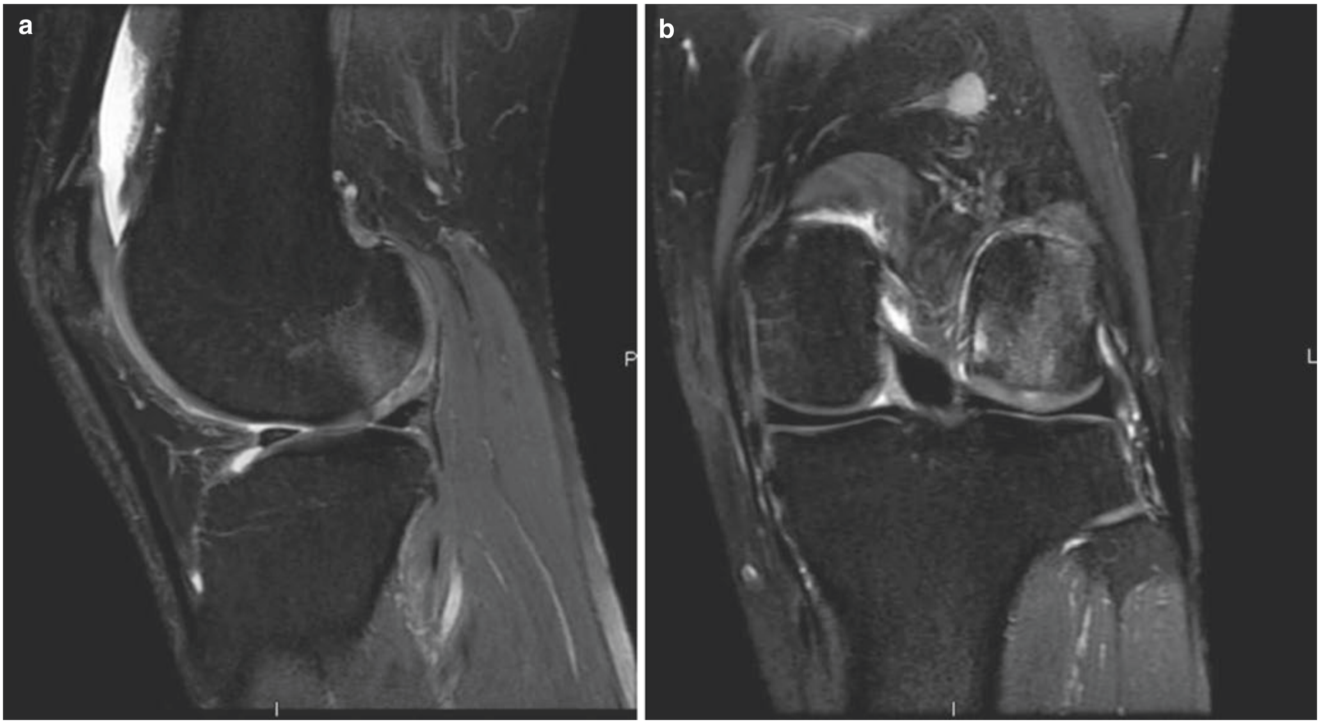

Fig. 4.6 (**a**, **b**) Select sagittal and coronal T2 views of the left knee with a 3-T MRI without contrast. They demonstrate a chondral lesion involving the posterior portion of the lateral femoral condyle. There is fluid signal between the cartilage and underlying subchondral bone, suggesting a flap-type configuration to the chondral lesion. The lesion measures 15 mm in the AP dimension and 9 mm in the medial to lateral dimension. There is also signal within the bone without cyst formation or bone loss

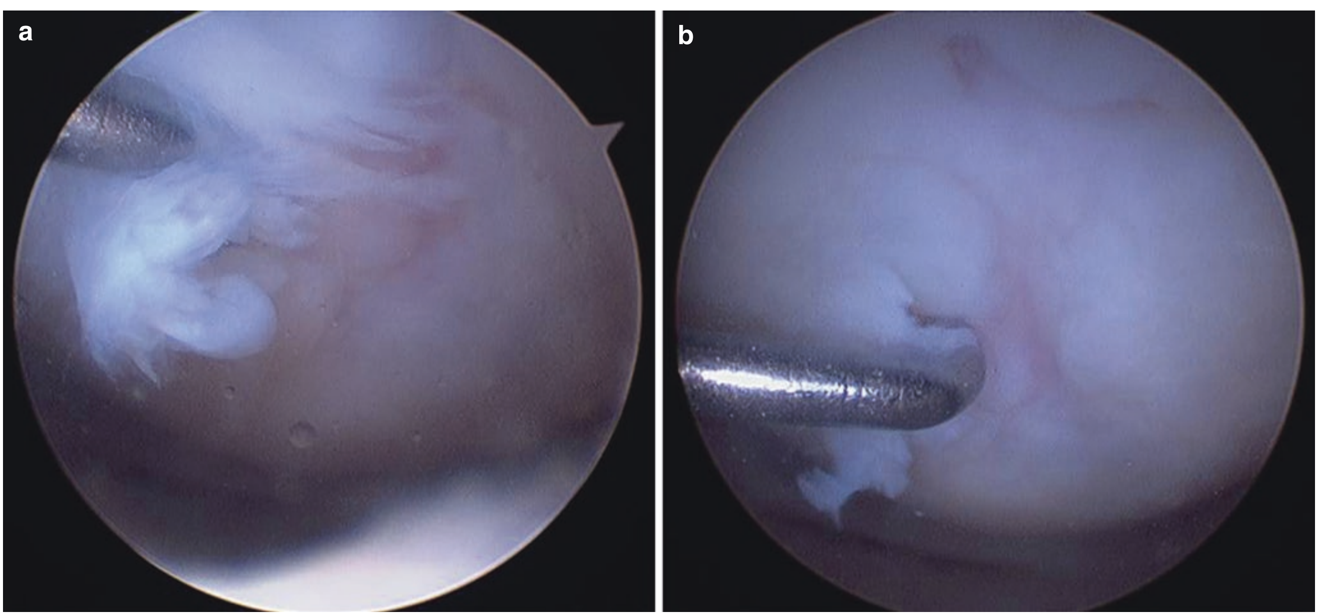

Fig. 4.7 (**a**, **b**) Arthroscopic views showing a large flap lesion of the posterior portion of the lateral femoral condyle with the knee flexed to 45°

fissuring. The fissures do not extend down to the subchondral bone. Grade III chondral changes present as cartilage thinning and fissuring that extends all the way to the subchondral bone. Finally, grade IV changes appear as full-thickness cartilage defects that extend to the subchondral bone.

In treating these chondral lesions, grade I changes are typically left alone. Grade II changes are debrided to stable transitions between the normal and thinned cartilage. Grade III and grade IV chondral defects require more aggressive treatment. The treatment begins with debriding the lesions

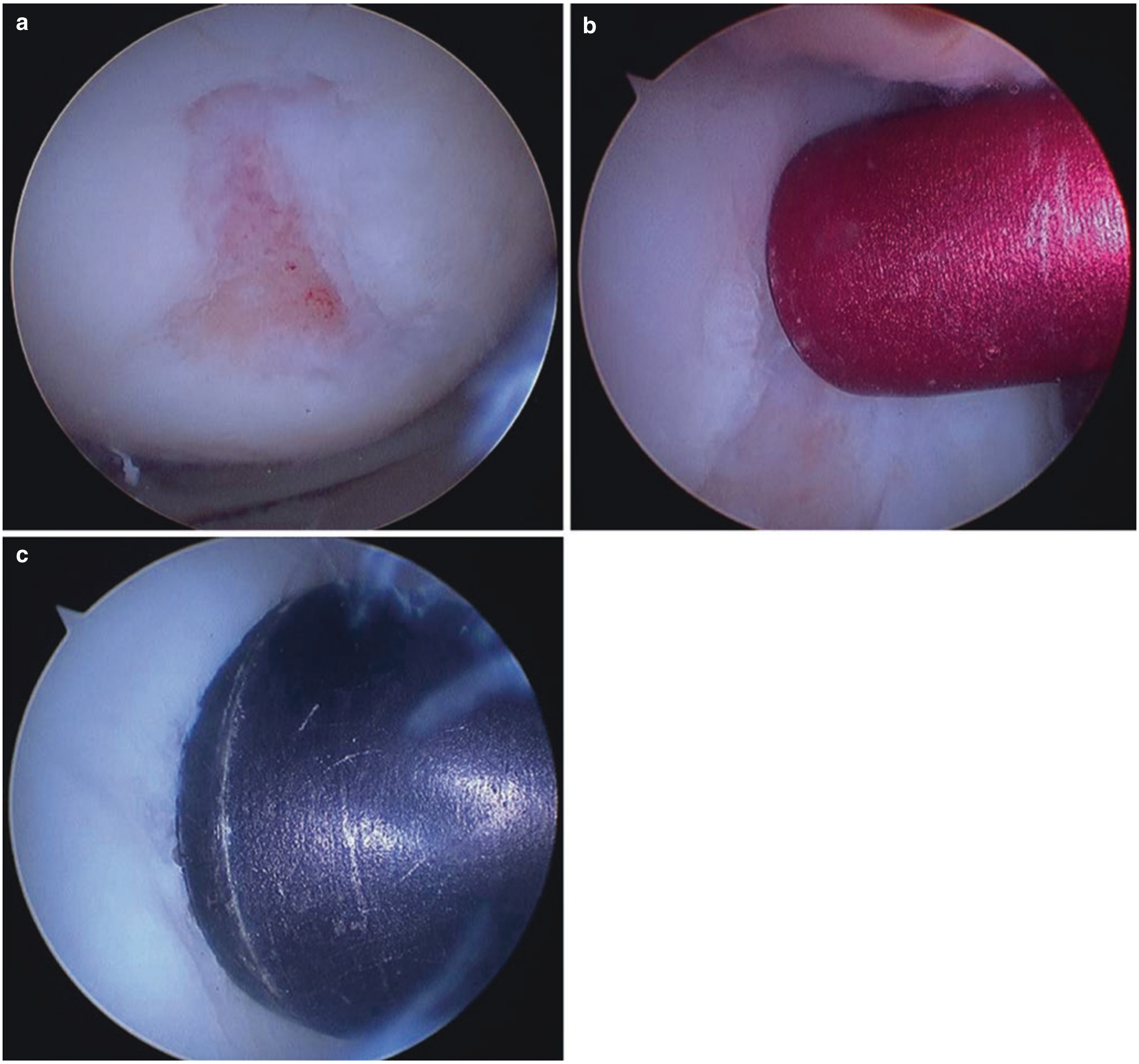

Fig. 4.8 (**a**–**c**) Arthroscopic view of the lesion after debridement. The two components of the lesion measured 6 mm and 10 mm in diameter, respectively

back to a stable cartilage shoulder. The calcified cartilage layer is then removed, exposing the subchondral bone. Further decisions on treatment are then made depending on the relative size of the lesion.

Microfracture and other bone marrow-stimulating techniques work well for lesions less than 2 cm^2. Short-term results are good, but larger lesions and multiple sites of microfracture have been associated with poorer outcomes [7]. However, the longevity of the fibrocartilage that fills in the cartilage defect is questionable in long-term studies secondary to the fibrocartilage's inferior biomechanical properties compared to hyaline cartilage. Further discussion of the juxtaposition of marrow-stimulating techniques and other procedures are discussed in Case 7.

Osteochondral autograft implantation is reserved for lesions that are typically less than 10 mm^2 or a stacked lesion, as seen in Case 2. Mosaicplasty can be used for larger lesions. The benefit of these procedures is that the cartilage defect is being filled with hyaline cartilage, with only a small band of fibrocartilage forming between the donor plug and surrounding cartilage. The disadvantage of these procedures is the morbidity of taking the donor plug from a non-weight-bearing portion of the knee. Another disadvantage of mosaicplasty is that it is likely that more fibrocartilage will fill in between the various plugs.

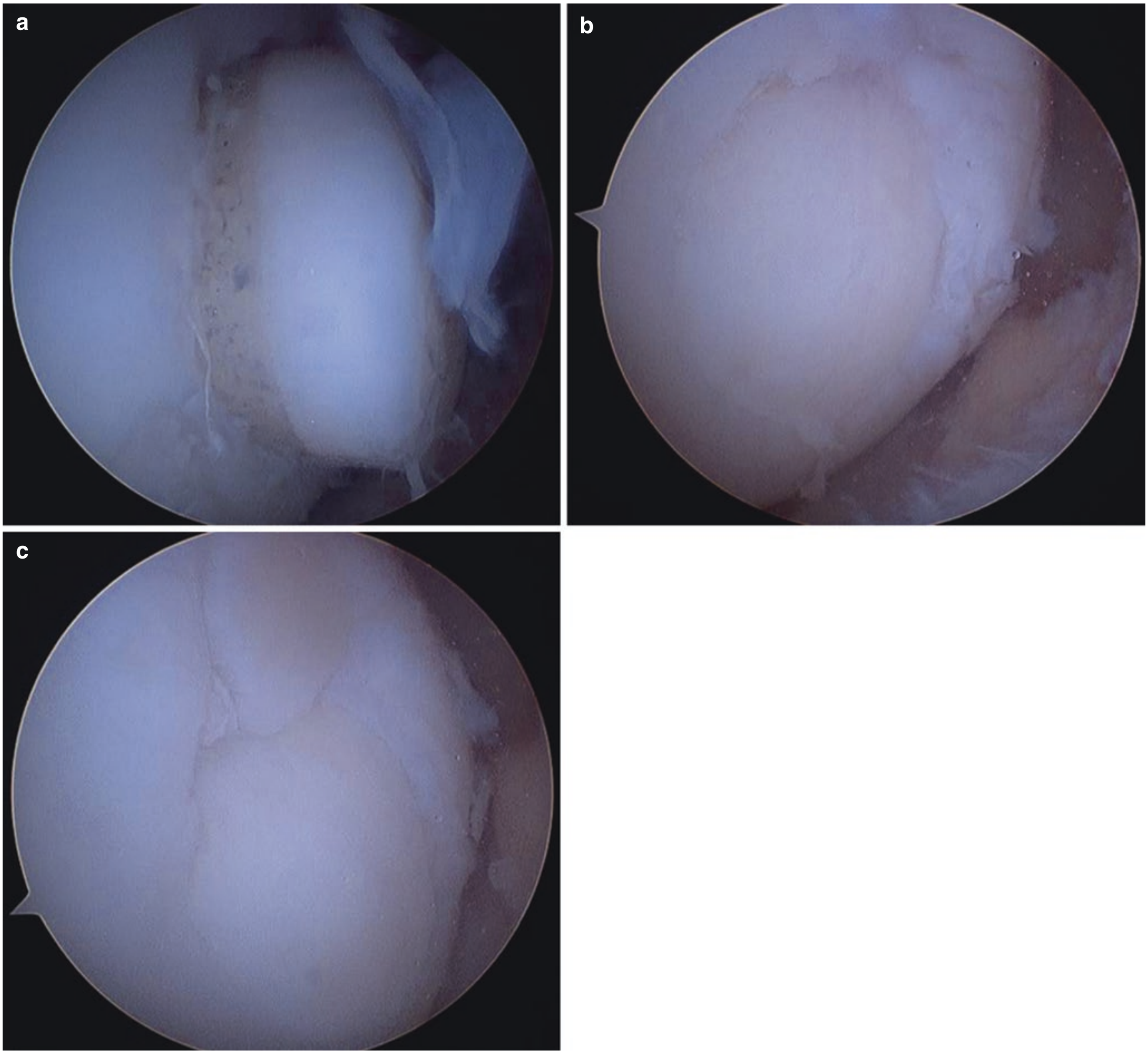

Fig. 4.9 (**a**–**c**) Arthroscopic views of the 10 × 14 mm plug being advanced into its receiving site until it was flush. Final arthroscopic view of the final two plugs in place at their receiving sites

4.4 Case 3: Nontraditional, Unstable Osteochondritis Dissecans (OCD) of the Knee Treated with Arthroscopic Fixation

4.4.1 History/Exam

A 13-year-old female presented to the orthopedic clinic after a 3-week history of right knee pain. This began as she increased her activity from softball to playing for three separate basketball teams. The pain was localized to the deep, lateral portion of the knee. It was aggravated by knee flexion and impact from running and jumping. There was associated swelling since the pain began, along with clicking and catching. She stated that the knee gave out on average of two times per day. She found that ice helped with the symptoms, but NSAIDS were not helpful. Of interest, the patient's older sister had a history of osteochondritis dissecans.

On exam, the right knee had intact skin. There was a small effusion. The knee was tender to palpation along both the medial and lateral joint lines. The knee was stable to varus and valgus stress. The Lachman's, anterior drawer, and posterior drawer test results were negative. McMurray and Wilson test results were also negative.

4.4.2 Imaging

Plain radiographs of the right knee demonstrated well-maintained joint spaces on the AP and Rosenberg views. There were no identified lucencies on these two views. On the Merchant view, a lucency was identified over the lateral trochlea. A suggestion of this lucency was also seen on the lateral, as shown in Fig. 4.10a, b.

Magnetic resonance imaging was obtained to further evaluate the meniscus and chondral surfaces. A full complement of images was obtained. The technique used included fat-suppressed, fast T2-weighted images acquired axially, sagittally, and coronally, as well as T1-weighted sagittal images.

A 16 × 19 mm osteochondral lesion was noted in the superior aspect of the lateral trochlea. There was a fragmented and sclerotic fragment overlying the osteochondral lesion. Fluid extended deep to the fragment, and there was subjacent marrow edema, all seen in Fig. 4.11a–c. The chondral surfaces of the patella, medial compartment, and lateral compartment were found to be intact. The medial meniscus and lateral meniscus were normal. All ligamentous structures were intact.

The MRI identified an unstable osteochondritis dissecans lesion of the superior portion of the lateral trochlea. After discussing the risks and benefits of surgical treatment of the osteochondral lesion, the patient and her family wished to proceed with osteochondral fixation.

4.4.3 Arthroscopy

The patient was taken to the operating room and placed in the supine position. A standard diagnostic right knee arthroscopy was performed. A 12 mm loose chondral piece was identified at the superolateral aspect of the trochlea. It was tethered at its most superior portion by a thin piece of cartilage, and there was exposed bone underneath, as seen in Fig. 4.12a–c. The fragment reduced easily into its donor site. The decision was made to proceed with fragment fixation. The base of the donor site was curetted through an accessory portal lateral to the patella, and bone marrow stimulation was performed, as shown in Fig. 4.13a–c. The fragment was reduced and held in place with a spinal needle. Another accessory portal was made next to the superolateral aspect of the patella. A guide wire was placed into the fragment. This was drilled by hand using a 1.7 mm drill bit. A 2 mm cannulated screw was then advanced to fix the fragment, demonstrated in Fig. 4.14a, b. Two additional cannulated screws were placed to form a triangular pattern of fixation, as shown in Fig. 4.14c. The fragment was stable following fixation. The screw heads were buried just below the articular cartilage. The knee was then debrided of any loose debris. The patient's weight-bearing status was not limited since the OCD lesion did not involve a weight-bearing portion of the knee. The postoperative plane was to remove the screws at 12 weeks.

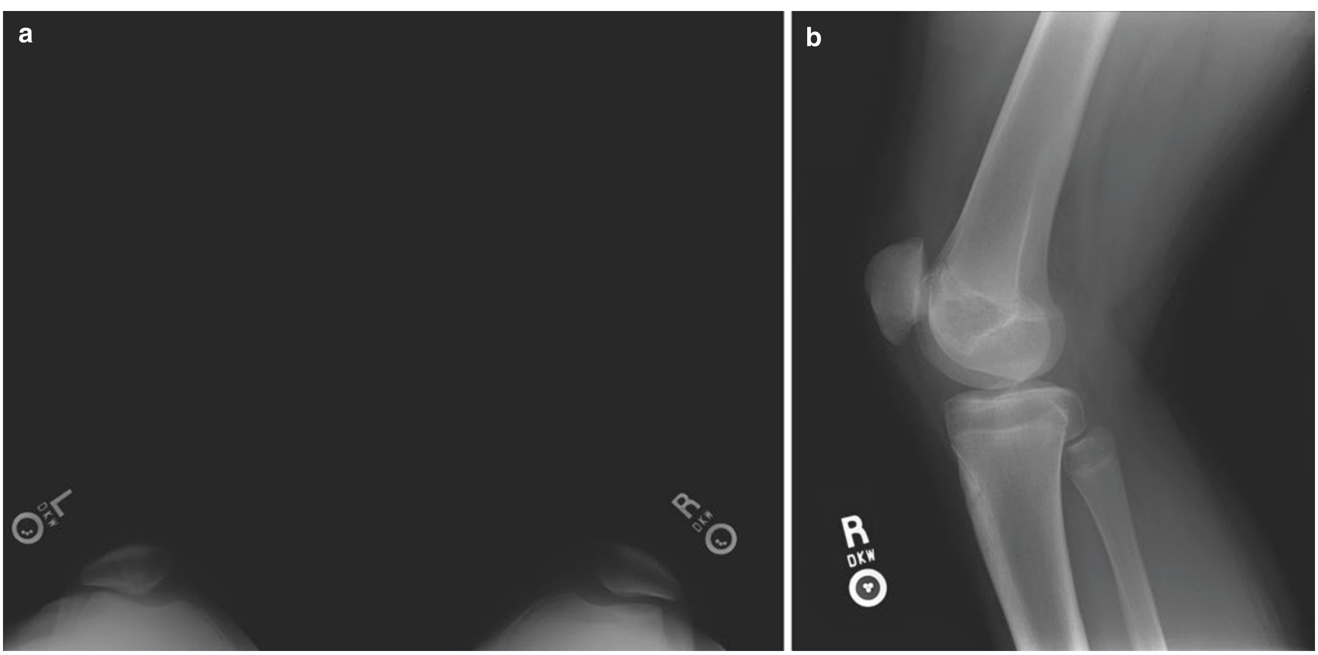

Fig. 4.10 (**a**, **b**) Merchant and lateral views of the right knee showing a lucency at the lateral trochlea

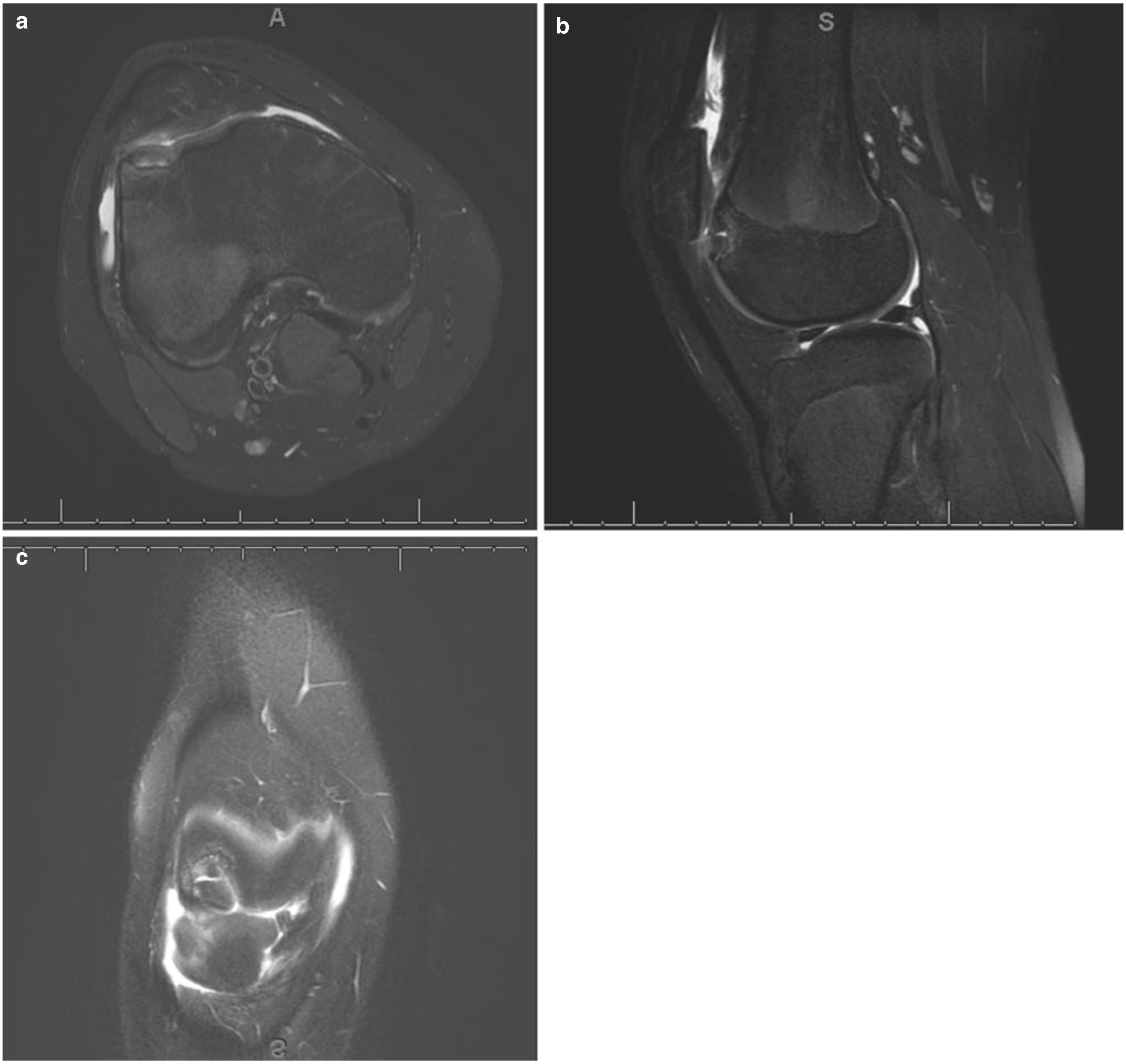

Fig. 4.11 (**a**–**c**) Select axial, sagittal, and coronal T2 views of the right knee from a noncontrast 3-T MRI. They demonstrate an unstable OCD lesion of the lateral trochlea which is fragmented and measures 16 × 19 mm

4.5 Case 4: Traditional, Unstable Osteochondritis Dissecans (OCD) of the Knee Treated with Open Fixation

4.5.1 History/Exam

A 15-year-old male presented with a several-month history of left knee pain. The pain started insidiously, without any history of trauma. The pain was described as being deep within the knee. The pain was aggravated by high-impact activities and deep knee flexion. He noted swelling and tightness within the knee since the pain began. He also stated that there was an associated catching sensation within the knee.

On exam, the left knee had intact skin with no erythema or warmth. There was a moderate-sized effusion. There was tenderness just to the medial side of the patellar tendon. The knee was stable to varus and valgus stress. The Lachman's, anterior drawer, and posterior drawer were negative. Medially based pain was reproduced with McMurray and Wilson testing. The remainder of the extremity was neurovascularly intact.

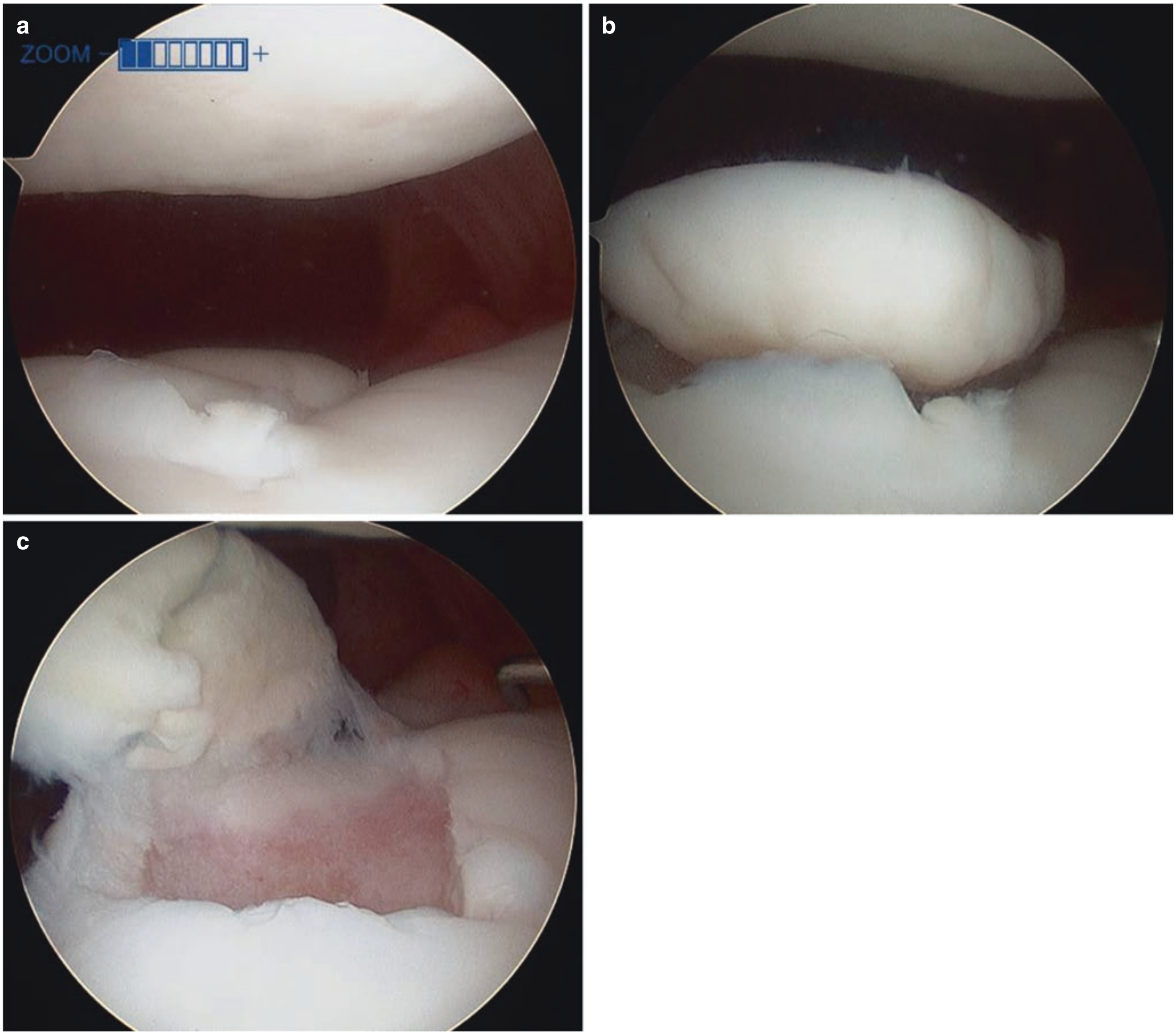

Fig. 4.12 (**a**–**c**) Arthroscopic views showing the unstable OCD lesion of the superior aspect of the lateral trochlea. It is a large flap connected by a small superior strip of intact cartilage. There are two bone fragments attached to the flap of cartilage

4.5.2 Imaging

The patient presented with magnetic resonance imaging already obtained. Additional magnetic resonance imaging was obtained to further evaluate the meniscus and chondral surfaces. A full complement of images was obtained. The technique used included fat-suppressed, fast T2-weighted images acquired axially, sagittally, and coronally, as well as T1-weighted sagittal images.

The MRI demonstrated a large focus of osteochondritis dissecans involving the posterolateral aspect of the medial femoral condyle. The lesion was fragmented into two separate pieces. There was a fluid signal on T2 imaging between the cartilage lesion and the underlying bone, demonstrated in Fig. 4.15a, b. The two fragments had a combined measurement of 34 × 22 mm. The T1 images showed a disruption in the cartilage surface with an irregularity of the underlying bone, shown in Fig. 4.15c. The remaining portions of the MRI were normal.

The MRI suggested that the OCD lesion was unstable. The unstable lesion was discussed at length with the patient and his parents. They elected to proceed with surgical fixation of the lesion after reviewing the risks and benefits.

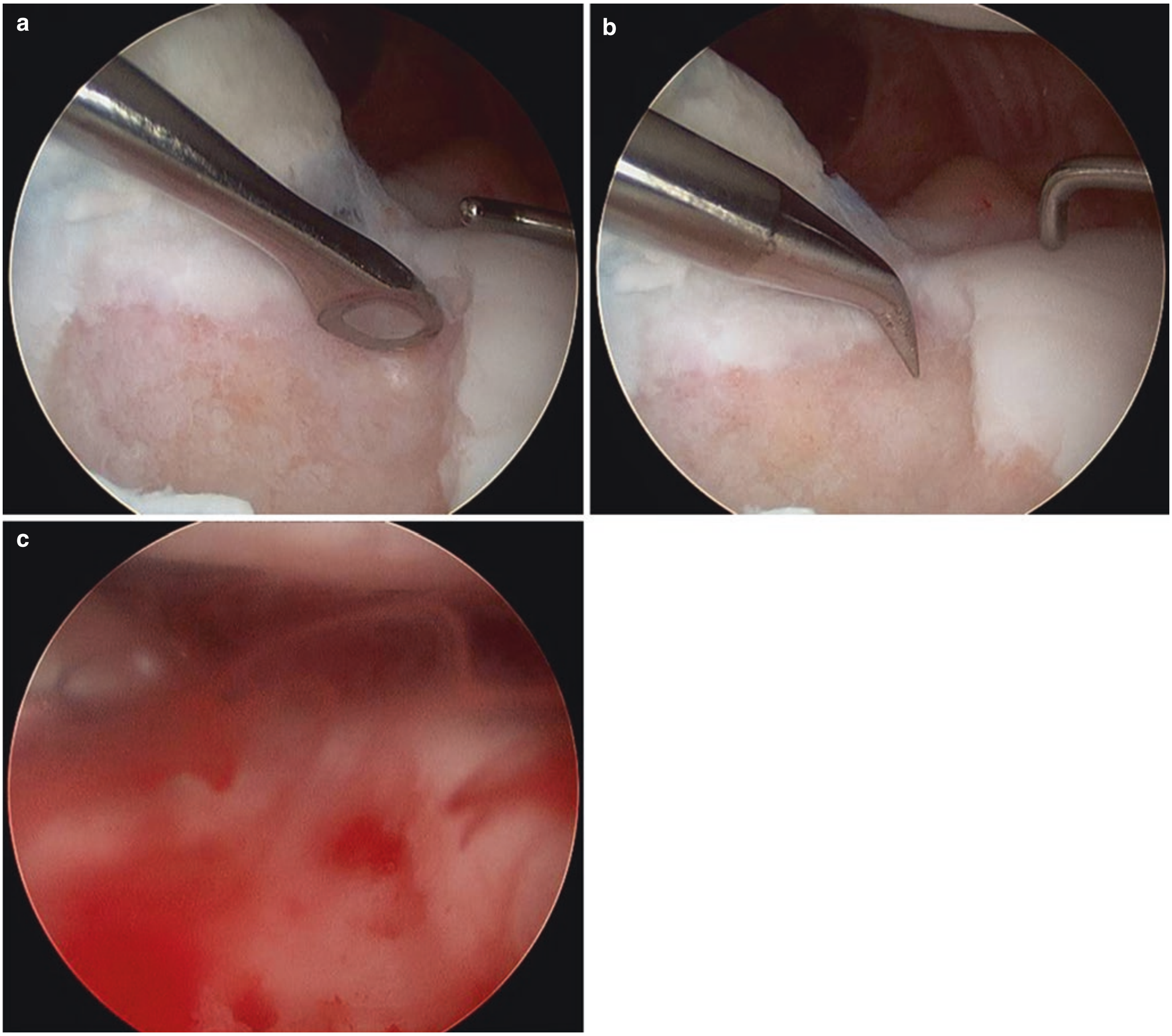

Fig. 4.13 (**a–c**) Arthroscopic views of the underlying bone being debrided and microfractured with an arthroscopic awl. Bone bleeding was stimulated by the microfracture

4.5.3 Arthroscopy

The patient was taken to the operating room and placed in the supine position. A standard diagnostic right knee arthroscopy was performed. Upon entering the medial compartment, a large fissure was identified involving the lateral portion of the medial femoral condyle, demonstrated in Fig. 4.16a. The fissure extended in a near circumferential pattern, with the only attachment being anterior, and extended down to the bone when probed, shown in Fig. 4.16b, c. When the flap was lifted, there was a large bony defect that measured 35 × 20 cm; see Fig. 4.16d. The missing bone was attached to the cartilage flap as two large fragments. The remainder of the knee was found to be normal.

A medial parapatellar arthrotomy was then made to access the medial femoral condyle, and the OCD lesion was identified, seen in Fig. 4.17a. The bony bed of the OCD lesion was cleared of all fibrous tissue. The chondral flap, with its attached bone, was reduced into the bony bed. Three 2.0 mm screws were then used to stabilize the OCD lesion. The screw heads were buried just below the articular cartilage, demonstrated in Fig. 4.17b. The knee was then taken through a range of motion smoothly, and the incisions were closed in a layered fashion.

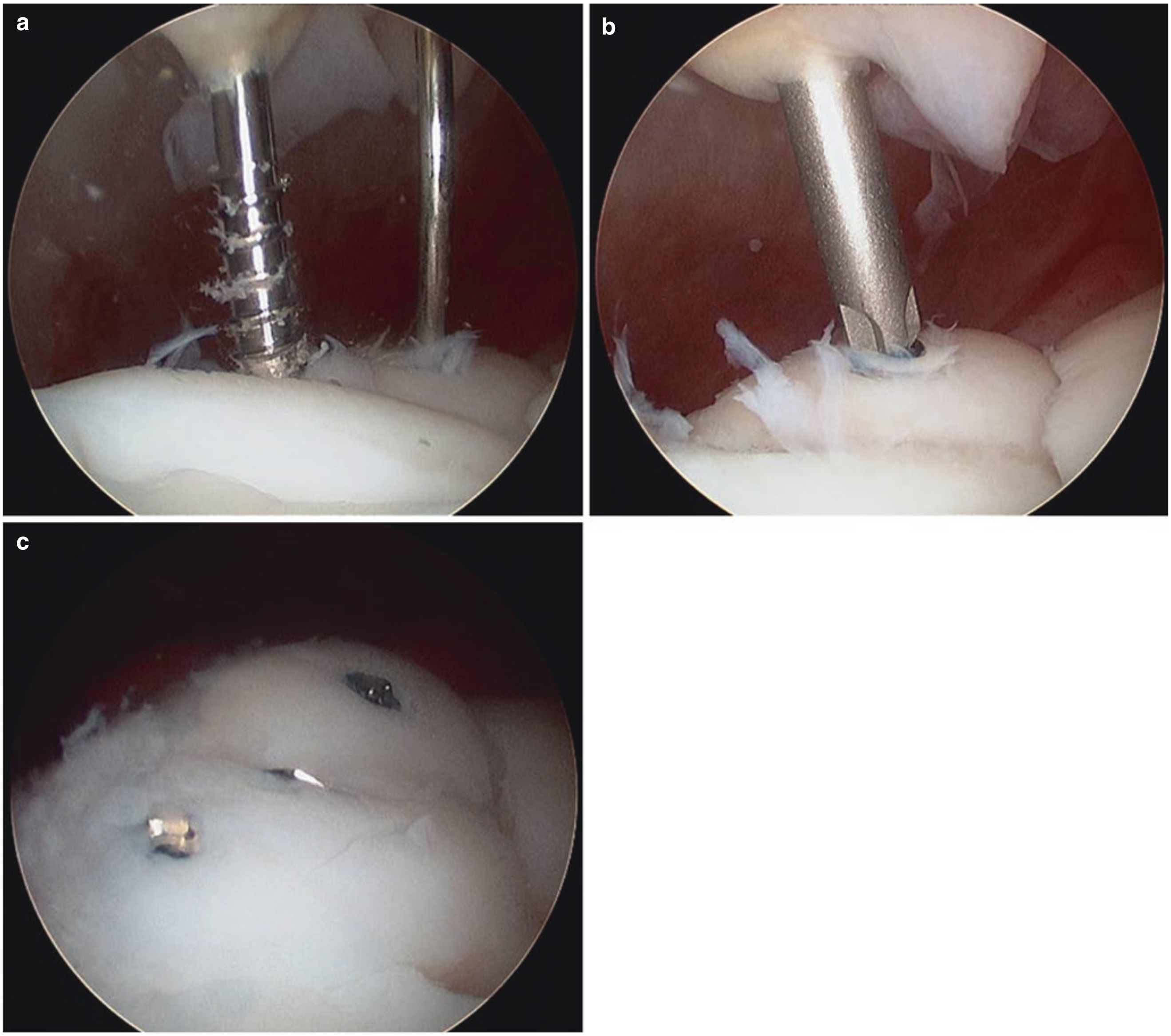

Fig. 4.14 (**a**–**c**) Arthroscopic images of the OCD lesion being stabilized with a spinal needle as a cannulated screw is advanced over a K-wire. The final fixation was achieved with three 2.0 mm cannulated screws

4.5.4 Discussion for Osteochondritis Dissecans (OCD)

Osteochondritis dissecans lesions of the knee are commonly seen in adolescents. They typically involve the posterolateral portion of the medial femoral condyle, as seen in Case 4. However, they can involve other portions of the knee, like the superolateral trochlea as seen in Case 3. The treatment algorithm in adolescents depends on the state of the physis and the stability of the lesion. The stability of the lesion is most easily assessed with an MRI. These lesions are evident on both T1 and T2 sequencing. On T1 sequencing, the cartilage may appear normal in a stable lesion. However, the underlying bone will have an irregular surface as this is both a cartilage and bone issue. The T2 images are more telling as to the stability of the lesion. In both Case 3 and Case 4, the OCD lesion was unstable. This was evident by the white signal of the joint fluid interposed between the OCD lesion and underlying bone. The MRI findings correlate nicely with the findings at arthroscopy. Lesions greater than 8 mm may best addressed with open reduction and internal fixation when the lesion is amenable, while an attempt at arthroscopic reduction and fixation can be made with lesions less than 8 mm. When possible, it is important to attempt fixation of the OCD lesion, as it preserves the patient's native hyaline cartilage and bone. Successful fixation will maintain joint congruence, eliminate mechanical symptoms, and relieve pain.

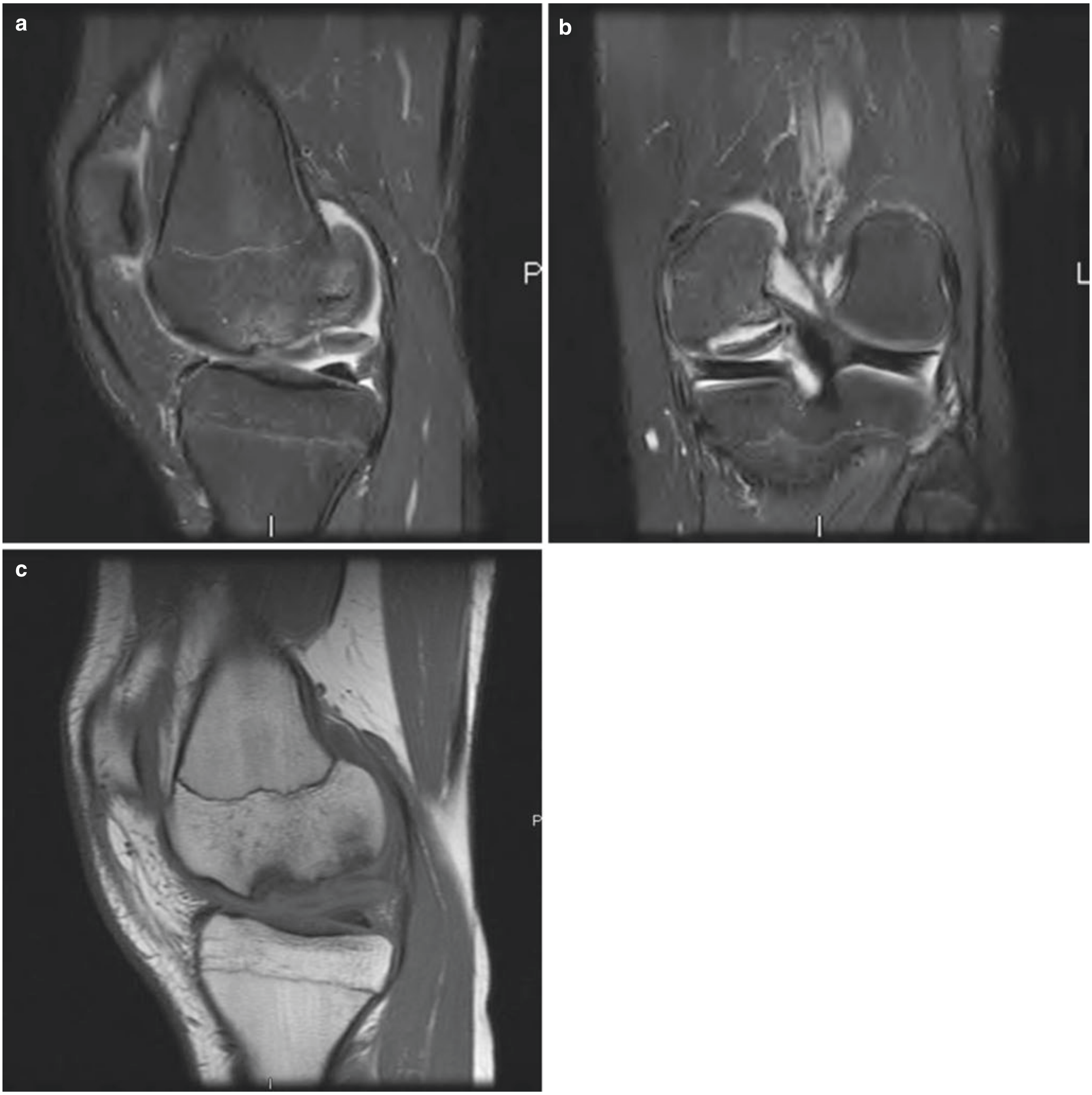

Fig. 4.15 (**a**–**c**) Select sagittal and coronal T2 images from a 3-T MRI of the left knee show an unstable, fragmented OCD lesion involving the posterior aspect of the medial femoral condyle. The lesion measures 34 × 22 mm. A select sagittal T1 image demonstrates irregularity of the underlying bone

4.6 Case 5: Grade II–III Femoral Condyle Lesion After Failed Chondroplasty Treated with Osteochondral Allograft

4.6.1 History/Exam

A 42-year-old male presented for evaluation of persistent right medial knee pain. The patient underwent ACL reconstruction 1 year previously and chondroplasty of the medial femoral condyle. He has no complaints of instability or mechanical symptoms. He is very active and desires to continue to cycle, ski, and hike. He is unable to run without significant medial knee pain. He has had only minimal relief with a medial compartment unloader brace.

On physical exam, he walks with an antalgic gait and has neutral alignment. He has good symmetric quadriceps mass, full range of motion, and no effusion. He has a stable Lachman's and does not pivot. He has mild tenderness along

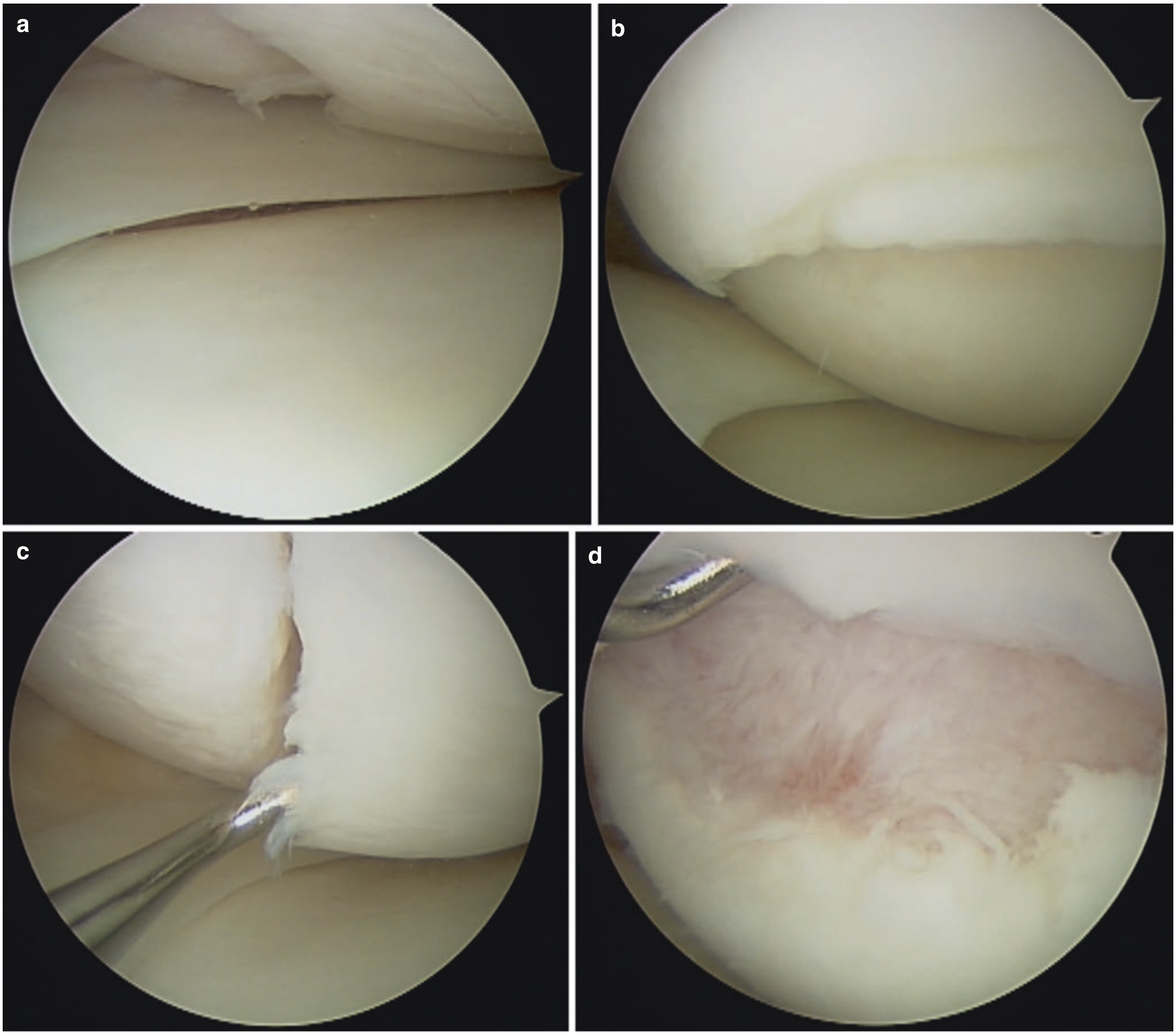

Fig. 4.16 (**a**–**d**) Arthroscopic views of the posterior portion of the medial femoral condyle. It was near circumferential with only a small flap of cartilage holding the lesion in place. The underlying bone had a thin layer of fibrous tissue over it. The lesion measured 35 × 20 mm

the medial joint line and tenderness over the medial femoral condyle. Exam otherwise is normal.

Plane radiographs showed good tunnel position and no degenerative changes. A full-length alignment film showed neutral alignment. Advanced imaging with MRI was obtained to evaluate the cartilage lesion on the medial femoral condyle.

4.6.2 Imaging

MRI without contrast of the right knee was obtained on a 3-T magnet. Standard sequences obtained were axial proton-density (PD) fat saturation, coronal T1 and T2, and sagittal T1 and T2. A contained grade II–III cartilage lesion is seen on the medial femoral condyle and measures approximately 13 × 14 mm (Fig. 4.18a–f). There is underlying subchondral edema without any cysts (Fig. 4.18b–e).

4.6.3 Arthroscopy

The patient failed to improve despite nonoperative treatment including extensive physical therapy and bracing. Diagnostic arthroscopy was discussed for planning for staged cartilage restoration procedure. Risks and benefits were reviewed. He elected to proceed.

Examination under anesthesia was normal. Arthroscopic pictures are shown in Fig. 4.19a–c. A standard diagnostic

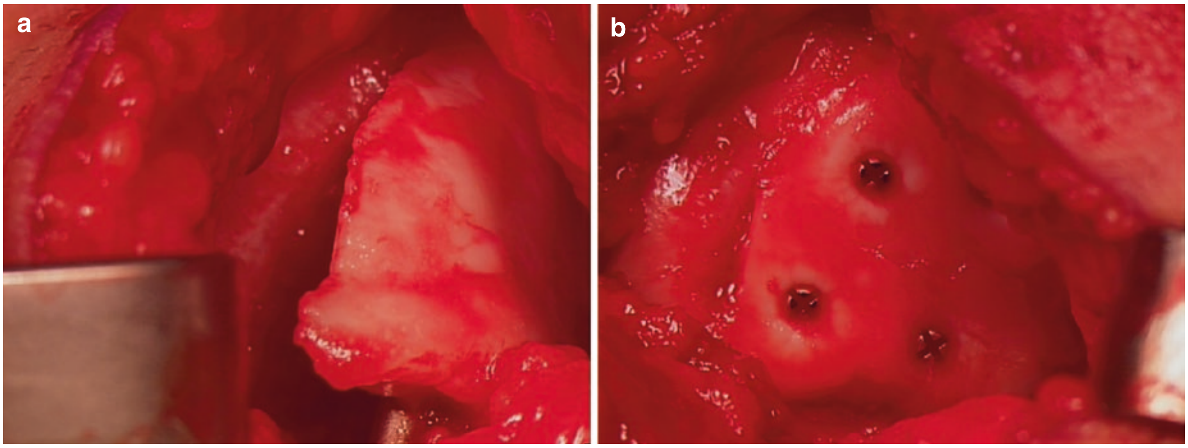

Fig. 4.17 (**a**, **b**) A medial parapatellar arthrotomy was made to expose the lesion. The bone bed was prepared and the lesion was fixed with three 2.0 mm screws

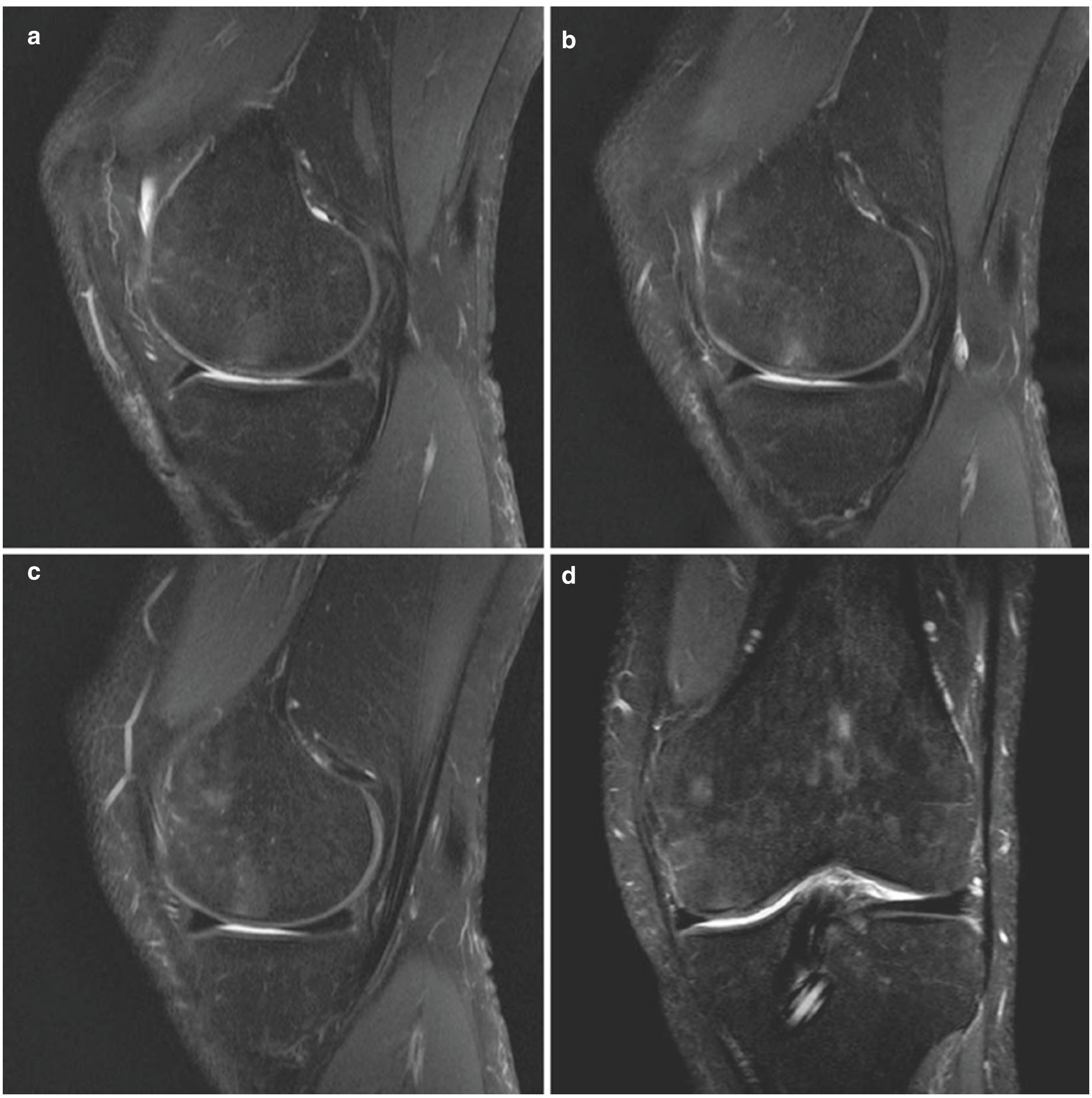

Fig. 4.18 (**a**–**f**) Select sagittal and coronal images from a 3-T MRI without contrast of the right knee. A contained grade II–III cartilage lesion is seen on the medial femoral condyle and measures approximately 13 × 14 mm. There is underlying subchondral edema without any cysts or deficient bone

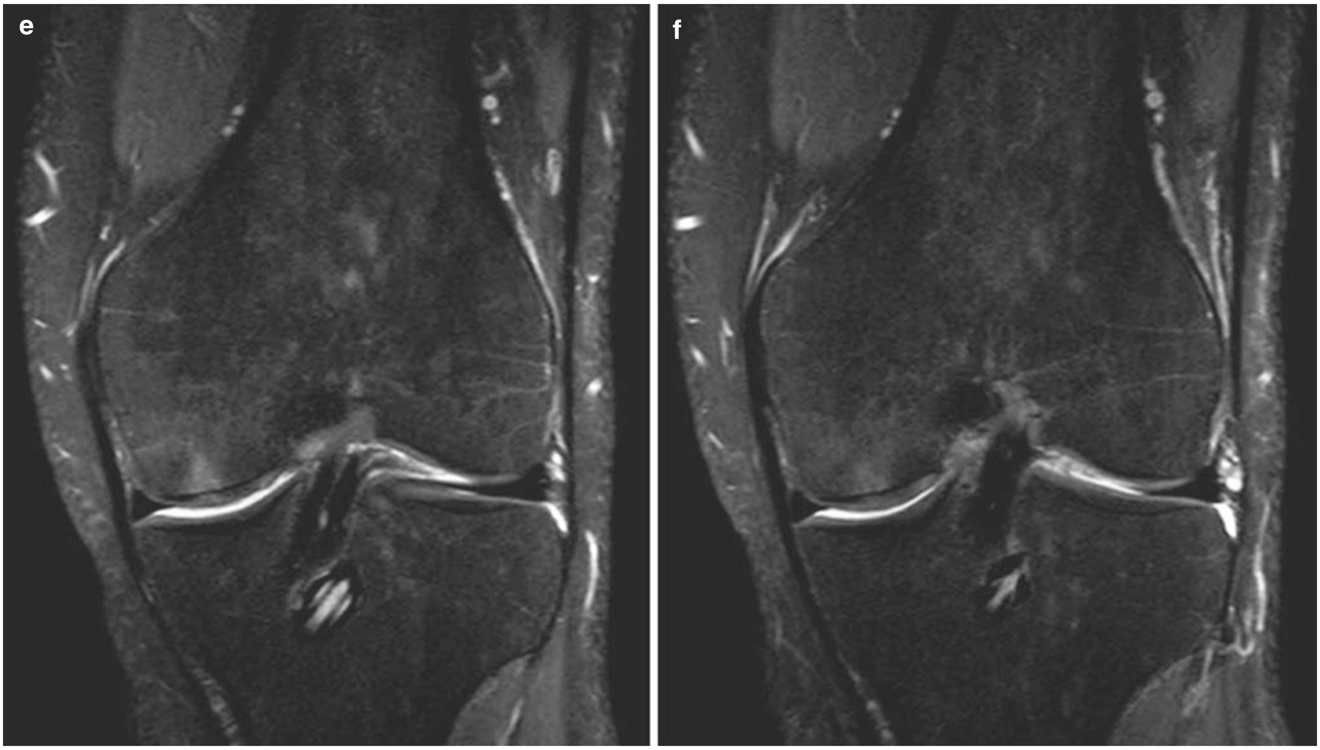

Fig. 4.18 (continued)

arthroscopy revealed an intact ACL and normal lateral compartment and patellofemoral compartment. Evaluation of the medial compartment revealed a normal meniscus and an 18 × 18 mm round high-grade cartilage defect in the central weight-bearing portion of his medial femoral condyle. This was probed, and there was fibrocartilage in the base but was soft, and subchondral bone could be probed through multiple fissures. His tibial cartilage was normal.

Given the size of the lesion, normal surrounding cartilage, normal menisci, and that he failed to improve after chondroplasty, further cartilage restorative procedures were discussed. He elected to proceed with an osteochondral allograft to the medial femoral condyle and underwent osteochondral allograft to the medial femoral condyle 4 months later (Fig. 4.20a–c).

4.6.4 Discussion

This patient's findings on magnetic resonance imaging on a 3-T magnet were subtle other than the subchondral edema seen in the medial femoral condyle. However, this was nearly a 4 cm^2 lesion that had filled with fibrocartilage and had multiple fissures to subchondral bone. Diagnostic arthroscopy proved to be very helpful in this case to better understand the extent of this lesion. He responded well to an osteochondral allograft to the medial femoral condyle and had significant improvement in his medial knee pain. A high tibial osteotomy was not indicated based on his alignment.

4.7 Case 6: Grade IV Femoral Condyle Lesion with Deficient Bone Treated with Osteochondral Allograft

4.7.1 History/Physical

A 20-year-old male university club soccer player presented for evaluation of acute lateral knee pain and swelling that happened while playing soccer. He denies any trauma. He is unable to fully extend his knee and unable to bear weight secondary to pain. He did report some previous mild lateral knee pain but has always been able to play through the discomfort. He denies history of swelling or mechanical symptoms.

On physical exam he had a moderate effusion and lacks 15° of extension. He had tenderness along the lateral joint line but none medially. Ligamentous exam was stable. He demonstrated significant pain with attempted weight bearing. He has neutral appearing alignment.

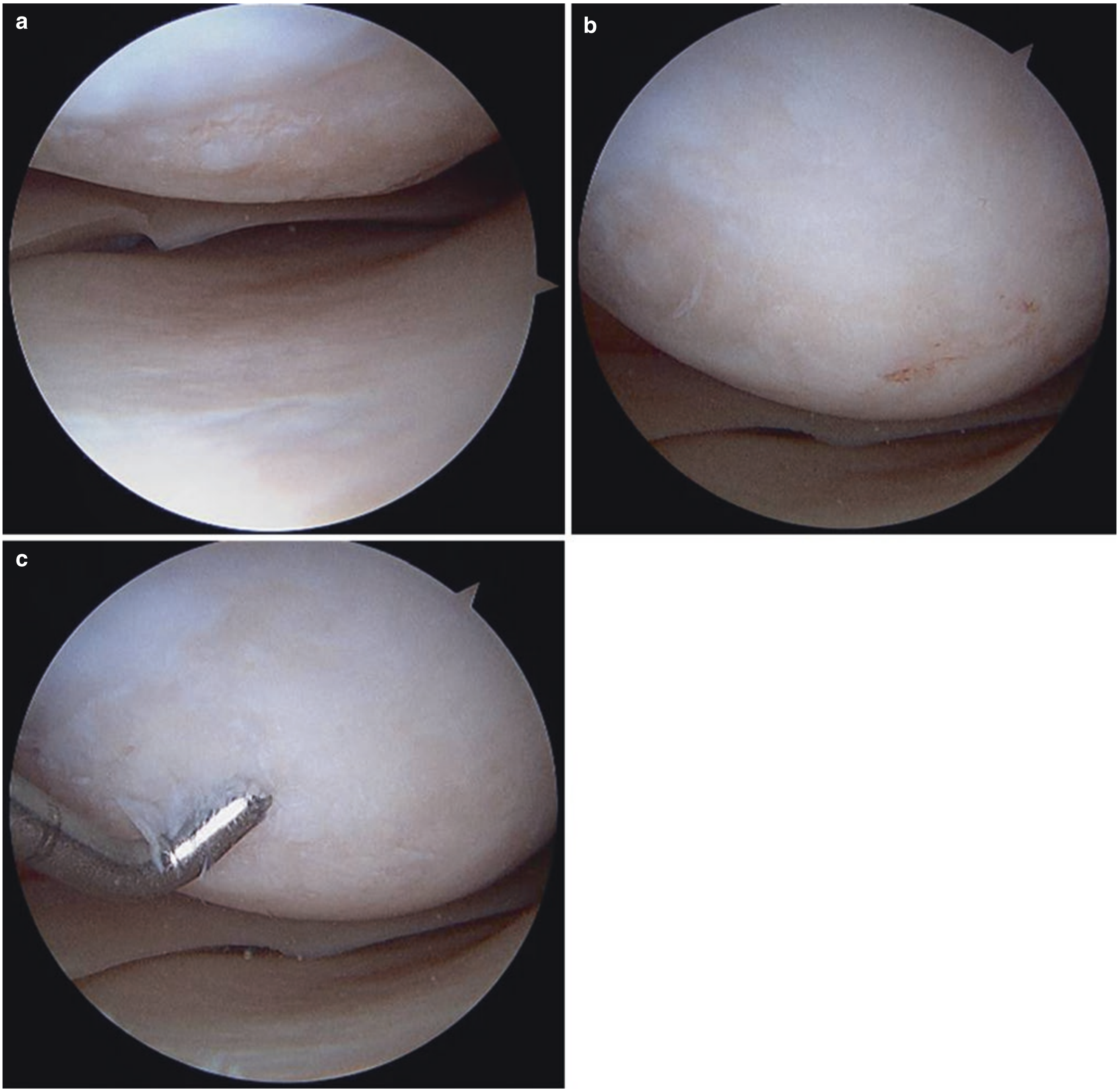

Fig. 4.19 (**a**–**c**) Arthroscopic images of the medial compartment show an 18 × 18 mm round lesion in the central weight-bearing portion of his medial femoral condyle filled in with fibrocartilage. The subchondral bone could be probed through multiple fissures. His tibial cartilage was normal

4.7.2 Imaging

Plane films of the knee showed a well-delineated focal defect in the center of the lateral femoral condyle with irregularity and deficiency of the subchondral bone. Given his symptoms and radiographic findings, an MRI of the knee was ordered to further evaluate the extent of the lesion.

MRI without contrast of the right knee was obtained on a 3-T magnet. Sequences obtained were axial proton-density (PD) fat saturation, coronal T1 and T2, and sagittal T1 and T2. A large grade IV osteochondral defect with deficient subchondral bone is seen on the lateral femoral condyle (Fig. 4.21a, b). The lesion is large but is contained. There is underlying edema within the bone and cystic changes. These findings are appreciated on both the coronal and sagittal T2 sequences seen in Fig. 4.21a, b. The cruciate and collateral ligaments are intact. Medial and lateral menisci are normal appearing. Cartilage in the medial and patellofemoral compartments is unremarkable.

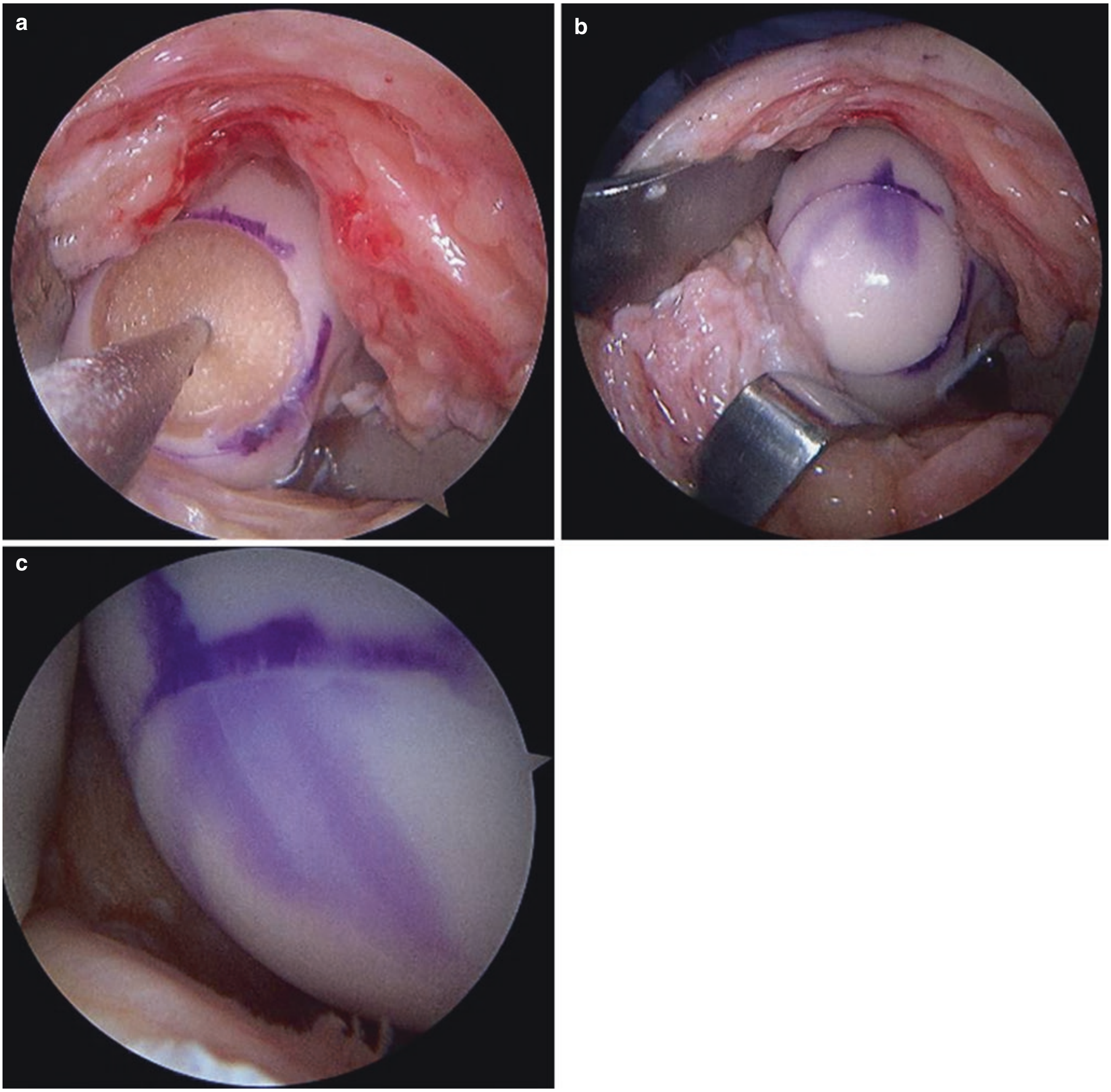

Fig. 4.20 Open (**a**, **b**) and arthroscopic (**c**) images at the time of osteochondral allografting of the lesion on the femoral condyle. The recipient socket is shown (**a**). (**b**) and (**c**) show the osteochondral plug after implantation

4.7.3 Arthroscopy

Given the patient's symptoms and imaging findings, the decision was made to proceed with diagnostic arthroscopy, debridement, and removal of loose bodies. It was planned that he would undergo subsequent osteochondral allograft at a later date. He underwent sizing radiographs and was placed on a list for a lateral femoral condyle osteochondral allograft.

Diagnostic arthroscopy revealed normal medial and patellofemoral compartments. Evaluation of the lateral compartment revealed a focal osteochondral defect of the femoral condyle with deficient subchondral bone (Fig. 4.22a–c). Surrounding cartilage was normal and cartilage on the tibial plateau was normal. There was some fraying of the lateral meniscus. Multiple osteochondral loose bodies were encountered and removed. He underwent debridement of some fraying of the body of the lateral meniscus. Postoperatively, he was placed in a lateral compartment unloader brace, while he awaited an osteochondral allograft. The patient returned to the operating room 5 months later and underwent osteochondral allograft to the lateral femoral condyle (Fig. 4.23a, b).

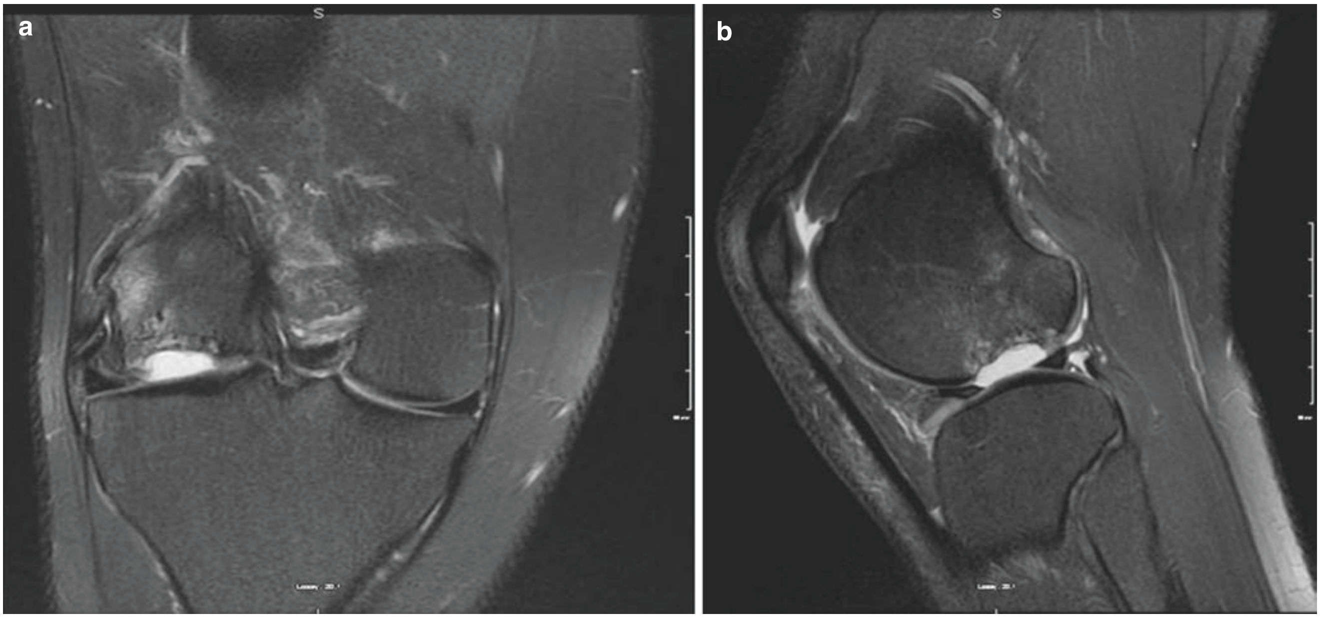

Fig. 4.21 Select coronal (**a**) and sagittal (**b**) 3-T MRI images show a large grade IV osteochondral defect with deficient subchondral bone which is seen on the lateral femoral condyle. The lesion is large but is contained. There is underlying edema within the bone and cystic changes

4.7.4 Discussion

This patient's MRI findings correlated well with his findings at arthroscopy. The MRI showed a contained full-thickness cartilage defect with deficient subchondral bone in the medial femoral condyle. Given the size of the lesion and deficient subchondral bone, it was felt that an osteochondral allograft was most appropriate. Close evaluation of his standing radiographs revealed neutral alignment, so an offloading procedure (i.e., osteotomy) was not indicated. Similarly, while the patient underwent debridement of some fraying of the body of the lateral meniscus, but was not meniscus deficient, meniscus transplant was not indicated.

4.8 Case 7: Grade IV Medial Femoral Condylar Defect Treated with Matrix Autologous Chondrocyte Implantation®

4.8.1 History/Exam

A 30-year-old female sustained an anterior cruciate ligament (ACL) rupture, medial meniscal tear, and full-thickness cartilage after jumping down off the bed of a truck. She had a distant history of ipsilateral knee injury but did not seek care for it at that time due to lack of insurance. She presented with acute pain, effusion, and loss of range of motion. She endorsed mechanical catching with associated pain at the medial joint line.

On initial examination she had a moderate effusion, with extension equal to her contralateral uninjured knee, but lacked 10 degrees of full flexion. She had a positive McMurray test, along with medial joint line tenderness. She displayed a grade II pivot shift [8, 9] and a IIB Lachman, but maintained stability in the coronal plane. She had no neurovascular deficits.

4.8.2 Imaging

Plain radiographs revealed no loose bodies or fractures, and her alignment on longstanding films was neutral.

The sequence of images obtained included axial proton-density (PD) fat saturation, coronal T1 and T2, and sagittal T1 and T2. These images were obtained on a 1.5-T magnet. Select coronal PD and sagittal T2 sequence images are shown in Figs. 4.24a, b and 4.25a–c. The MRI demonstrates full-thickness chondral loss extending from midcoronal condyle extending past the posterior meniscal body. There is *no* underlying cystic changes nor bony edema. The size of the lesion measures approximately 1.2 × 1.7 cm. The lesion appears well contained. Note on image on image 4.25b there is a complete ACL tear with no associated bony bruising and on 4.26c there is a "double PCL sign" indicating a bucket-handle medial meniscus tear.

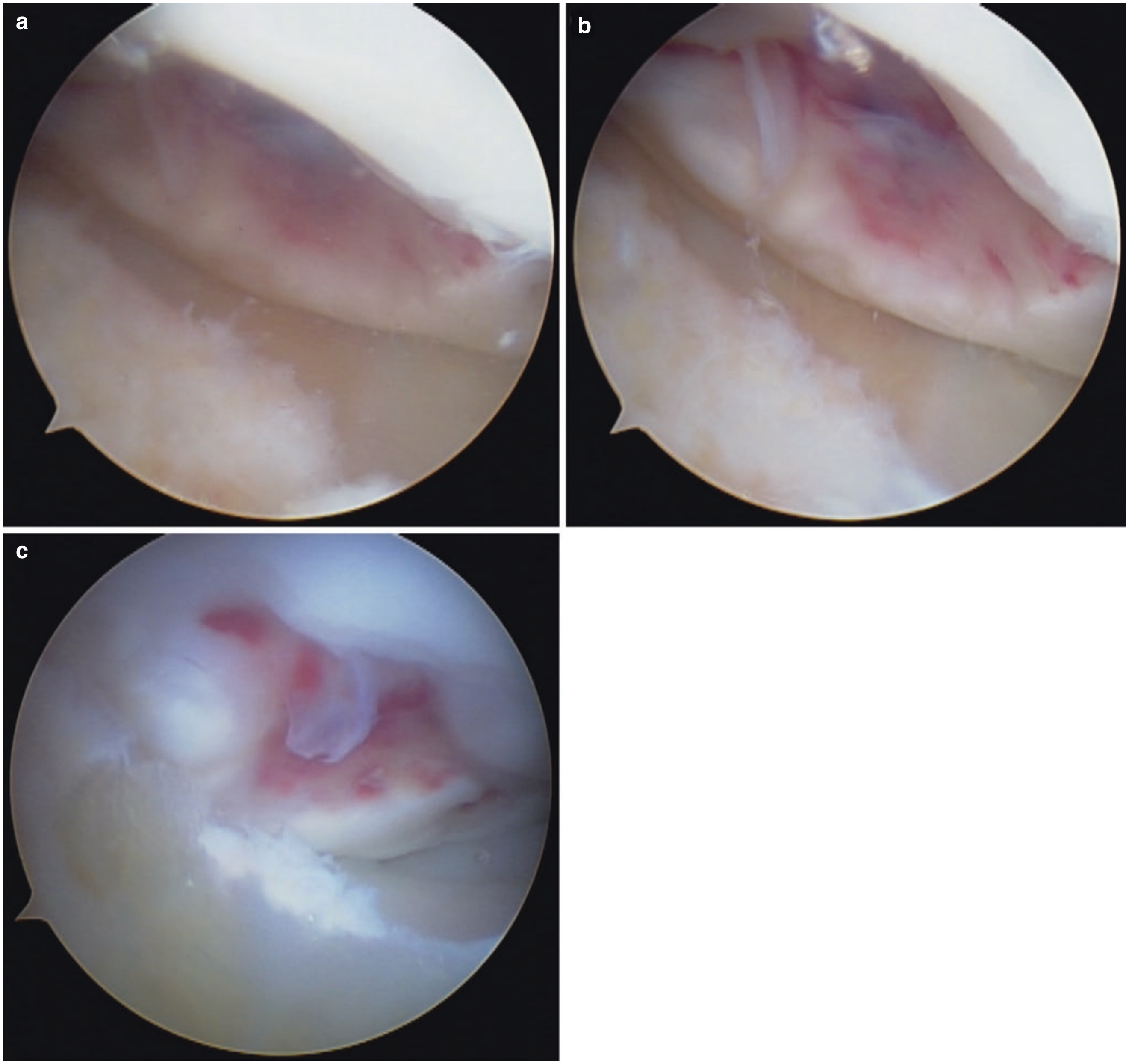

Fig. 4.22 (**a**–**c**) Arthroscopic images of the lateral compartment show a focal osteochondral defect of the femoral condyle with deficient subchondral bone. Surrounding cartilage is normal and cartilage on the tibial plateau is normal. There is some fraying of the body of the lateral meniscus

4.8.3 Arthroscopy

Given the cartilage defect, ACL rupture, and seen on MRI consistent with the patient's clinical examination, risks and benefits of operative intervention were discussed with the patient. Given the lack of bony edema, and contained cartilage defect, the recommendation was diagnostic arthroscopy, ACL reconstruction with autograft (quadriceps tendon with a bone block in this case, per patient preference), debridement, and medial meniscal repair versus debridement. Additionally, cartilage biopsy was discussed to better understand the extent of the lesion for planning for potential staged cartilage restoration. In the interim between ACL reconstruction and cartilage implantation, the patient would remain in a hinged knee brace and would perform rehabilitation via the MOON protocol [10]. Risks and benefits were reviewed. She elected to proceed.

Diagnostic arthroscopy showed a ruptured ACL, chronic appearing medial meniscus tear that was not amenable to repair but constituted <15% of the total volume of the meniscus and no cartilage wear in the medial tibia. She had a grade IV lesion noted on the medial femoral condyle

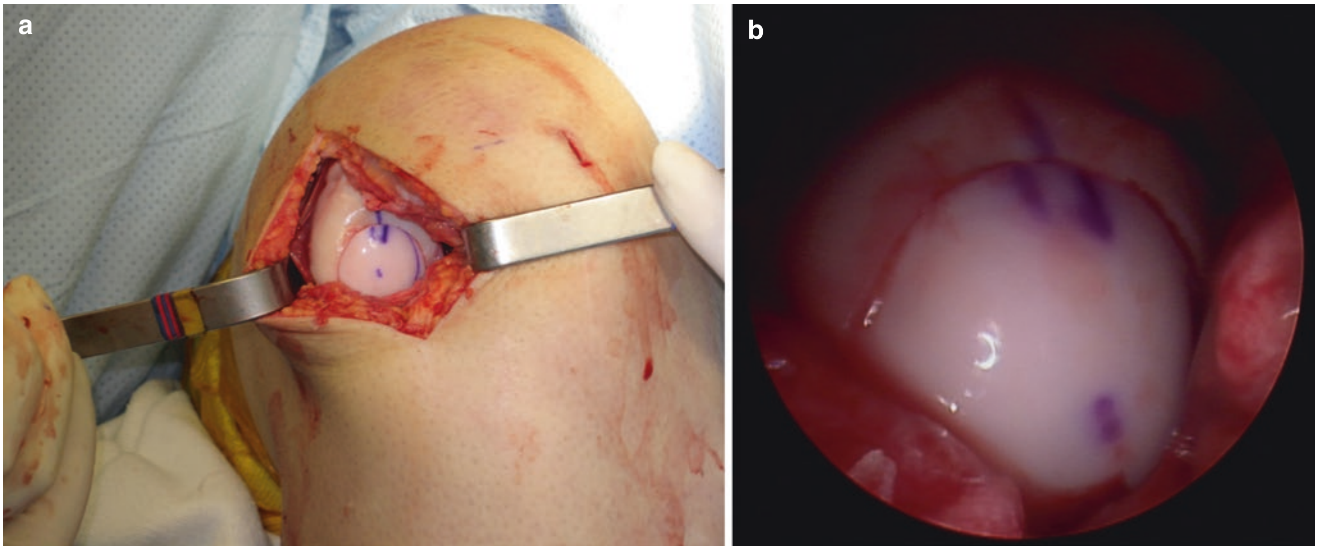

Fig. 4.23 (**a**, **b**) Open pictures at the time of osteochondral allografting through a lateral parapatellar arthrotomy demonstrating the allograft in place in the lateral femoral condyle

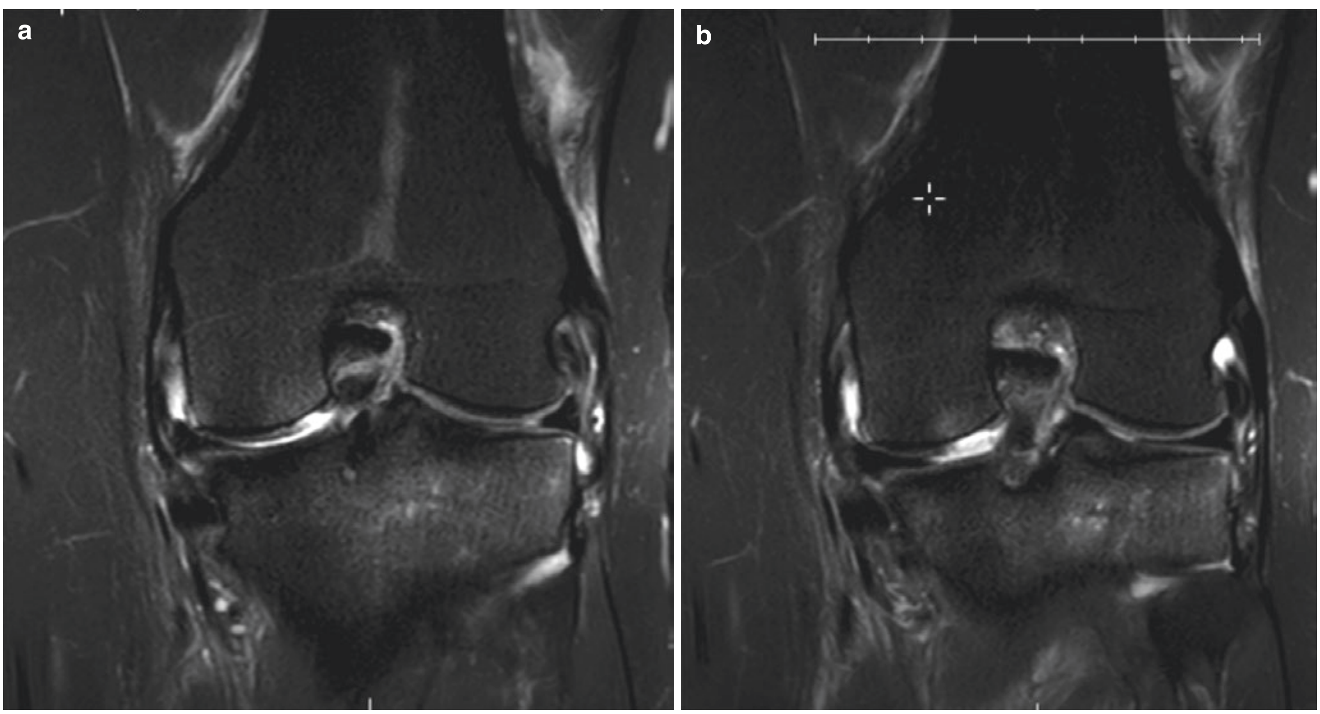

Fig. 4.24 (**a**, **b**) Coronal T2 PD images reveal a full-thickness chondral defect about the medial femoral condyle measuring 1.2 cm in width

(Fig. 4.26a–d). The unstable edges of the lesion were debrided to a stable rim and measured to be 25 × 10 mm (Fig. 4.26c). Calcified cartilage layer debridement and microdrilling were performed on the lesion (Fig. 4.26d). The remainder of the knee showed no cartilage loss. During her initial ACL reconstruction and medial meniscal debridement, "tic-tac"-sized cartilage biopsies were obtained from the notch for staged matrix autologous chondrocyte implantation (MACI®) procedure.

The patient was progressing well with her physical therapy, and regained full strength and range of motion by 6 months post ACL reconstruction, but continued to have medial sided knee pain weight-bearing flexion. She returned to the operating room at 6.5 months after her ACL reconstruction and underwent matrix autologous chondrocyte implantation (MACI ®). Figure 4.27a, b shows the lesion before and after MACI ®. A small medial arthrotomy was made and the lesion was directly identified. The edges of the

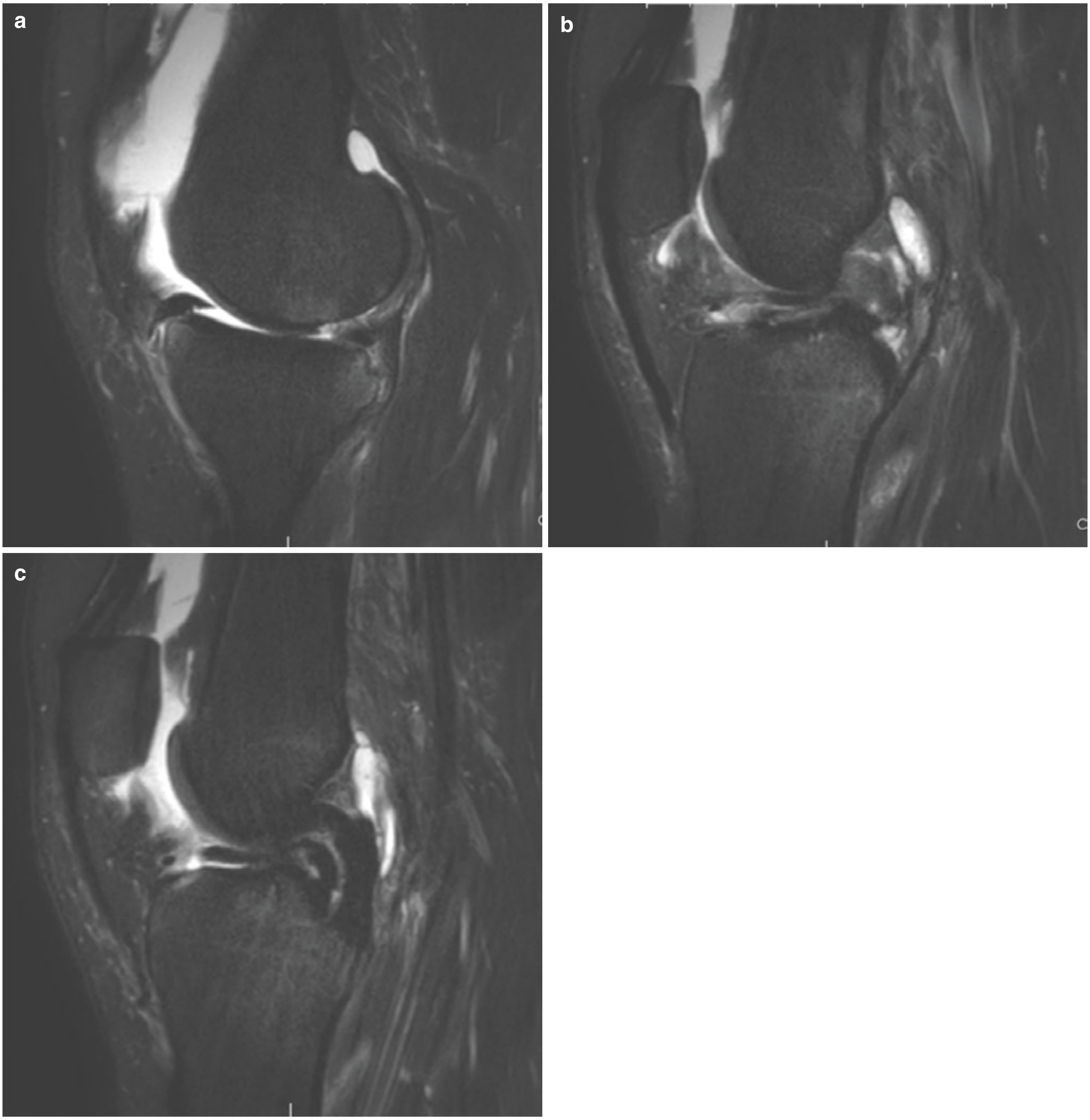

Fig. 4.25 (**a**–**c**) Sagittal T2 images from 1.5-T magnet show full-thickness chondral loss. Medial femoral condyle extending posteriorly past the meniscal body. A chronic appearing full-thickness ACL rupture is noted (**b**), as is a "double PCL sign" (**c**)

defect were easily identifiable and debrided to stable edges. The defect measured 15 × 23 mm. Fibrin glue was applied, and the MACI ® graft was implanted, followed by another layer of fibrin glue.

Postoperatively the patient underwent the MACI protocol, which progresses weight bearing and range of motion weekly [11].

4.8.4 Discussion

This patient had a complex injury and continued to have medial sided pain that recalcitrant to therapy that directly correlated to her medial femoral condyle cartilage defect. On repeat examination, the patient had filled in her cartilage defect with extensive fibrocartilage, but given her

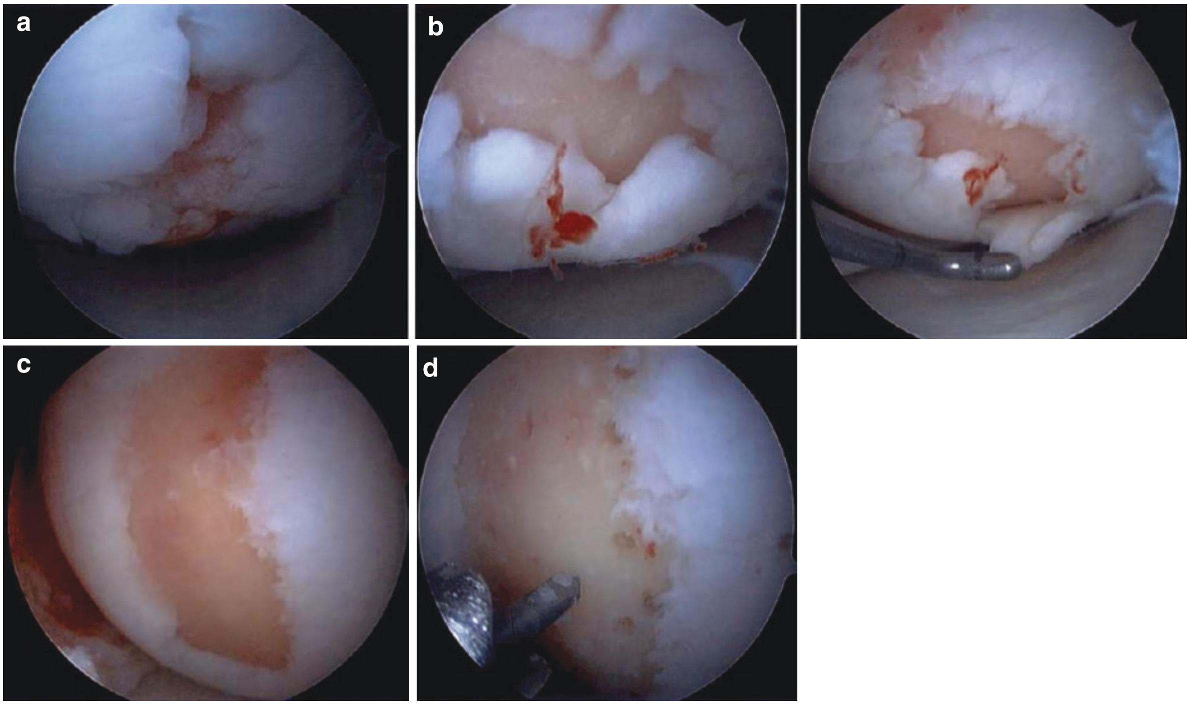

Fig. 4.26 (**a**–**d**) Arthroscopic images with a 30° arthroscopic camera from an anterolateral portal show a grade IV lesion extending along the medial femoral condyle. The lesion was debrided to stable edges and micro-drilling was performed

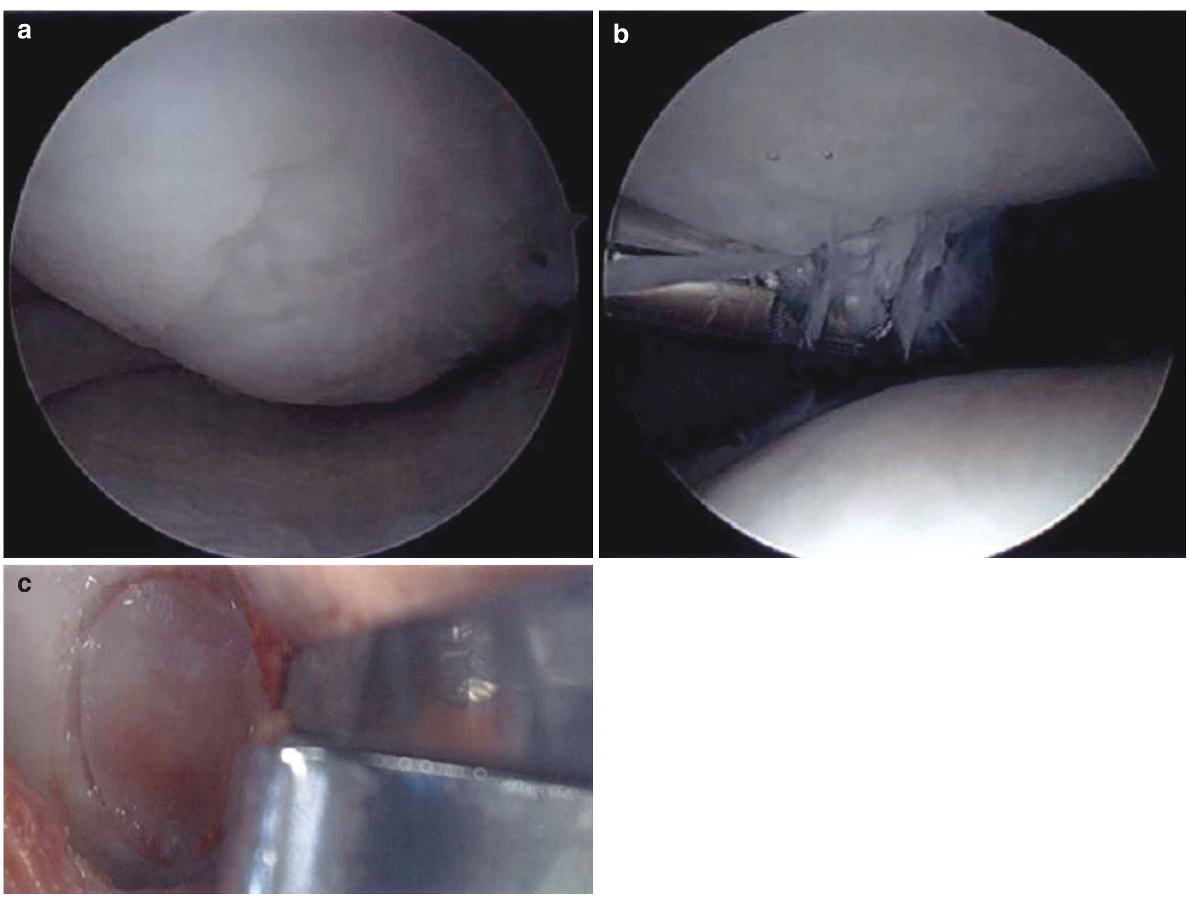

Fig. 4.27 (**a**–**c**) Arthroscopic photos of the medial femoral condyle via a 30° lens from the anterolateral portal pictures at the time of matrix autologous chondrocyte implantation (MACI®). The prior lesion was well filled with fibrocartilage; lesion was debrided to stable margins and through the calcified cartilage layer (**b**). Fibrin glue was applied following the MACI ® graft (**c**)

continued pain and a large cartilage defect in the context of no bony edema, a MACI ® was an acceptable cartilage restoration procedure. Five-year outcomes have shown consistent improvement in pain, function scores, and radiographic imaging with MACI® in the tibio-femoral compartments [12, 13].

While initial management using marrow stimulation techniques are often adequate for lesions <2 cm^2, continued pain and/or mechanical symptoms should warrant further workup. A recent review comparing microfracture, ACI, and MACI® revealed that improved outcomes were seen in both with a similar failure rate at an average of 7 years [14]. MACI ® biopsies are typically held for 5 years after initial biopsy, and surgeons can consider implantation as a viable option. There is currently little data guiding recommendations for whom to biopsy at the initial identification of a cartilage lesion.

From a technical perspective, lesions that extend past the posterior meniscal body on sagittal MRI should be approached with caution. These lesions often require positioning of the knee in deep flexion to appropriately examine and stabilize the posterior rim of cartilage. These lesions, especially when on the lateral femoral condyle, may require a larger arthrotomy to help with mobility of the patella for access and may require complete paralysis for appropriate exposure.

4.9 Conclusions

Cartilage injuries to the knee are well-established causes of pain, effusions, and mechanical symptoms. Diagnosing cartilage lesions within the knee can be difficult on physical exam due to ligamentous and meniscal injuries present in a similar manner. Establishing a correct diagnosis is based on a careful history, physical exam, and appropriate imaging. The imaging modality of choice for properly diagnosing cartilage lesions is magnetic residence imaging (MRI), but full-length alignment films are critical in determining the weight-bearing axis of the limb. Responsive cartilage lesions and unstable OCD lesions are best addressed with surgical intervention. The correct procedure is determined by patient age, weight, limb alignment, ligamentous and meniscal integrity, relative size of the lesion, and involvement of the underlying bone. Surgical options vary from simple debridement, microfracture, osteochondral autograft transplantation (OATS)/mosaicplasty, allograft transplantation, cartilage restoration with ACI- or DeNovo-type procedures, or internal fixation.

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