18 Management of Lateral Meniscus Deficiency in Revision ACL Reconstruction

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Introduction

Menisci in the tibiofemoral joint are essential, providing pivotal roles in knee stability and joint health including load transmission, stabilization, shock absorption, joint lubrication, and articular cartilage nutrition [1–3]. The two tibiofemoral menisci are biomechanically and anatomically unique with specific functions. While the medial tibial plateau is concave, the lateral tibial plateau is convex with the meniscus covering 80–85% of the surface and bearing up to 70% of the compartment axial load [1, 4, 5]. Complete meniscal deficiency in the form of total meniscectomy significantly decreases tibiofemoral contact area leading to 2–3× the contact force transmitted [4, 6]. The femur is also convex, creating complex kinematics and driving the unique "posterior roll-back" motion on the lateral side [7] (Fig. 18.1). These dynamic biomechanics lead to greater risk of chondral degeneration and collapse with earlier clinical symptoms when compared to medial compartment [8]. Therefore, lateral meniscus tears should be repaired when indicated, especially in young athletic patients. Lateral meniscus deficiency is often poorly tolerated with a higher prevalence of post-meniscectomy syndrome.

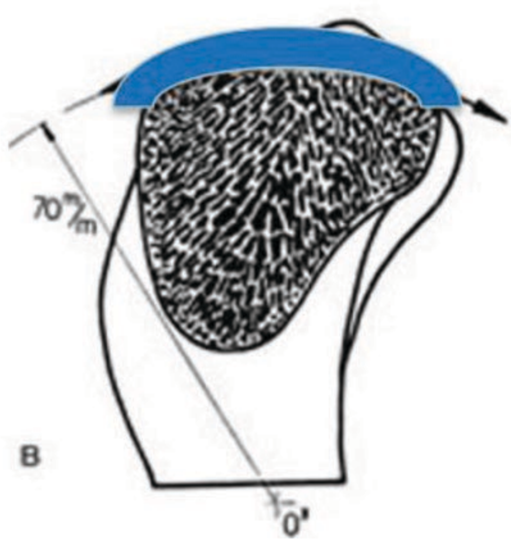

Fig. 18.1 The lateral tibial plateau is convex with the meniscus covering 80–85% of the surface and bearing up to 70% of the lateral compartment axial load

It is well known that the medial meniscus has a role in stability of the knee and acts as a secondary stabilizer to anterior-posterior displacement [9]. However, while previously believed to provide no secondary restraint, the lateral meniscus has recently been found to play a crucial role in the axial and rotatory stability of the knee [8, 10, 11]. It has been demonstrated that patients who

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have undergone lateral meniscectomy experience decreased rotatory stability along with increased functional deterioration [12–14]. Lateral meniscal injuries including tears and posterior root avulsions are a common associated injury with anterior cruciate ligament (ACL) tears, occurring in up to 12–14% of cases [15–21]. This combined injury is more common with acute ACL tears and in active males who sustain a contact injury [11, 21, 22].

Although the meniscus should be preserved and repaired whenever possible, functional or subtotal meniscectomy is sometimes unavoidable. While providing symptomatic relief, lateral meniscal deficiency places the knee at greater risk for post-operative instability and is a significant risk factor for graft failure in ACL reconstruction [23–26]. Parkinson et al. reported meniscal deficiency as the most significant risk factor associated with graft failure after ACL reconstruction [24]. Robb et al. demonstrated similar results in 123 primary ACL reconstructions, reporting a 3.5 times increased risk of ACL graft failure in the presence of lateral meniscal deficiency [25]. In the setting of ACL reconstruction, meniscectomy (medial or lateral) is also associated with lower subjective outcome scores, significant activity limitations, and progressive radiographic abnormalities [26, 27]. Lateral meniscus deficiency contributes to the accelerated deterioration of the lateral compartment chondral surfaces, particularly in patients with valgus malalignment and/or ACL deficiency [8].

MAT has been demonstrated to be one of the few treatment options for meniscal deficient knees in young patients. There have been considerable advancements since the first meniscal transplantation in 1984 [28], with expansion of evidence-based indications and techniques contributing to improved long-term outcomes. The fundamental goal of the MAT procedure is to attempt to re-establish the biomechanical properties of the native meniscus in an attempt to reduce pain, restore knee function, improve patient quality of life, and possibly delay osteoarthritis [29–31].

Given the detrimental effect of lateral meniscal deficiency on knee stability, ACL reconstruction graft failure rates, patient-reported outcomes, and radiographic degeneration, we consider performing lateral meniscal allograft transplantation (MAT) (Fig. 18.2) in select patients with lateral meniscal deficiency undergoing revision ACL reconstruction [8, 29–31]. Patient education is critical to successful revision surgery. Careful preoperative planning, meticulous surgical technique, and a stepwise and progressive rehabilitation plan are required to increase the chance of a successful outcome.

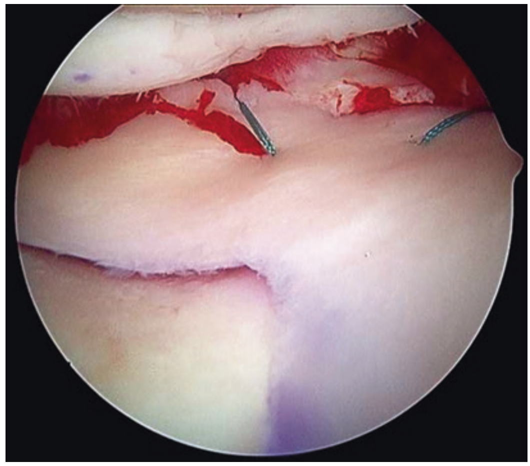

Fig. 18.2 Intraoperative photograph depicting a lateral meniscus allograft transplant (MAT)

Revision ACL Reconstruction: Preoperative Workup

The surgeon must perform a thorough and comprehensive evaluation including history, physical examination, and imaging studies. History should elucidate the reason for primary ACL graft failure. Lateral meniscus deficiency can be suspected from information found in previous operative report(s) or surgical pictures including prior meniscectomy or attempted lateral meniscus repair. This will be confirmed by imaging studies (i.e., MRI) and/or staging arthroscopy. Other causes of ACL failure must be systematically categorized (i.e., patient demographics, activity level, traumatic vs. insidious failure, suspicion for infection, prior graft choice, tunnel position, bony alignment, missed posterolateral or posteromedial corner injury). Localizing lateral pain, swelling, or mechanical symptoms may provide clues toward symptomatic lateral meniscal deficiency. Patient goals and expectations must be determined (i.e., occupation, recreation, level of competition).

Physical exam in patients with failed ACL and lateral meniscus deficiency may demonstrate an explosive grade III pivot shift. While the medial meniscus functions as a critical secondary stabilizer to anterior translation of the tibia during a Lachman maneuver, the lateral meniscus has been shown to be an important restraint to anterior tibial translation during combined valgus and rotatory loads applied during the pivot shift [8, 26, 32]. Multiple cadaveric studies have shown increased anterior tibial translation and tibial internal rotation with deficiency of the lateral meniscal root and meniscofemoral ligaments [33, 34]. Lateral joint line tenderness and effusion may also be present in patients with lateral meniscus deficiency and lateral chondral defects.

Standard imaging for revision ACL surgery includes comparison weightbearing AP, PA flexion, lateral, Merchant, mechanical axis radiographs as well as magnetic resonance imaging (MRI). Additionally, computed tomography (CT) imaging with 2D and 3D reconstructions allows the surgeon to precisely evaluate ACL tunnel position and tunnel widening and to measure tibial slope.

The above information is utilized to create a problem list for revision ACL surgery. If this list includes tunnel widening requiring bone grafting, malalignment requiring osteotomy, suspicion for meniscus deficiency, and/or focal chondral defect requiring cartilage restoration, a two-stage approach is reasonable. The first stage includes examination under anesthesia with direct comparison to the non-operative limb. Arthroscopy will confirm meniscus deficiency and will determine the exact size, depth, and location of any concomitant cartilage lesions. The surgeon may consider cartilage biopsy for future autologous-cultured chondrocytes (MACI®) or measure any defects for future osteochondral allograft. Unstable flaps of meniscus or cartilage are debrided, synovectomy performed, tunnels are inspected and bone grafted as needed, and realignment osteotomy performed if indicated. Second stage should include all definitive intra-articular procedures including revision ACL reconstruction, lateral meniscus transplantation, and cartilage restoration as indicated (Fig. 18.3).

Autograft ACL graft should be utilized when available. In 2014, a Multicenter ACL Revision Study (MARS) compared the outcomes of ACL graft choice at 2 years following revision ACL reconstruction [35]. This large cohort study demonstrated increased sports function and Patient Reported Outcomes (PRO) as well as decreased incidence of graft re-rupture when an autograft is

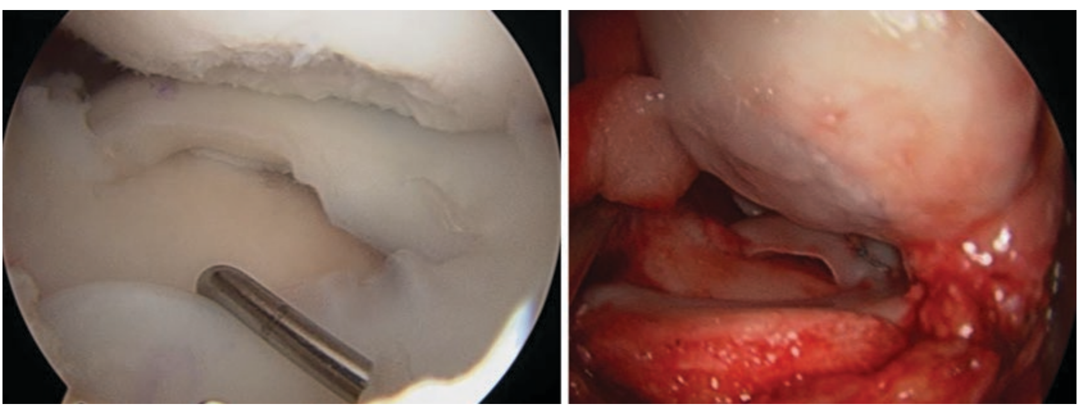

Fig. 18.3 Arthroscopic photograph of lateral MAT with concomitant cartilage repair procedure

utilized. Any osteotomy hardware may be removed at second stage if the bone has previously healed.

In the setting of a failed ACL reconstruction, indications for lateral MAT include painful effusions and/or functional instability (i.e., explosive pivot shift) associated with lateral meniscus deficiency. Patient alignment should be neutral or corrected to between the tibial spines. Tibial slope should be normal or corrected at the first stage. Chondral defects ICRS grade III-IV should be addressed concomitantly with MAT in the lateral compartment. Other secondary stabilizers should be addressed at the time of revision ACL reconstruction (i.e., posteromedial and posterolateral reconstruction). Standard contraindications for MAT should apply including elevated BMI, smokers, non-compliant patients, inflammatory disorders, and active infection. Care should be taken when considering concomitant MAT in contact/collision athletes. Alternative strategies for knee joint stabilization (i.e., lateral tenodesis and osteotomy) may be better suited to this very challenging high-demand population. Prolonged conservative rehabilitation and risk of graft breakdown with high-impact load limit the utility of MAT in this specific population [36].

MAT Sizing

Proper preoperative sizing of the allograft is an important aspect of meniscal transplantation. Inadequate sizing of the graft can lead to improper biomechanics, meniscus extrusion, and transplant failure requiring additional surgical procedures [37]. Graft size should be within 10% of the native meniscus [22]. Oversized grafts result in increased risk of graft extrusion, which can cause increased compressive forces across the articular cartilage and ultimately graft failure [23]. However, an undersized allograft experiences increased biomechanical load across the graft, which can result in graft disruption [37, 38]. Therefore, correct preoperative measurements along with the availability of a reliable tissue bank is necessary.

Several different methods have been recommended for meniscus sizing by utilizing radiographs, computed tomography (CT), magnetic resonance imaging (MRI), and arthropometric data [38]. The Yoon equation for length and arthropometric method for width are often preferred when planning for preoperative lateral MAT procedure. It is important to consider that the mediolateral sizing is more important than anteroposterior sizing [39]. Lee and colleagues recommend that when both dimensions cannot be matched, the graft size should be determined by the width [40]. Obtaining an MRI of the contralateral knee may be beneficial [41]; however, this should be used for select cases only. Shaffer et al. reported data that suggests that compared to radiographs, the use of MRI is only moderately more accurate in determining the correct size of the meniscus [42]. Additionally, MRI has the associated burden of increased cost [26].

Surgical Technique for Revision ACL Reconstruction and Lateral MAT

For revision ACL and lateral MAT, order of operations should be systematic and stepwise. Patient is taken to the operating room after regional anesthesia is administered in the holding area. In general, a motor-sparing adductor canal catheter are utilized but a femoral block may be considered. Following induction of general anesthesia, an examination under anesthesia is performed for both limbs. Comparison of joint ROM (i.e., hyperlaxity), as well as ligamentous laxity (Lachman, pivot shift), should be performed. Note that stress fluoroscopy to rule out posteromedial/posterolateral injuries is performed as indicated during the initial staging arthroscopy in the majority of these cases. Tourniquet is placed but not inflated. We typically begin with ipsilateral ACL graft harvest. In most revision cases, quadriceps autograft is harvested without bone and prepared as an all-inside construct using suspensory cortical fixation. Graft has a diameter of 9–10 mm and a length of 70 mm. The extensor is meticulously repaired. A damp sponge is placed in this small wound which is closed toward the end of the case. The graft is prepared and pretensioned on the back table.

Standard arthroscopy is performed. Synovectomy and scar lysis of adhesion are performed as indicated. ACL tunnels have been previously evaluated, debrided, and/or bone grafted. The lateral meniscus is prepared to leave a 2–3 mm rim of healthy tissue. A shaver and/or biter are utilized for this step. The meniscal rasp is used to create bleeding rim and fresh synovium/capsule.

The lateral meniscus is oval shaped, vertically oriented in the axial plane with less distance between the anterior and posterior roots than on the medial side of the joint (Fig. 18.4). For this reason, lateral MAT has classically been performed with bone bridge techniques [43–45]. Advantages include strong time-zero root fixation and maintained relationship between the anterior and posterior horns attached to the same bone block. There are limitations including technical difficulty flipping the meniscus into the joint, loss of bone stock, inability to handle graft mismatch, among others. Classic bone plug technique has advantages including easier passage into the joint, ability to accommodate for graft mismatch, and no associated risk of any ACL disruption and tissue loss for either medial or lateral MAT (Fig. 18.5) [11, 15, 21]. Known disadvantages include challenges seating an 8–10 mm deep plug into the tibial sockets and lower time-zero root fixation strength. There is also concern regarding tunnel convergence laterally with standard drilling techniques, given the close proximity of the roots. Soft tissue–only MAT is technically easiest and often performed around the globe. Concerns include decreased root fixation strength with classic suturing techniques and the increased risk of MAT extrusion when compared to bony techniques.

We have developed a hybrid technique that harnesses the advantages of all techniques (soft tissue, bone plug, and bone-bridge MAT) while limiting several of the disadvantages. Our techniques described fulfills several important criteria: (1) anatomic footprint restoration, (2) minimally invasive (all-arthroscopic), (3) technically straightforward passing the MAT into the joint (4), strong time-zero fixation allowing for early ROM, (5) ability to handle graft mismatch in real time, (6) attempt to handle extrusion with capsular fixation to the tibia (capsulodesis), and (7) maintenance of bone stock in the event a revision is required in the future.

The lateral MAT is prepared on the back table. Each lateral root has small bone plugs of 9 mm width and 3 mm depth. The posterior bone plug and adjacent root soft tissue are prepared similar

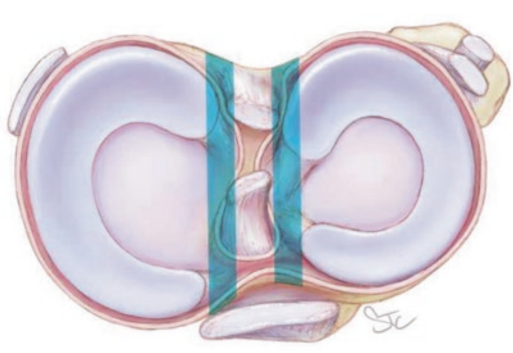

Fig. 18.4 Axial view illustration depicting medial and lateral meniscus anatomy and lines depicting the location for meniscal transplant trough placement both medially and laterally in relation to the cruciate ligaments

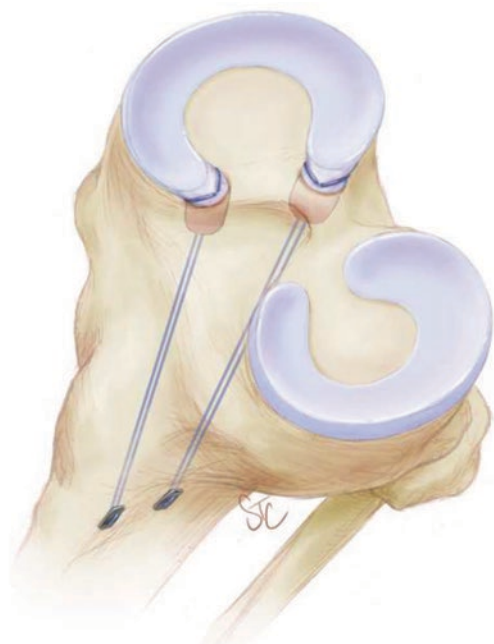

Fig. 18.5 Illustration depicting the bone plug meniscus allograft transplant (MAT) technique

to a QuadLink® Tightrope ABS suspensory fixation (Arthrex, Naples, Florida). This will allow modulation of the posterior root depth to accommodate either graft mismatch or time-zero graft extrusion during the case. The anterior root is prepared with FiberLoop suture tape (Arthrex, Naples, Florida) that is whip-stitched to include both soft tissue and bone. A labral tape is placed in horizontal mattress fashion at the junction of the mid-meniscus with the posterior horn of the MAT. This can be utilized as a shuttle stitch to deliver the MAT into the joint. The femoral surface of the MAT is marked with an "A" for anterior and "P" for posterior for orientation purposes.

In the Fig. 18.4 position, a retrocutter is utilized through the medial portal directed at the posterior root insertion of the lateral meniscus (Fig. 18.6). Incision is made longitudinal on the tibial cortex midway between anterior crest and posterior border. This incision can be utilized for ACL and lateral MAT cortical fixation. A 9 mm wide by 10 mm deep socket is reamed and a shuttle suture is passed and retrieved out the lateral portal. The socket is reamed deeper than the size of the posterior root bone plug (9 mm × 3 mm) to accommodate for any graft mismatch. The femoral ACL tunnel is then reamed in standard fashion and shuttle suture retrieved out the lateral portal.

The tibial ACL socket is reamed and shuttle retrieved medially. Finally, a retrocutter is utilized through medial portal (visualizing high and lateral) to create the anatomic socket for the anterior root of the lateral meniscus. The ACL tibial socket is typically more vertical and exits the tibia just medial to the tibial tubercle. The lateral MAT socket is adjacent but not overlapping the ACL footprint and reamed to a 3–5 mm depth. The shuttle suture exits the tibial cortex posterior and medial in relation to the ACL socket.

The lateral meniscus is more mobile than the medial meniscus, with no additional attachments to the LCL or the popliteal hiatus. There is concern regarding limiting lateral MAT mobility if meniscotibial fixation is performed. However, there is also concern regarding lateral MAT extrusion if there is weak capsule or minimal native remnant for fixation. For these reasons, we utilize a lateral capsulodesis to try and reduce the risk of lateral MAT extrusion but minimize overconstraint [46, 47]. A spinal needle is utilized to pierce the lateral capsule just above the meniscus remnant at the junction of the mid-meniscus with the anterior and posterior horns respectively (Fig. 18.7). Two pairs of horizontal mattress labral tape sutures are shuttled into the capsule using the spinal needles and a plastic cannula in the lateral portal. These sutures are anchored

Fig. 18.6 Arthroscopic photograph of the retrocutter positioned on the posterior root of the lateral meniscus

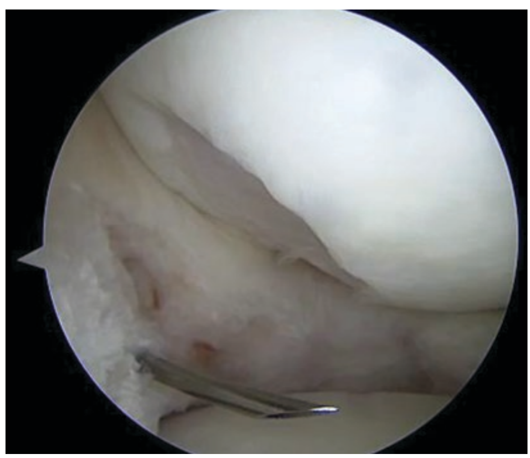

Fig. 18.7 Spinal needle at the lateral capsule. Surgeon should place the needle above the meniscus remnant at the junction of the mid-meniscus with the anterior and posterior horns to complete the lateral capsulodesis

(Pushlock Anchors® Arthrex, Naples, Florida) to the lateral tibia just below the meniscus remnant through small central open lateral incision. This brings the capsule to the tibia prior to shuttling the MAT into the joint. An inside-out device is utilized to pass a shuttle stitch at the junction of the native mid-meniscus with the posterior horn. This is retrieved out the lateral portal.

After a cannula is placed, the sutures for the anterior and posterior root sockets and posterolateral shuttle stitch are retrieved. The cannula is then removed. The posterior root and posterolateral shuttle stitch are utilized to shuttle the respective aspects of the lateral MAT into the joint through lateral portal under direct arthroscopic visualization. The anterior horn/root is then shuttled into the anterior socket. The attachable button is applied, and provisional fixation is performed for the posterior root. The anterior root is seated and firmly fixed with knotless anchor (SwiveLock Anchor® Arthrex, Naples, Florida) (Fig. 18.8). At this point, graft mismatch is assessed. If the graft is too large, the suspensory cortical mechanism may be shortened to bring some of the posterior horn/root deeper into the posterior socket. Usually, no more than 3–5 mm of mismatch is initially present. Hybrid fixation is then performed including all-inside posterior, inside-out for mid-meniscus, and outside-in as needed. In total, 6–8 points of fixation are typically utilized. The MAT is probed carefully and taken through ROM arc after final fixation.

At this point, attention is turned to completion of the ACL reconstruction in standard fashion. If concomitant cartilage restoration is to be performed, the ACL graft may be passed but not fixated on the tibial side. A limited lateral arthrotomy can be performed for cartilage restoration. Once complete, final ACL tensioning can be performed along with direct repair of the anterior horn of the MAT to the native meniscus rim and capsule. Final fluoroscopic images are taken. Examination under anesthesia is again performed. Wound is closed and dressing applied in standard fashion.

Below is a list of the steps:

1. *MAT prepared (bone plugs: 9 mm × 3 mm)*
2. *Posterior root drilled (*Fig. 18.4 *position; retrocutter through medial portal; 9 mm × 10 mm socket)*
3. *Femoral ACL tunnel reamed (shuttle retrieved laterally)*
4. *ACL socket reamed (shuttle retrieved medially)*
5. *Retrocutter utilized to create anterior root socket (3–5 mm depth)*
6. *Lateral capsulodesis*

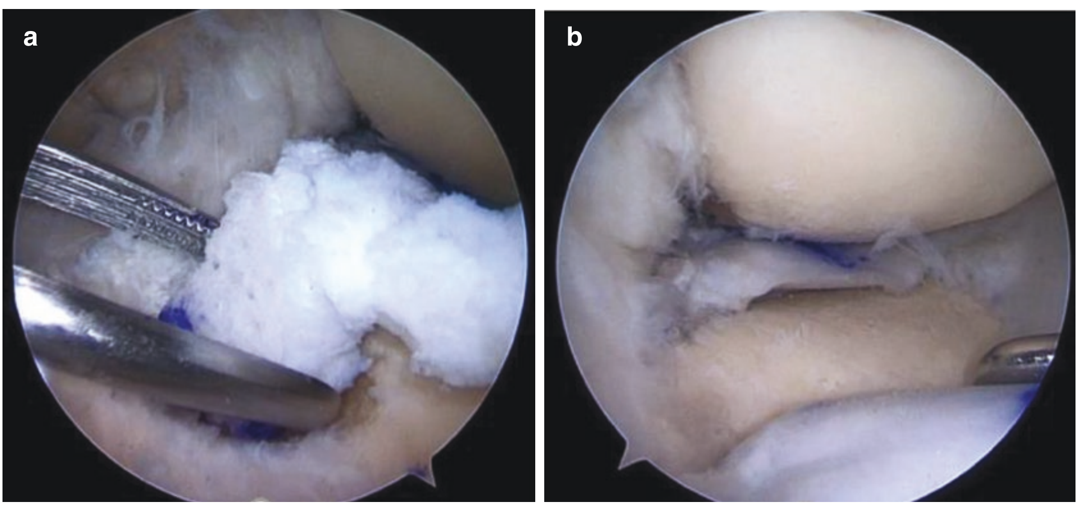

Fig. 18.8 (**a**) Prior to seating the anterior bone-plug. (**b**) After seating the anterior bone-plug in the socket adjacent to the ACL

7. *Sutures retrieved for anterior and posterior root sockets*
8. *Lateral MAT shuttled into joint*
9. *Anterior horn/root shuttled into the anterior socket*
10. *Attachable button applied*
11. *Provisional fixation performed for the posterior root*
12. *Anterior root fixed with knotless anchor*
13. *Graft mismatch assessed*
    (a) *Too large ➔ the suspensory cortical mechanism shortened to bring posterior horn/root deeper into socket*
14. *Hybrid fixation performed (typically 6–8 fixation points)*
    (a) *All-inside posterior*
    (b) *Inside-out for mid-meniscus*
    (c) *Outside-in as needed*
15. *ROM arc after final fixation*
16. *ACL reconstruction proceeded*
17. *ACL tensioning*
18. *Direct repair of anterior horn of MAT*
19. *Final flouroscopic images*
20. *EUA*
21. *Wound closure*

Rehabilitation

Postoperative rehabilitation includes flat-foot 0% weightbearing in a hinged knee brace for approximately 6 weeks. Range of motion (ROM) progression is slow initially to reduce the risk of graft extrusion [48]. Gravity-assisted ROM or CPM may be started within the first 1–2 weeks. Early goals include full terminal extension, quadriceps activation, and passive gravity-assisted ROM to 90° by 6 weeks. After 6 weeks, patients transition to Weight bearing as tolerated (WBAT) and unlock the brace with quadriceps control. They can discontinue the brace to a knee sleeve at this time. Progressive ROM continues while avoiding closed chain squatting past 90° for 3–4 months. Mid-rehabilitation focuses on restoration of gait, daily life activities, and low impact. Linear progression may be initiated based on minimum time (~9 mos) and functional criteria. In general, complex lateral movements and impact loading are avoided in most of these patients. Select athletes (noncontact, noncollision) may progress per protocol between year 1 and year 2 as long as the joint has regained homeostasis (i.e., no effusion or pain) and regain neuromuscular strength, flexibility, and control as demonstrated on return-to-sport testing. The majority of patients are undergoing this procedure to improve previous damage, and do not progress past normal daily activites and low impact recreational sport.

Outcomes of Meniscus Allograft Transplantation

Meniscus allograft transplantation (MAT) has emerged as a viable option for treatment of meniscus deficiency, with recent studies showing improved knee function and return to activity [49–52]. Overall, there have been reliable studies demonstrating the good outcomes of MAT [49–57]. Very few studies have determined the mid- to long-term outcomes of concomitant revision ACL reconstruction and lateral MAT specifically. Zaffagnini et al. performed 50 combined ACL reconstructions with MAT (medial or lateral); 44% had primary ACL reconstruction with MAT, while 39% underwent revision ACL reconstruction and MAT. Additionally, 17% of the cohort underwent ACL reconstruction with MAT in addition to high tibial osteotomy. At 5 years post-surgery, patients reported significant improvements in outcomes (Tegner score, Lysholm score, and Visual Analog Scale [VAS]). Furthermore, 85% of patients were able to return to sport with 37% returning to the same or higher performance level when compared to pre-injury performace level. Failure and reoperation rates were 15% and 17%, respectively [58].

Saltzman et al. also prospectively followed 40 patients who underwent combined ACL reconstruction (primary or revision) and MAT (33 medial MAT, 7 lateral MAT) [59]. At a follow-up of 5.7 years, 50% of patients were able to return to sport (39% to same level of play), and patients had significantly improved outcome scores. While the re-operation rate was high at

35%, a majority were simple arthroscopic debridement procedures. The failure rate was reported at 20% with 15% undergoing total knee arthroplasty. Of note, the lateral MAT subgroup showed significantly improved patient-reported outcomes compared to the medial MAT subgroup, and the lateral MAT subgroup had no cases of reoperation or failure. This suggests that patients who undergo lateral MAT with ACL reconstruction may have better outcomes than those who undergo combined ACL reconstruction and medial MAT [59]. Table 18.1 *outlines additional studies of MAT outcomes.*

Table 18.1 Outcomes of lateral MAT and concomitant ACL reconstruction

Study	Case number (n)	Methods/fixation	Follow-up	Outcome
Saltzman et al., 2017 [59]	**27**	Bone bridge (33 medial, 7 lateral) + Anterior Cruciate Ligament Reconstruction (ACLR)	**Mean: 5.7 years**	19 concomitant procedures, including 9 HWR and 9 OCA. Significant improvements in 11/14 PRO measures at final follow-up. 50% had return to sport. No significant joint space narrowing was noted. Overall survival rate at final follow-up was 80%. Failures occurred at a mean of 7.3 years. Lateral MAT group should significantly improve PRO measures compared to medial MAT group. No failures in lateral MAT group
Marcacci et al., 2014 [50]	**16**	12 MAT in professional soccer players (6 medial, 6 lateral), soft tissue only	**36 months**	11 of 12 returned to play at semiprofessional or higher level. No significant differences in return to training/first game for medial vs. lateral or isolated vs. concomitant procedure
Chalmers et al., 2013 [52]	**18**	Bone bridge (10 lateral); bone plug (3 medial)	**Mean: 3.3 years**	10 of 13 patients (77%) returned to sporting activity at final F/U. The mean KOOS score for the sport subset was 76 (SD, 18), the mean IKDC score was 77 (SD, 14), and the mean Lysholm score was 81 (SD, 13). Of the 13 patients, 3 (23%) required further surgery, comprising one revision MAT, one partial meniscectomy, and one meniscal repair
Saltzman et al., 2012 [53]	**19**	22 MAT (13 medial with bone plug technique, 9 lateral with keyhole technique), 14 had a concomitant procedure (8 ACLR or revision ACLR)	**Mean 8.5 years**	Lateral MAT has significantly higher Overall Knee Condition and postop IKDC scores compared to medial MAT. MAT with concomitant procedure demonstrated greater improvement in most PROs than isolated transplants
Verdonk et al., 2006 [54]	**20**	Soft tissue only	**Mean: 12.1 years**	Significant improvement was seen in modified HSS pain, walking, and stair scores at final FU ($p = 0.011$, $p = 0.007$, $p = 0.018$). KOOS scores obtained at the final FU showed substantial disability/symptoms and reduced quality of life. 13/32 knees did not show any joint space narrowing. MRI showed 70% were partially extruded. There was an 18% overall failure rate. 90% of patients were satisfied with the procedure
Zaffagnini et al. 2019 [58]	**26**	50 combined ACLR-MAT	**Mean 5 years**	Significantly improved PRO measures. 85% returned to sport, 37% at same or higher performance level. Failure and reoperation rates were 15% and 17%, respectively

(continued)

Table 18.1 (continued)

Study	Case number (n)	Methods/fixation	Follow-up	Outcome
Verdonk et al., 2005 [31]	***	Soft tissue only	**Mean: 7.2 years**	11/39 (28%) of the medial allografts and 10/61 (16%) of the lateral allografts failed. Mean cumulative survival time (11.6 years) was identical for the medial and lateral allografts. The cumulative survival rates for the medial and lateral allografts at 10 years were 74.2% and 69.8%, respectively. The mean cumulative survival time and the cumulative survival rate for the medial allografts used in combination with a high tibial osteotomy were 13.0 years and 83.3% at 10 years, respectively
Yoldas et al., 2003 [60]	***	31 patients (11 isolated MAT [9 lateral, 2 medial], 20 ACLR+MAT [3 lateral, 14 medial, 3 combined]; bone plugs (medial) or bone bridge (lateral)	**Mean: 2.9 years**	No significant difference in PRO based on medial versus lateral transplant, with or without concomitant ACLR. Eighty-three percent primary ACLR+MAT and 75% revision ACLR+MAT returned to moderate sport activity
Van Arkel and de Boer, 1995 [61]	***	63 allografts (34 lateral,17 medial, 6 combined); soft tissue fixation	**Mean: 5 years**	Cumulative survival rate for lateral allografts 76% (at 11 years), medial allografts 50% (at 10 years), and combined 67% (at 9 years). Significant negative correlation between ACL rupture and successful medial MAT
Yoon et al 2020 [62]	***	31 MAT after ACLR (16 medial, 15 lateral); no concomitant ACLR-MAT; keyhole (lateral), bone plugs (medial)	**Minimum: 2 years**	Medial MAT patients had significantly greater improvement in PROs than lateral MAT patients. Significant improvements postoperatively in pivot shift test for medial MAT, but not lateral MAT. Preop side-to-side difference in anterior tibial translation was significant only in medial MAT
Sekiya et al. 2003 [63]	***	28 MAT+ACLR (21 medial [bone block], 4 lateral [bone bridge], 3 both), 19 ACLR and 9 revision ACLR	**Mean: 2.8 years**	Significantly better IKDC group rating in primary ACLR vs. revision. No significant difference in PROs based on location of MAT. No significant change in joint space narrowing. No difference in ligamentous laxity
van der Wal et al., 2020 [64]	***	109 MAT (36 medial, 73 lateral), 16 concomitant ACLR; soft tissue + suture anchor	**Median: 54 months**	MAT failure rate 10% (2 medial, 9 lateral). Mean survival 16.1 years, no significant difference between medial and lateral. Survival associated with age at baseline (greater in those <35 years old). Survival not associated with compartment treated, with or without ACLR. Less improvement in KOOS scores with concomitant CALR, greater number of knee surgeries prior to MAT

*** P values less than 0.001.

Case Example

History/Exam

Patient is a 17-year-old female, competitive soccer player, with a history of previous left knee ACL hamstring autograft reconstruction at an outside institution 3 years ago. She also underwent subtotal lateral meniscectomy in a separate procedure after return to play. Unfortunately, the athlete continued to have lateral pain, effusions, and a feeling of intermittent “giving out” of her knee with activity. She had an “episode” one day prior to presentation.

On exam, the patient had an antalgic gait, diffuse and lateral joint line tenderness, 0-0-135° range of motion, negative McMurray, grade IIIB Lachman, and explosive grade III pivot shift. Imaging studies were ordered and thoroughly evaluated. Radiographs demonstrated previous ACL with overall anatomic alignment combined with preserved joint spaces (Fig. 18.9). CT was evaluated to examine ACL tunnel position and to measure tibial slope. Tunnel widening >14 mm was demonstrated (Fig. 18.10). MRI demonstrated lateral meniscal deficiency and a disrupted ACL graft (Fig. 18.11).

Given her complex condition, inability to perform in her sport, and symptoms even with daily life activity, the patient was indicated for salvage surgical intervention. A comprehensive problem list was created. This includes failed ACL reconstruction with widened prior anatomic tunnels and lateral meniscus deficiency. Patient goals and expectations were carefully discussed including quality of life and risk/benefit and timeframe of future return to sport. A two-stage solution was proposed, as bone grafting the widened tunnels was necessary. The patient underwent diagnostic arthroscopy with bone grafting (Fig. 18.12) followed by concomitant ACL revision and lateral meniscal allograft transplantation (Fig. 18.13) once the tunnels had consolidated. Postoperative

Fig. 18.9 Initial radiographs of case example demonstrating previous ACL with overall anatomic alignment combined with preserved joint spaces

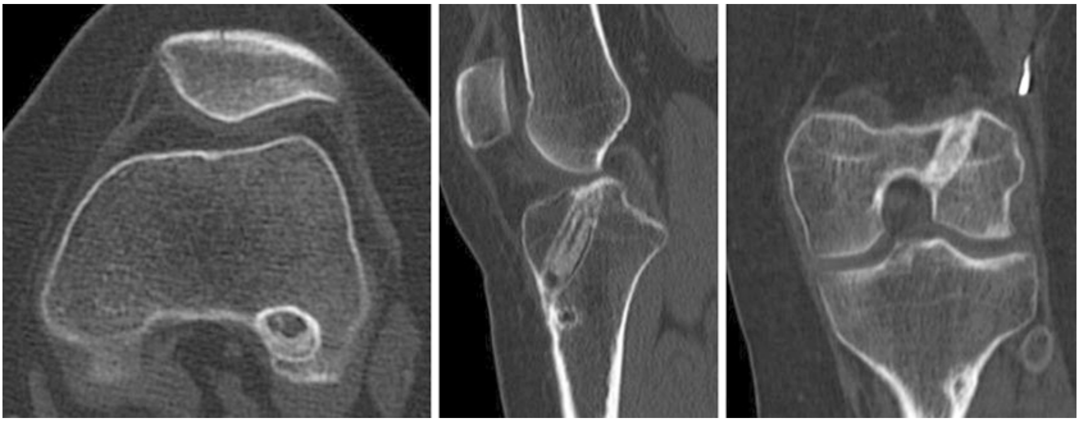

Fig. 18.10 CT revealed ACL tunnel widening of >14 mm

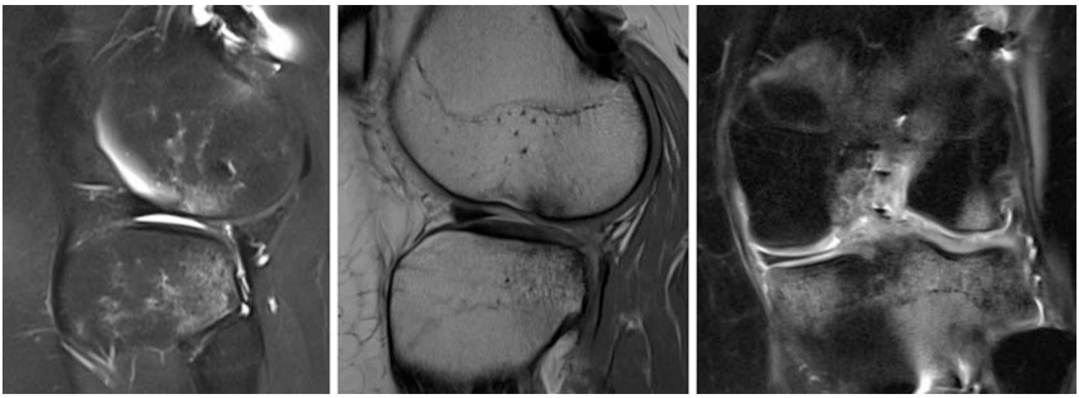

Fig. 18.11 MRI demonstrated lateral meniscal deficiency and a disrupted ACL graft

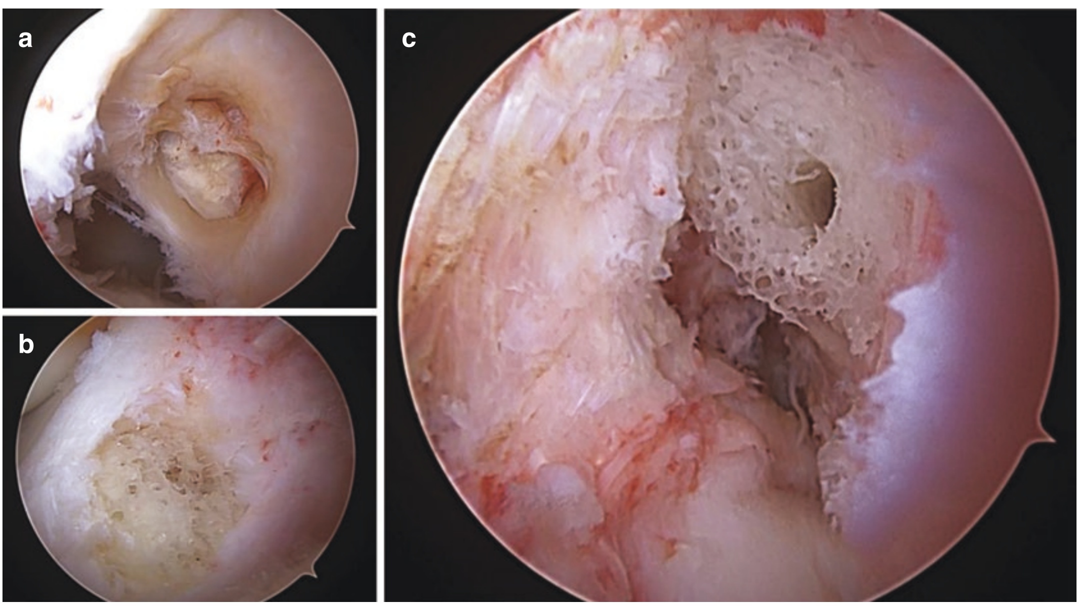

Fig. 18.12 Intraoperative arthroscopic images of diagnostic arthroscopy demonstrating disrupted ACL (**a**) and then post-removal and placement of bone graft (**b**, **c**)

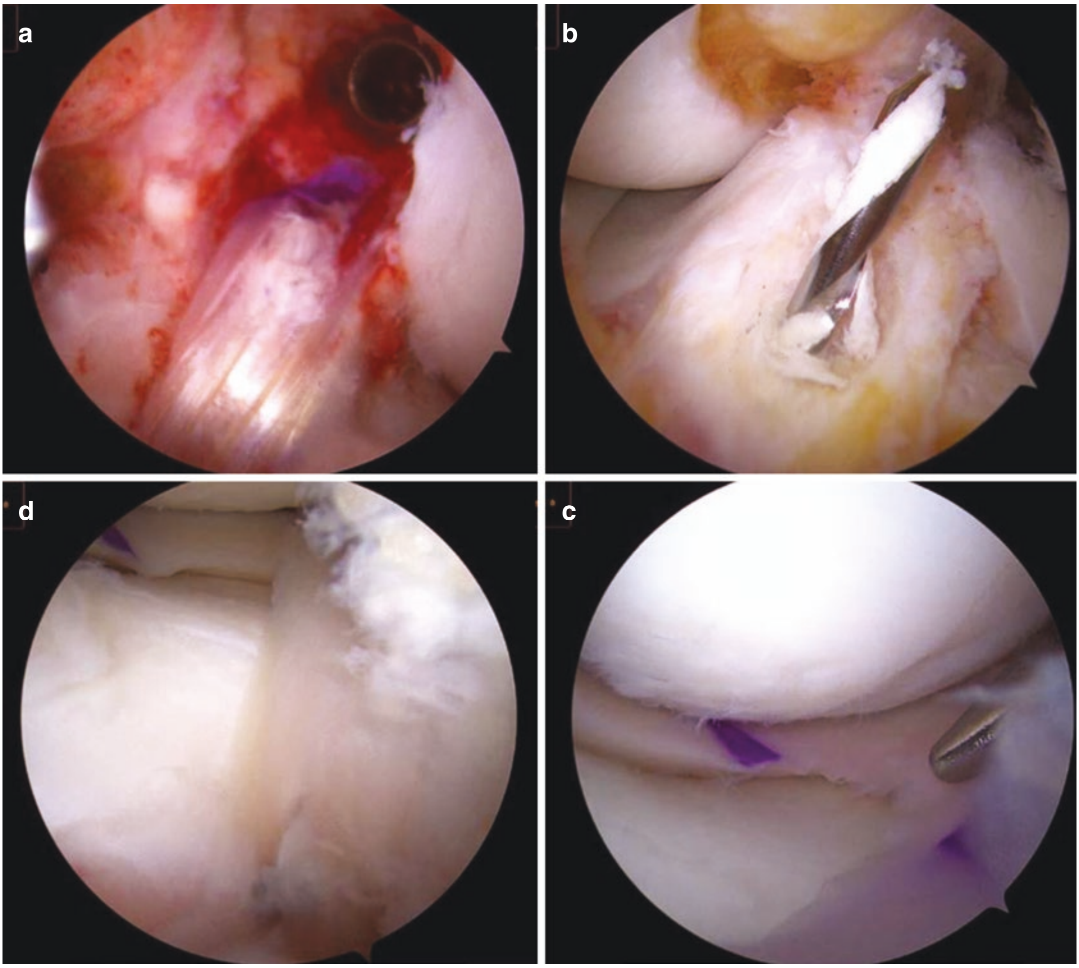

Fig. 18.13 During diagnostic arthroscopy, the patient underwent concomitant ACL revision (**a**, **b**) and lateral meniscal allograft transplantation (**c**, **d**)

radiographs demonstrate metallic screws for revision ACL autograft and buttons for concomitant lateral MAT (Fig. 18.14). The patient is doing well at short-term follow-up (<6 months) but has long recovery timeframe ahead.

Conclusion

In select patients, revision ACL reconstruction and lateral MAT can be a powerful combination to address increased rotatory instability and/or symptomatic post-meniscectomy syndrome. Appropriate indications and careful preoperative planning including staging arthroscopy are often required. Surgical precision and stepwise rehabilitation are critical. Patient expectations must be addressed to ensure optimal subjective and objective outcome. These are bridging procedures often performed in salvage. Patients should be aware of the likelihood of requiring future nonoperative or operative intervention for their challenging condition.

Fig. 18.14 Postoperative radiographs demonstrate metallic screws for revision ACL autograft revision and buttons for concomitant lateral MAT

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