Medial Meniscus Transplantation and Bone-Tendon-Bone Anterior Cruciate Ligament Reconstruction

Adam B. Yanke, MD PhD
Hailey P. Huddleston, MD
Jorge Chahla, MD, PhD
Brian J. Cole, MD, MBA

ASSOCIATED VIDEO

From the Department of Orthopedic Surgery, Rush University Medical Center, Chicago, IL.

Correspondence to Dr. Yanke: adam.yanke@rushortho.com

Video content is available in the full text article online. Please visit https://dx.doi.org/10.5435/JAAOS-D-20-00363

J Am Acad Orthop Surg 2022;30:104-110

DOI: 10.5435/JAAOS-D-20-00363

ABSTRACT

Performing medial meniscus allograft transplantation in combination with anterior cruciate ligament (ACL) reconstruction is technically demanding. Medial meniscus allograft transplantation in combination with ACL reconstruction may be indicated for patients with meniscal deficiency in whom ACL reconstruction has failed and patients with medial-sided knee pain secondary to meniscal deficiency in combination with ACL deficiency. Despite the complex nature of this combined surgical procedure, numerous studies have reported considerable clinical improvements at midterm and long-term follow-up. This technique article describes the indications, preoperative considerations, surgical technique, postoperative rehabilitation, and outcomes of medial meniscus allograft transplantation in combination with ACL reconstruction.

An intact medial meniscus is essential in maintaining anatomic strain and displacement of the anterior cruciate ligament (ACL).[1] Biomechanics studies have demonstrated that AP tibial translation is substantially increased in ACL-deficient knees. This AP translation is also exacerbated by medial meniscus deficiency. For example, DePhillipo et al reported a significant increase in translation at 30° and 90° after lesioning the posterior horn of the medial meniscus. This finding has also been confirmed in a clinical setting.[2] Dejour et al reported that partial medial meniscectomies were a risk factor for increased static and dynamic anterior tibial translation after ACL reconstruction.[2-7] In addition, medial meniscus deficiency can lead to an increase of ACL graft strain, up to a 46% increase at 90°.[1] This results in increased peak cartilage loading and a posterior shift in contact location.[6] Specifically, in an ACL-deficient state, the medial cartilage contact location is moved posteriorly by 2 mm.[6] In additional biomechanics studies, meniscal allograft transplantation (MAT) has been shown to restore ACL graft strain to normal levels, decrease AP tibial translation, and decrease tibiofemoral contact pressure.[7,8]

Clinically, studies have demonstrated meniscal deficiency to be a risk factor for ACL reconstruction failure and inferior postoperative clinical outcomes. For example, Parkinson et al reported that medial meniscal deficiency was a significant predictor of graft failure, with a hazard ratio of 15.1.[9] In addition, in a study evaluating ACL reconstructions in patients older than 50 years, medial meniscal lesions were found to be a risk factor for poor functional outcomes.[10] Similarly, Trojani et al found that patients who had a conserved meniscus had significantly higher International Knee Documentation Committee (IKDC) scores than those who underwent a total meniscectomy.[11] These studies illustrate the importance on an intact meniscus on improving functional outcomes and preventing ACL failure.

Patients who are ACL and meniscal deficient or patients with medial-sided knee pain secondary to meniscal deficiency in combination with ACL deficiency may be indicated for a MAT with concomitant ACL reconstruction. This technique article describes the indications and preoperative considerations in those indicated for a MAT with ACL reconstruction. In addition, the full surgical technique will be described in addition to postoperative rehabilitation and clinical outcomes after medial MAT in combination with ACL reconstruction.

Patient Evaluation

Medial MAT in combination with ACL reconstruction is indicated in two primary patient scenarios. The first scenario is a patient who lacks a secondary anterior translation restraint because of medial meniscus deficiency and in whom ACL reconstruction has failed. This scenario may be the result of a previous complete meniscectomy or a posterior root tear, the latter of which typically can be repaired primarily. Typically, patients will have undergone an initial surgical procedure that involved the management of a medial bucket-handle meniscus tear that resulted in complete medial meniscectomy during primary ACL reconstruction. The failure of ACL grafts in these patients is more commonly attributed to loosening rather than an acute event not preceded by any abnormality. The second scenario is a patient who has medial-sided knee pain secondary to meniscal deficiency, with or without a symptomatic tibiofemoral focal chondral defect, and ACL deficiency. Typically, surgeons allow these patients to push through linear activities despite ACL deficiency to determine whether medial-sided management is necessary for pain relief.

Absolute contraindications to MAT in combination with ACL reconstruction include severe osteoarthritis (Kellgren and Lawrence grade III and grade IV), Outerbridge grade IV focal chondral defects of the tibiofemoral compartment that are not amenable to cartilage repair, and femoral condyle flattening. Relative contraindications include patients older than 50 years. Body mass index (BMI) and activity participation should also be considered when making a preoperative treatment plan. The senior authors do not use strict BMI cutoffs, and patients are counseled on an individual basis based on a variety of surgical risk factors including BMI. However, patients at an increased age and low activity level with a BMI >35 kg/m^2 may be counseled against surgery as a higher BMI has been associated with inferior clinical outcomes after MAT.[12] In addition, procedures to correct malalignment, such as high tibial osteotomy and distal femoral osteotomy, should be considered in patients with varus or valgus alignment, respectively. Cartilage restoration procedures, such as osteochondral allografting, also may be necessary in patients with a medial tibiofemoral focal chondral defect.

Clinical evaluation is necessary to determine whether MAT in combination with ACL reconstruction is indicated. The physical examination should focus on rotational and AP laxity and should include a Lachman test and a pivot shift test. Typically, patients with a deficient medial meniscus and ACL have a grade 3 Lachman test (>10 mm translation) and a pivot shift because of the lack of a secondary restraint.[13] Imaging studies should include standard radiography (ie, AP, lateral, flexion, and Merchant views), mechanical axis radiography, and MRI. Tibiofemoral joint space narrowing, ACL tunnel widening, and malalignment should be evaluated on radiographs, and the status of the meniscus, cartilage, and ACL should be assessed on MRI. For patients with significant malalignment on a mechanical axis radiograph, a distal femoral or high tibial osteotomy may be considered for addressing valgus and varus malalignment, respectively. The authors suggest

Yanke or an immediate family member serves as a paid consultant to JRF Ortho, Olympus, Patient IQ, Smith & Nephew, and Sparta Biomedical and has received research or institutional support from Arthrex, Inc, and Organogenesis. Chahla or an immediate family member serves as a paid consultant to Arthrex Inc, Smith & Nephew, and CONMED Linvatec. Cole or an immediate family member has received royalties from Arthrex, Inc, and Elsevier Publishing; serves as a paid consultant to Regentis and Arthrex, Inc; has stock or stock options held in Bandgrip Inc, and Ossio; has received research or institutional support from Aesculap/B.Braun, Arthrex, Inc, and National Institutes of Health (NIAMS & NICHD); has received nonincome support (such as equipment or services), commercially derived honoraria, or other non–research-related funding (such as paid travel) from Athletico, JRF Ortho, and Smith & Nephew; and serves as a board member, owner, officer, or committee member of the Arthroscopy Association of North America, International Cartilage Repair Society; on the editorial or governing board of the *American Journal of Orthopedics*, *American Journal of Sports Medicine*, *Journal of Shoulder and Elbow Surgery*, *Cartilage*, and *Journal of the American Academy of Orthopaedic Surgeons*. Neither Huddleston nor any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article.

Table 1. **Pearls and Pitfalls of Meniscal Allograft Transplantation and Concomitant Anterior Cruciate Ligament Reconstruction**

Pearls	Pitfalls
Bone grafting may be considered in patients who have undergone multiple prior ACL surgical procedures in whom tunnel widening is observed on preoperative radiographs	Arthroscopic visualization of the posterior meniscus during medial meniscectomy is imperative to ensure that the capsular ligaments are left intact
Anteromedial meniscectomy may be difficult to perform because of limited access; a No. 11 blade inserted through the ipsilateral or contralateral portal can be used to create additional surface area for removal via the shaver	The trajectory of the spinal needle must be compared with the ACL footprint or tunnel convergence may occur
Meniscectomy should be performed as anterior as possible to afford direct visualization for planning the trajectory of the meniscal slot	The ACL femoral guide pin should be visualized to confirm little to no tunnel overlap with the tibial slot, which may result in tunnel convergence
Visualization of the extravasation of marrow elements during slot reaming suggests proper reaming depth	Overlap between the ACL tibial tunnel and the tibial slot at the cortical edge may result in considerable disruption of the transplanted graft
Rasping of the slot with the use of a 7-mm and then 8-mm rasp smooths the slot edges and confirms proper slot depth and width	—
Soft tissue can be removed after reaming the tibial ACL tunnel to assess the amount of overlap between the tunnel and the tibial slot	—
Removal of a piece of the meniscus bone block may be necessary to allow for unobstructed ACL graft passage	—
The meniscus graft can be tapered posteriorly to aid in overall graft insertion	—

ACL = anterior cruciate ligament

performing the osteotomy as a combined procedure with MAT and ACL instead of a staged procedure. If concerns for tibial tunnel expansion or convergence with the planned transplant trough exist based on preoperative imaging studies, the tunnel should be grafted (Table 1), and reconstruction should be performed in a staged fashion.

Patient Positioning

The patient is positioned on the surgical table in the ACL position with the knee bent, allowing for full flexion. General anesthesia is administered. Preoperative regional anesthesia is not suggested due to the potential of quadriceps strength deficits after femoral nerve block.[14] Instead, a postoperatively nerve block can be used as needed if the patient reports of continued pain. An examination under anesthesia should be performed to assess all ligamentous structures. The distal pole of the patella, standard portal locations, and the incision location for meniscal graft passage are marked. The anteromedial tibial incision location also is marked.

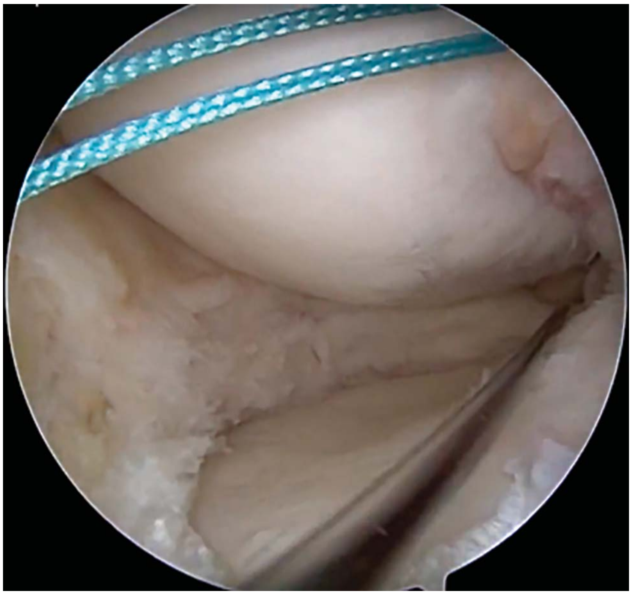
Surgical Technique

Inferomedial and inferolateral portals are established, and diagnostic arthroscopy is performed to evaluate the medial and lateral compartments and the ligamentous structures (Video 1). The presence and location of meniscal and cartilage pathology is confirmed.

Under visualization of the ACL, the graft remnant or native ACL can be débrided. The femoral tunnel is addressed first via a standard approach for revision ACL reconstruction because of extravasation. By addressing the femoral tunnel first, less fluid extravasation occurs during this portion of the procedure. A femoral tunnel is then created through the inferomedial portal via placement of an over-the-top guide followed by a Beath pin. Reaming is then performed based on the graft size, ensuring that a separate patent tunnel is created. In patients with an adequately placed femoral tunnel, the tunnel can be débridement and used for the revision procedure.

Attention is then shifted to the tibial side, including medial MAT and tibial tunnel creation. When working in the medial compartment, trephination of the proximal

Figure 1



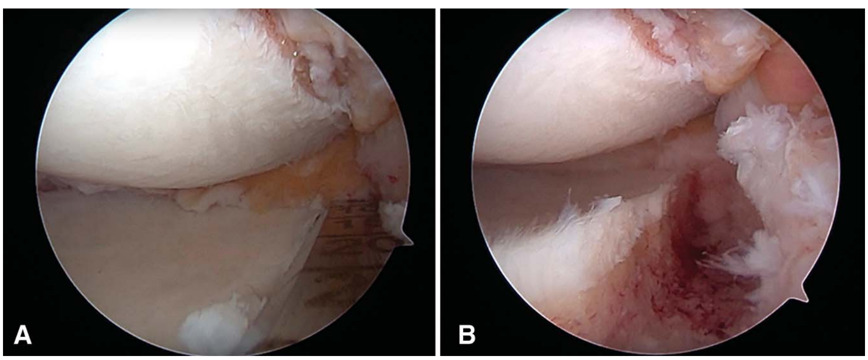
Arthroscopic image of a knee shows insertion of an 18-gauge spinal needle to determine the location of the mini-arthrotomy for meniscal allograft transplantation. The trajectory of the needle is visualized to ensure that it overlays the anterior and posterior medial meniscus footprint with minimal overlap of the anterior cruciate ligament footprint to ensure minimal convergence.

medial collateral ligament often improves visualization of the posterior horn of the meniscus and for meniscal trough preparation. Trephination of the medial collateral ligament is performed using an 18-gauge spinal needle while applying a valgus load to the knee. Although reverse notchplasty may be helpful, the senior authors do not think that it improves visualization as much as trephination. The medial meniscus is then removed with the use of a basket and a shaver for the posterior meniscus and a No. 11 scalpel for the anterior horn.

Determining the appropriate position of the mini-arthrotomy for MAT is crucial. With the arthroscopic camera in the inferolateral portal with the viewing direction at the anteromedial meniscus insertion, an 18-gauge spinal needle is inserted into the location of the planned mini-arthrotomy. Under arthroscopic visualization, the trajectory of the needle through the anterior and posterior meniscus footprints is confirmed (Figure 1), and the incision is created. Through this incision, aggressive soft-tissue débridement is performed to visualize the entire anterior meniscus footprint. The medial tibial spine eminence is then removed with the use of a rotary or linear rasp shaver to create space for the meniscal guide and create the slot. An over-the-top slot guide is inserted in line with the anterior and posterior meniscus footprints, ensuring that the guide is parallel to the tibial plateau and rotated in line with the longitudinal axis of the tibia. To avoid convergence between the ACL tibial tunnel and the MAT slot, the tibial trough should be cheated as far medial as possible while still intersecting with both meniscus root insertions. This is typically at or just medial to the medial tibial spine. After trough creation, the ACL tunnel typically abuts or intersects the MAT trough by about <20% to avoid damaging the lateral meniscus root. To create the slot, the guide pin is advanced, after which a 7-mm reamer is advanced. A boxcutter, pituitary rongeur, shaver, and pick-up are then used to remove and remaining osseous fragments to complete the creation of the slot. A dilating 8-mm rasp and a bone cutting shaver are used to complete preparation of the recipient slot (Figure 2).

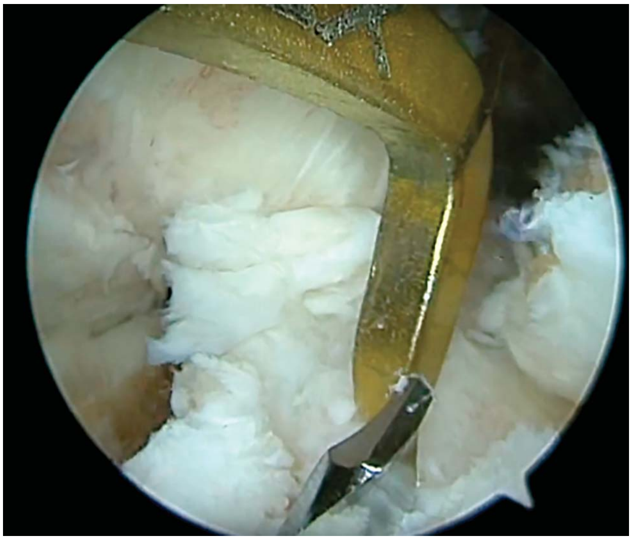
A bone-patellar tendon-bone (BTB) ACL autograft is prepared in a standard fashion based on the graft being used. A BTB autograft is the author's preference due to its low failure rate and cost-effectiveness, although other graft options can be considered including Achilles or BTB

Figure 2



Arthroscopic images of a knee show rasping of the tibial slot with the use of a 7-mm rasp followed by an 8-mm rasp. **A**, The rasp should be flush with the tibial surface to ensure an appropriate bone slot depth. **B**, The subsequent tunnel should have smooth edges.

Figure 3



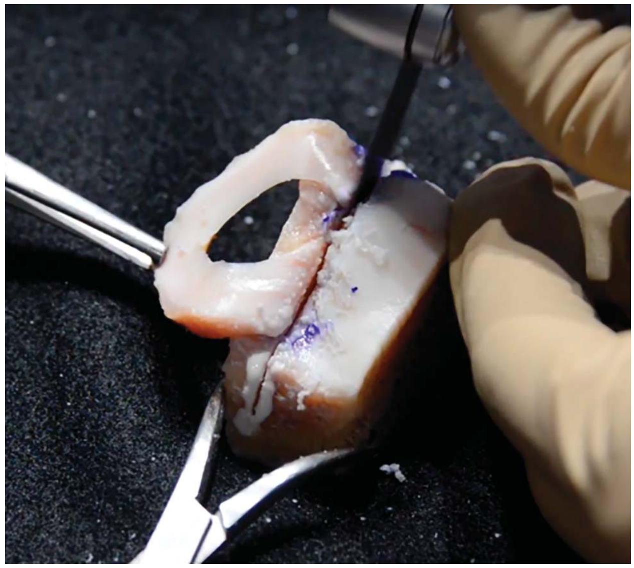
Arthroscopic image of a knee shows creation of the tibial anterior cruciate ligament tunnel. An elbow-type aimer is placed in the center of the anterior cruciate ligament footprint, and a guide pin is inserted.

allograft.[15,16] The tibial ACL tunnel is created via an anteromedial approach; however, an anterolateral approach can be used if concerns for tunnel convergence exist. An elbow-type aimer aligned on the ACL footprint can be used to advance the guide pin (Figure 3), taking care to not place it too medially. A reamer is then advanced over the guide pin, typically beginning with an 8-mm reamer and increasing to the final 10- to 11-mm reamer; however, the reamer size depends on the size of the bone plug and original tunnel. Small amounts of overlap with the tibial tunnel may occur but will not result in considerable adverse effects unless overlap is at the cortical edge of the meniscal transplanted graft. The ACL graft is then passed in a standard fashion and fixed to the femur with the use of an interference screw. However, the ACL graft also can be passed after the meniscal graft, depending on the amount of overlap present. If the meniscal transplanted graft is passed before the ACL graft, the reamer can be readvanced by hand to remove any cancellous bone from the anterior aspect of the meniscal transplant graft that may interfere with graft passage.

Two passing stitches are then created for the bone plug and soft tissue of the transplanted meniscal allograft. An ACL aimer is inserted and aligned with the center of the trough, and a guide pin followed by a reamer and stiff suture or nitinol wire with suture are inserted into this location. The suture is pulled out through the central mini-arthrotomy. The soft-tissue passing suture is passed through the posteromedial aspect of the knee via a standard inside-out meniscal approach as previously described.[17]

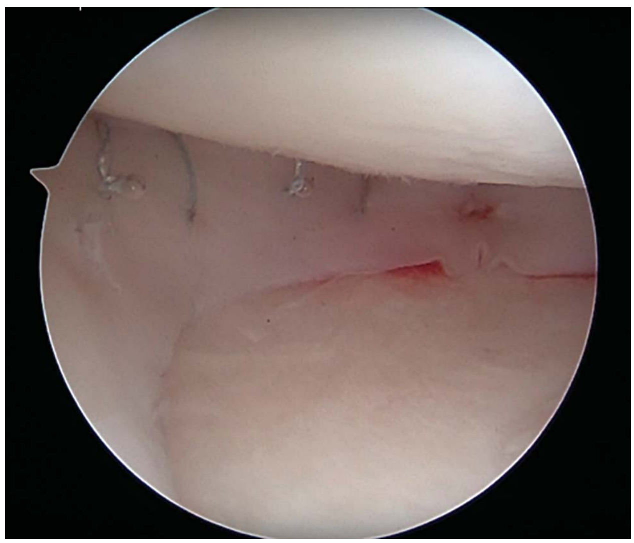
The meniscal allograft is then prepared on the back table. The rasp that was used to create the tibial tunnel is aligned with the anterior and posterior meniscus insertions along the meniscal allograft. A marker is used to mark and

Figure 4



Intraoperative photograph shows preparation of the meniscus allograft on the back table. The rasp that was used to create the tibial bone slot is used as a guide for marking and scoring of the graft to an appropriate width. An anterior cruciate ligament saw blade is then used to cut along this line.

Figure 5



Arthroscopic image of a knee shows the meniscal allograft secured posteriorly via an all-inside technique. The peripheral aspects of the graft are secured with the use of 8 to 10 vertical mattress sutures via an inside-out technique.

score the slot width along the graft. An ACL saw blade is used to cut along the marked line (Figure 4). The rasp is then used to mark the depth on the graft, and an ACL saw blade is used to cut along this line. Care should be taken to not remove the tibial spine because the graft is more likely to fracture in this area. The graft is assessed to ensure that it fits in a 7- or 8-mm slot (width) and is approximately 1 cm in depth. The soft-tissue suture is then placed in the posteromedial meniscus, and the bone bridge suture is passed through the center of the bone bridge. The graft is inserted into the joint by tensioning each suture individually. The graft is fixed posteriorly via an all-inside technique and is fixed along the periphery with the use of 8 to 10 vertical mattress sutures via an inside-out technique (Figure 5). For the inside-out technique, once in a proper position along the periphery of the meniscus, the needle is advanced and punctured through the meniscus.[17] The needle is further slowly advanced out of the posteromedial knee. A second needle is then inserted through the meniscus in a vertical mattress configuration and advanced, and the suture ends are knotted appropriately. The anterior portion is fixed through the anterior arthrotomy to the capsule with the use of a No. 1 Vicryl suture. The bone bridge is fixed transosseously via a knotless suture anchor on the anteromedial tibia, using the passing sutures. Separately, a suture anchor can be used as an interference screw between the bone bridge and the slot. Finally, the ACL graft is fixed at the tibia via an interference screw with the knee in maximal extension. Any additional cartilage procedures, such as osteochondral allografting, are then performed.

Postoperative Management

The patient's leg is placed in a hinged knee brace that allows motion from extension to 90° of flexion. Heel-based partial weight bearing is allowed for the first 6 weeks postoperatively. Physical therapy is initiated immediately postoperatively. From 6 to 12 weeks postoperatively, use of the brace is discontinued, and full range of motion and full weight bearing are allowed. After 12 weeks postoperatively, the focus of physical therapy shifts to increasing strength via specific drills. Postoperative rehabilitation may last as long as 6 to 18 months, depending on procedure complexity and patient goals.

Discussion

The goal of this technique article was to describe a surgical technique for performing MAT with concomitant ACL reconstruction. Although many studies have reported on clinical outcomes and survivorship of MAT, the clinical outcome literature for MAT with concomitant ACL remains limited. However, a few studies have reported considerable improvements in the clinical outcomes of patients who undergo MAT in combination with ACL reconstruction as many as 20 years postoperatively.[18,19] For example, Sekiya et al[20] reported substantial improvements in the 36-Item Short Form Survey (SF-36) scores and normal or near-normal Lachman and pivot shift tests in 90% of patients at a follow-up of 2.8 years. In addition, Yoldas et al[21] reported no considerable difference in the 2.9-year patient-reported outcomes of patients who underwent MAT in combination with ACL reconstruction and those of patients who underwent isolated MAT. In our institutional cohort of 40 patients at a mean follow-up of 5.7 years, patients demonstrated significant improvements on Lysholm, IKDC, Tegner, and all Knee Injury and Osteoarthritis Outcome Scores and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) subscores, except WOMAC stiffness, at final follow-up compared with baseline.[22] The survival rate of MAT in combination with ACL reconstruction was 80% at a mean follow-up of 7.3 years.[22] In addition, no significant decrease was found in joint space for the medial or lateral tibiofemoral compartment for patients who underwent a medial or lateral MAT, respectively. Similarly, Zaffagini et al reported on a cohort of 46 patients who underwent MAT with ACL reconstruction.[18] They reported significant improvements on Lysholm, visual analog scale, and Tegner scores and a 5-year survivorship of 85%. In addition, they reported an 85% return to sport rate; subgroup analysis revealed a lower return to sport rate in those who underwent a revision ACL (72% compared with 90% of primary ACLs).

Despite improved outcomes and a low failure rate, there is still a risk for postoperative complications. Patients are at risk for all usual surgical-related factors such as bleeding and infection. In addition, patients after ACL with MAT may experience persistent pain or stiffness postoperatively.[18] Furthermore, Saltzman et al[23] reported that in their cohort analysis, the most common subsequent procedure was débridement followed by total knee arthroplasty, meniscectomy, and ACL implant removal. Although complex and technically challenging, MAT in combination with ACL reconstruction has been demonstrated to significantly improve patient clinical outcomes and should be considered when indicated. Watch the video trailer: http://links.lww.com/JAAOS/10.5435/JAAOS-D-20-00363.

References

References printed in **bold type** are those published within the past 5 years.

1. Papageorgiou CD, Gil JE, Kanamori A, Fenwick JA, Woo SL-Y, Fu FH: The biomechanical interdependence between the anterior cruciate ligament replacement graft and the medial meniscus. *Am J Sports Med* 2001;29:226-231.

2. DePhillipo NN, Moatshe G, Brady A, et al: Effect of meniscocapsular and meniscotibial lesions in ACL-deficient and ACL-reconstructed knees: A biomechanical study. *Am J Sports Med* 2018;46:2422-2431.

3. Dejour D, Pungitore M, Valluy J, Nover L, Saffarini M, Demey G: Tibial slope and medial meniscectomy significantly influence short-term knee laxity following ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2019;27:3481-3489.

4. Grassi A, Macchiarola L, Urrizola Barrientos F, et al: Steep posterior tibial slope, anterior tibial subluxation, deep posterior lateral femoral condyle, and meniscal deficiency are common findings in multiple anterior cruciate ligament failures: An MRI case-control study. *Am J Sports Med* 2019;47:285-295.

5. Cristiani R, Rönnblad E, Engström B, Forssblad M, Stålman A: Medial meniscus resection increases and medial meniscus repair preserves anterior knee laxity: A cohort study of 4497 patients with primary anterior cruciate ligament reconstruction. *Am J Sports Med* 2017;46:357-362.

6. Arner JW, Irvine JN, Zheng L, et al: The effects of anterior cruciate ligament deficiency on the meniscus and articular cartilage. *Orthop J Sports Med* 2016;4:2325967116639895.

7. Spang JT, Dang AB, Mazzocca A, et al: The effect of medial meniscectomy and meniscal allograft transplantation on knee and anterior cruciate ligament biomechanics. *Arthroscopy* 2010;26:192-201.

8. Kim JG, Lee YS, Bae TS, et al: Tibiofemoral contact mechanics following posterior root of medial meniscus tear, repair, meniscectomy, and allograft transplantation. *Knee Surg Sports Traumatol Arthrosc* 2012;21:2121-2125.

9. Parkinson B, Robb C, Thomas M, Thompson P, Spalding T: Factors that predict failure in anatomic single-bundle anterior cruciate ligament reconstruction. *Am J Sports Med* 2017;45:1529-1536.

10. Fayard JM, Wein F, Ollivier M, et al: Factors affecting outcome of ACL reconstruction in over-50-year-olds. *Orthop Traumatol Surg Res* 2019;105:S247-S251.

11. Trojani C, Sbihi A, Djian P, et al: Causes for failure of ACL reconstruction and influence of meniscectomies after revision. *Knee Surg Sports Traumatol Arthrosc Official J Esska* 2010;19:196-201.

12. Fanelli D, Mercurio M, Gasparini G, Galasso O: Predictors of meniscal allograft transplantation outcome: A systematic review. *J Knee Surg* 2019;34:303-321.

13. Torg JS, Conrad W, Kalen V: Clinical I diagnosis of anterior cruciate ligament instability in the athlete. *Am J Sports Med* 1976;4:84-93.

14. Everhart JS, Hughes L, Abouljoud MM, Swank K, Lewis C, Flanigan DC: Femoral nerve block at time of ACL reconstruction causes lasting quadriceps strength deficits and may increase short-term risk of re-injury. *Knee Surg Sports Traumatol Arthrosc* 2020;28:1894-1900.

15. Genuario JW, Faucett SC, Boublik M, Schlegel TF: A cost-effectiveness analysis comparing 3 anterior cruciate ligament graft types. *Am J Sports Med* 2012;40:307-314.

16. Nagda SH, Altobelli GG, Bowdry KA, Brewster CE, Lombardo SJ: Cost analysis of outpatient Anterior cruciate ligament reconstruction: Autograft versus allograft. *Clin Orthop Relat Res* 2009;468:1418-1422.

17. Chahla J, Serra Cruz R, Cram TR, Dean CS, LaPrade RF: Inside-out meniscal repair: Medial and lateral approach. *Arthrosc Tech* 2016;5:e163-e168.

18. Zaffagnini S, Grassi A, Romandini I, Marcacci M, Filardo G: Meniscal allograft transplantation combined with anterior cruciate ligament reconstruction provides good mid-term clinical outcome. *Knee Surg Sports Traumatol Arthrosc* 2019;27:1914-1923.

19. von Lewinski G, Milachowski KA, Weismeier K, Kohn D, Wirth CJ: Twenty-year results of combined meniscal allograft transplantation, anterior cruciate ligament reconstruction and advancement of the medial collateral ligament. *Knee Surg Sports Traumatol Arthrosc* 2007;15:1072-1082.

20. Sekiya JK, Giffin JR, Irrgang JJ, Fu FH, Harner CD: Clinical outcomes after combined meniscal allograft transplantation and anterior cruciate ligament reconstruction. *Am J Sports Med* 2003;31:896-906.

21. Yoldas EA, Sekiya JK, Irrgang JJ, Fu FH, Harner CD: Arthroscopically assisted meniscal allograft transplantation with and without combined anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2003;11:173-182.

22. Saltzman BM, Cotter EJ, Stephens JP, et al: Preoperative tibial subchondral bone marrow lesion patterns and associations with outcomes after isolated meniscus allograft transplantation. *Am J Sports Med* 2018;46:1175-1184.

23. Saltzman BM, Meyer MA, Weber AE, Poland SG, Yanke AB, Cole BJ: Prospective clinical and radiographic outcomes after concomitant anterior cruciate ligament reconstruction and meniscal allograft transplantation at a mean 5-year follow-up. *Am J Sports Med* 2017;45:550-562.