Technical Note

Medial Meniscus Radial Tear: A Transtibial 2-Tunnel Technique

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Abstract: Complete radial tears of the medial meniscus significantly decrease the meniscal tissue's ability to dissipate tibiofemoral loads and have been described as functionally similar to a total meniscectomy, predisposing patients to early osteoarthritis. At present, no consensus exists regarding the optimal surgical treatment of a radial meniscal tear. Current repair techniques have led to a reportedly high rate of incomplete healing or healing of the meniscus in a nonanatomic, gapped position, which compromises its ability to withstand hoop stresses. Improvement regarding the ability to repair and heal medial meniscus radial tears has the potential to result in enhanced preservation of the articular cartilage in the medial compartment of the knee. This technical description details a method for repairing radial tears of the medial meniscus using a transtibial 2-tunnel technique.

Radial meniscal tears are common in active individuals and are frequently associated with anterior cruciate and multiligament knee injuries.[1] Because of their resultant inability to withstand meniscal hoop stresses, complete radial tears have been described as functionally similar to a total meniscectomy, predisposing patients to early osteoarthritis and rapid joint degeneration when left untreated.[2-6] Historically, the gold-standard treatment for patients with radial tears of the medial meniscus was a partial or total meniscectomy to alleviate symptoms of pain but this often led to accelerated articular cartilage degenerative consequences.[1] Given the suboptimal outcomes and high reoperation rates, especially in high-demand individuals, there has been increased interest in repairing radial meniscus tears over the past several years.[7]

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Numerous surgical techniques for repairing radial meniscal tears have been described in the literature.[8,9] Current techniques focus on a variation of horizontal mattress suture fixation: either an all-inside horizontal mattress repair or an inside-out repair with single, double, or crossed horizontal mattress sutures.[8,10,11] Although the outcomes after these technique are promising in terms of healing rates of the peripheral meniscus,[10] overall there has been a significantly unsatisfactory low rate of meniscal healing in the meniscal midbody for complete radial tears.[9,10] Therefore, techniques have been developed to address the shortcomings of the current repair techniques.[11]

Recent biomechanical studies have shown that improved stability of meniscal repairs is a favorable factor during the healing process of meniscal repairs.[12,13] Thus, the purpose of this technical note was to describe an anatomic transtibial 2-tunnel method for radial medial meniscus tears.

Surgical Technique

Preoperative Physical Examination

A physical examination is performed to evaluate the alignment of the lower limbs, knee motion, and ligament stability. Often, patients show tenderness to palpation along the medial joint line and present with posterior knee pain with squatting. The patients usually have medial joint line pain, and the Apley and McMurray tests are frequently positive. In some instances, especially in thin patients, meniscal extrusion

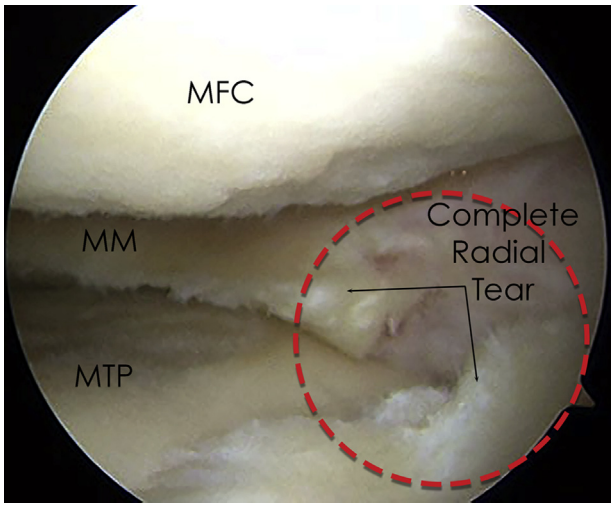

Fig 1. Arthroscopic image of a midbody complete radial tear of the medial meniscus (MM) in a right knee. (MFC, medial femoral condyle; MTP, medial tibial plateau.)

may be palpated over the medial joint line. Plain radiographs are obtained, and a magnetic resonance imaging series is assessed to confirm the diagnosis.

Indications for Surgical Management

After the results of a detailed history, physical examination, and imaging are found to be consistent with a complete radial tear of the medial meniscus, treatment options including partial meniscectomy, meniscus repair, a possible staged meniscus allograft transplantation, and conservative management are discussed with the patient. In young patients or in patients with intact articular cartilage, consideration should be given to a radial meniscal repair.

Patient Positioning and Examination Under Anesthesia

The patient is placed in the supine position. After the induction of general anesthesia, a bilateral examination is performed to evaluate for any concurrent ligament instability and to assess for range of motion. The injured leg is placed in a leg holder (Mizuho OSI, Union City, CA), and the nonsurgical leg is flexed, abducted, and held in an abduction holder (Birkova Products, Gothenburg, NE). A well-padded high-thigh tourniquet is subsequently placed around the operative leg. The surgical leg is prepared and draped, and the tourniquet is inflated (Video 1).

Surgical Approach

Standard medial and lateral arthroscopic portals are made adjacent to the patellar tendon, and the arthroscopic camera is inserted into the joint. A complete diagnostic arthroscopy is performed with a 30° arthroscope (Smith & Nephew, Andover, MA). Once the radial midbody tear is identified (Fig 1), adhesions along the meniscocapsular junction must be released to allow the meniscus to have enough mobility to be reduced into a more anatomic position. Arthroscopic scissors are used to release the peripheral edges of the meniscus from the joint capsule approximately 1 cm in either direction from the tear site. Care must be taken not to injure the deep capsule or meniscal tissue.

Transosseous Tunnel Creation

After release of each radial tear edge, two 2.4-mm tunnels are reamed at the meniscocapsular region of the tibia with the center of the tunnels located 5 mm apart and on either side of the radial meniscus tear. It is very important to place the tunnel at the meniscocapsular region of the tibia to allow for a more anatomic reduction of the tear when the sutures are crossed. The first tunnel can be created with the use of an anterior cruciate ligament tibial aimer guide and a sheathed drill (Smith & Nephew). Once the drill bit is in the appropriate position, the sheath is left in place and a 5-mm parallel drill guide (Smith & Nephew) is used to align the second tunnel parallel to the first. Generally, it is easier to drill the most posterior tunnel first and then use the parallel guide to drill the more anterior tunnel (Fig 2).

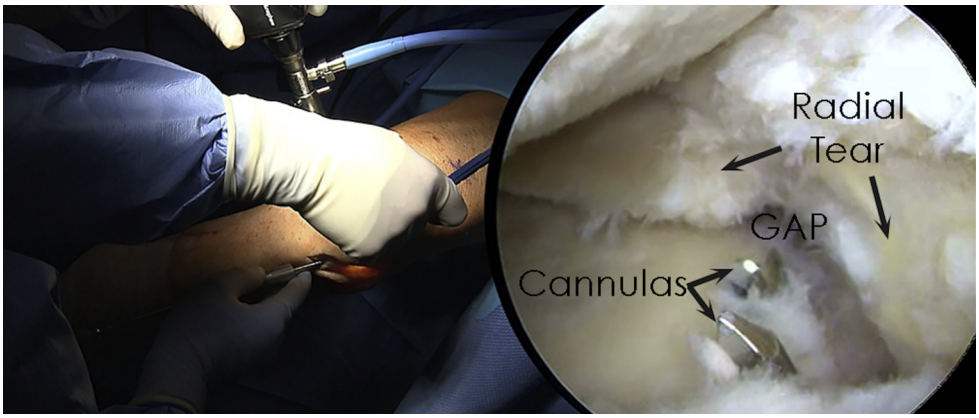

Fig 2. Operative (left) and arthroscopic (right) views of the 2 transtibial 2.4-mm tunnels with 5 mm of separation reamed at the meniscocapsular region of the tibia in a right knee.

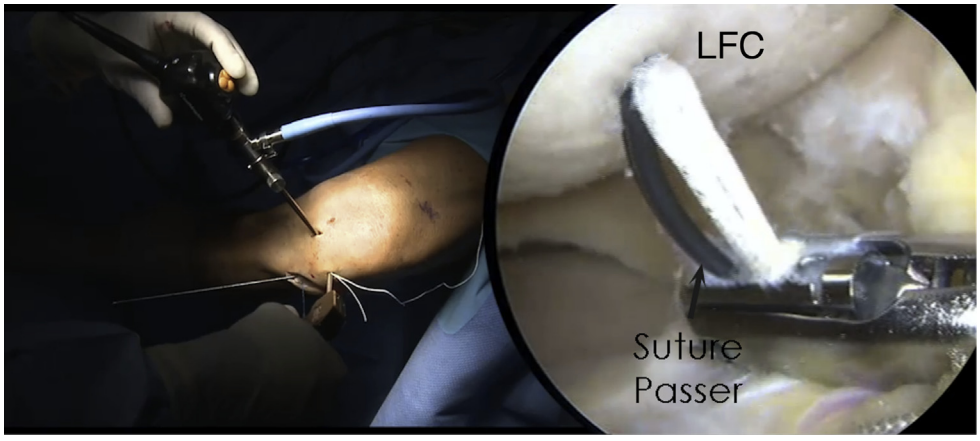

Fig 3. Operative (left) and arthroscopic (right) views of a suture of the posterior horn of the meniscal flaps with a self-capture suture passer device in a right knee. (LFC, lateral femoral condyle.)

Suture Passage

A No. 2 Ultrabraid suture (Smith & Nephew) is first passed through the posterior corner of each meniscal flap using a noncutting needle. Typically, suture passage is performed through one anteromedial portal with a FirstPass suture-passing device (Smith & Nephew) (Fig 3). Alternatively, this can be accomplished with a crescent suture passer through the anteromedial portal and a grasper holding the meniscal flap through an accessory portal. It is imperative that the suture be passed on the posterior corner of each flap to improve the ability to obtain an anatomic reduction.

Suture Shuttling Through Tunnels

A nitinol lasso can be used to shuttle each No. 2 suture in a crisscross fashion through the transosseous tunnels. The anteriorly placed sutures are passed through the posterior transtibial tunnel, and the posteriorly placed sutures are passed through the anterior tunnel. The crisscross orientation of the sutures is the key for approximation of the margins of the medial meniscus and restoration of the continuous semilunar shape of an intact meniscus. Applying a traction force to the transtibial sutures reduces the meniscus into its final position, and the suture ends exiting the tibial tunnels are tied using a standard surgeon's knot over a button on the anteromedial tibial cortex with the knee in 90° of flexion (Fig 4). The restoration of the shape and stability of the repair is confirmed by visualization and probing.

Inside-out Meniscal Sutures

After the transosseous portion of the repair is completed and sutures are tied over the button, further inside-out sutures are placed to further augment the repair. First, a probe is placed through the medial side of the knee onto the capsule to determine where the corresponding incision should be positioned. Next, a 4-cm vertical incision is made through the skin at this location. The subcutaneous tissues are divided, and the sartorial fascia is encountered and incised with the knee in 90° of flexion. The saphenous nerve and vein, sartorius tendon and fascia, and semitendinosus and gracilis tendons are retracted posteriorly. The interval between the medial head of the gastrocnemius, direct arm of the semimembranosus, and posteromedial joint capsule is then developed, and a meniscal retractor is placed to protect the posterior neurovascular structures.

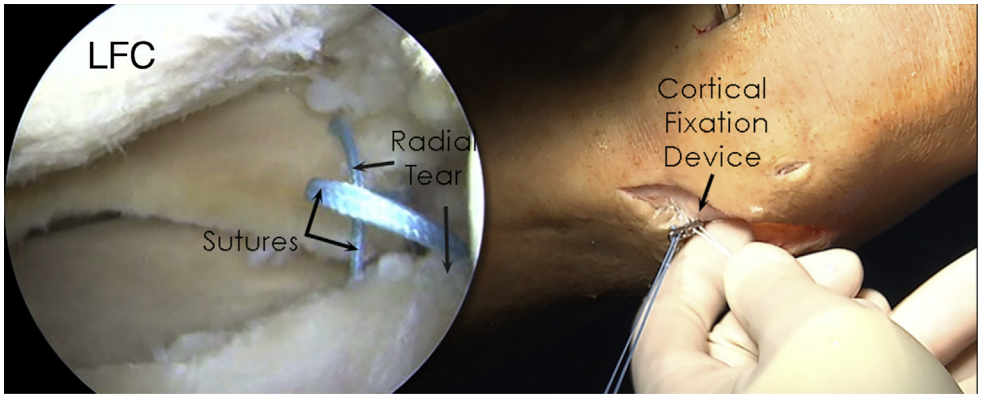

Fig 4. Arthroscopic view (left) showing the anatomic reduction of the radial tear and operative view (right) showing extra-articular tying of the knot to secure it to the anteromedial tibial cortex with a button device in a right knee. (LFC, lateral femoral condyle.)

HOWARD HEAD SPORTS MEDICINE
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Meniscus Repair

Name: _____ DOB: _____
Dr: Robert F. LaPrade, M.D., Ph.D. Date: _____

ROM RESTICTIONS

PROM 0-90 x 2 wks.

BRACE SETTINGS

0-0 x 6 weeks

Weight Bearing status

NWB x 6 wks.

TIME LINES

Week 1(1-7POD)
Week 2(8-14POD)
Week 3(15-21POD)
Week 4(22-28POD)

●= Do exercise for that week

Week														
Initial Exercises	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**16**	**20**	**24**
Flexion/Extension - wall slides	●	●	●	●	●	●	●	●						
Flexion/Extension – seated	●	●	●	●	●	●	●	●						
Patella/Tendon mobilization	●	●	●	●	●	●	●	●						
Extension mobilization	●	●	●	●	●	●	●	●						
Quad series	●	●	●	●	●	●	●	●						
Hamstring sets							●	●	●	●				
Sit and reach for hamstrings (towel)	●	●	●	●	●	●	●	●	●	●				
Ankle pumps	●	●	●	●	●	●	●	●	●	●				
Toe and heel raises							●	●	●	●				
Balance series								●	●	●	●	●	●	●
Cardiovascular Exercises	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**16**	**20**	**24**
Bike/Rowing with well leg	●	●	●	●	●	●	●	●						
Bike with both legs – no resistance							●	●	●					
Bike with both legs - resistance									●	●	●	●	●	●
Aquajogging									●	●	●	●	●	●
Treadmill – walking 7% incline									●	●	●	●	●	●
Swimming with fins										●	●	●	●	●
Elliptical trainer											●	●	●	●
Rowing											●	●	●	●
Stair stepper												●	●	●
Weight Bearing Strength	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**16**	**20**	**24**
Double knee bends							●	●	●	●	●	●	●	
Double leg bridges									●	●	●			
Reverse lunge – static hold							●	●	●	●	●			
Beginning cord exercises									●	●	●			
Balance squats										●	●	●	●	●
Single leg deadlift										●	●	●	●	●
Leg press										●	●	●	●	●
Sports Test exercises											●	●	●	●
Agility Exercises	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**16**	**20**	**24**
Running progression												●	●	●
Initial – single plane												●	●	●
Advance – multi directional													●	●
Functional sports test													●	●
High Level Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**16**	**20**	**24**
Golf												●	●	●
Outdoor biking, hiking, snowshoeing												●	●	●
Skiing, basketball, tennis, football, soccer													●	●

No deep squats or sitting cross-legged x 4 months

Therapist Name:

Fig 5. Postoperative protocol for a 2-tunnel radial meniscal repair. (NWB, non−weight bearing; POD, postoperative day; PROM, passive range of motion; Quad, quadriceps; ROM, range of motion.)

Table 1. Advantages, Risks, and Limitations

Advantages	Risks and Limitations
There is a significant decrease in the gap distance at the repair site.	
By anchoring the meniscus to the tibia, transtibial sutures decrease the dissipating forces produced by the femur onto the meniscus.	The long-term consequences of decreased meniscal mobility are undetermined.
The release of biological factors near the tear site due to tunnel drilling may have beneficial effects.	Care must be taken when drilling into the joint space to avoid iatrogenic osteochondral damage.

At this point, 2 inside-out sutures using standard No. 2-0 meniscal suture material are placed on both the superior and inferior portion of the meniscus in a horizontal mattress fashion as previously described. The inside-out sutures are passed arthroscopically with an assistant retrieving the needle through the medial knee incision. The sutures are tied directly onto the joint capsule. The deep tissues are closed with No. 0 and 2-0 Vicryl followed by a running subcuticular Monocryl stitch (Ethicon [Johnson & Johnson], New Brunswick, NJ).

Postoperative Protocol

Non–weight bearing is recommended for 6 weeks. Passive range of motion is restricted from 0° to 90° of flexion for the first 4 weeks and increased as tolerated thereafter. After 6 weeks, partial protected weight bearing and cycling on a stationary bike are initiated. A medial unloader brace is used to protect the repair once the weight-bearing phase commences. Deep squatting, leg lifting, and sitting cross-legged are prohibited for 4 months postoperatively to maximize healing potential. After 4 months, the patient is allowed to resume unlimited low-impact activities (Fig 5).

Discussion

This article details our crisscross transtibial repair technique for the treatment of radial midbody tears of the medial menisci. This anatomic repair technique increases the stability of the repair construct.[14] An enhancement in the capacity to repair medial meniscus radial tears, as well as improve the patients' healing rate, ultimately results in improved preservation of the articular cartilage of the medial compartment of the knee.[15]

It has been reported that a complete radial tear of the medial meniscus significantly decreases the ability of the meniscus to dissipate tibiofemoral loads. This injury has been characterized as functionally similar to a total meniscectomy, potentially predisposing patients to early osteoarthritis. At present, there is no consensus regarding the optimal surgical treatment of a radial meniscal tear, and current repair techniques have shown high rates of incomplete or nonanatomic healing, especially toward the interior and midportion of the menisci.[10] The all-inside technique for midbody tears of the lateral meniscus described by Choi et al.[9] showed poor results at 3 years of follow-up on magnetic resonance imaging, with a 57% rate of partial healing and a 7% rate of no healing. Similarly, in a retrospective review of 14 patients undergoing all-inside repair of complete radial meniscal tears, Van Trommel et al.[16] described poor results, with just 60% of radial meniscal repairs (3 of 5) having excellent healing at second-look arthroscopy. Of these 3 patients with satisfactory radial tear healing, 2 still required subsequent partial meniscectomy to trim problematic flaps of tissue. In addition, Beamer et al.[17] reported on an all-inside versus inside-out technique for repairing radial meniscal tears in 36 fresh-frozen porcine menisci. The repairs were tested for cyclic loading and load to failure. For repair of radial tears of the meniscus, the vertical suture configuration created by the all-inside technique resulted in lower displacement, higher load to failure, and greater stiffness compared with the horizontal inside-out technique.

Other authors have advocated performing a partial meniscectomy of the inner portion of the meniscus combined with a double inside-out horizontal mattress repair of radial midbody meniscal tears given the poor rate of healing of the central third of the meniscus. Although all-inside repair techniques are technically easier than the method described in our report, these techniques have not been reported to provide consistently favorable healing rates and outcomes.[17]

In the described technique, the use of 2 crisscross sutures passing through 2 transtibial tunnels combined with a quadruple inside-out horizontal mattress suture significantly decreases the gap distance at the meniscal repair site, providing significantly more stability to the repair construct in an anatomic fashion.[14] In a prior case report, there was complete healing of all 3 zones of the meniscus, including the white-white junction, at second-look arthroscopy.[11] In addition, with our technique, we hypothesize that the contribution of biological factors, in the form of mesenchymal stem cells and growth factors released by the transtibial tunnel drilling directly underneath a midbody meniscal repair construct, may augment the meniscal healing response as it does in other tissue-healing repairs around the body.[13] Attempts at improving the healing rate of radial meniscal repairs, historically a very challenging problem, may have profound advancements for improved preservation of the articular cartilage in the medial compartment of the knee[2] (Table 1).

Although the technique is very effective at reducing the meniscus, there are inherent challenges. First, to

Table 2. Pearls and Pitfalls

Pearls	Pitfalls
Before the meniscal tear is repaired, meniscocapsular adhesions must be released to allow for more anatomic tear reduction.	
Transosseous tibial tunnels should be reamed so that their entry into the knee joint occurs at the meniscocapsular region of the tibia to allow for anatomic tear reduction.	Concurrent injuries should be considered in order to rule out secondary causes of ACL injury.
The first transosseous tunnel can be reamed with an ACL tibial aimer guide. The second tunnel should be reamed with a parallel drill guide to prevent tunnel convergence.	
Generally, it is easier to drill the posterior tunnel first.	
Suture passage is performed through one portal with a self-capture suture device or a crescent-shaped suture passer.	Alternative suturing methods can be considered, but care must be taken to avoid any osteochondral damage, particularly with devices that possess suturing tools oriented superiorly toward the femur.
A nitinol lasso can aid in shuttling the suture through the transosseous tunnels.	The suture should be passed through the meniscus at the posterior corner of each flap to aid in creating a more anatomic reduction.
The sutures are crisscrossed in orientation, with the posterior suture passed through the anterior tunnel and the anterior suture passed through the posterior tunnel.	
Arthroscopic visualization and probing of the reduced tear are used to confirm the correct tensioning of the sutures before final knot tying.	
The sutures are tied directly over a button on the anteromedial cortex.	To ensure that the button is securely fixated on the anteromedial tibial surface, the surgeon should use a No. 15 surgical blade to remove any remaining fascial tissue at the entrance site of the 2 tunnels.
To perform placement of the inside-out meniscal sutures, a probe is used to approximate the incision location to allow for the most convenient suturing trajectory.	A meniscal retractor is placed to protect the posterior neurovascular structures.

ACL, anterior cruciate ligament.

reduce the meniscus from the extruded position, the peripheral attachments of the scarred, unreduced meniscus must be freed using arthroscopic scissors. Failing to do so will not allow an end-to-end reapproximation when the crisscross sutures are tensioned. Second, a valiant effort should be made to position the tibial tunnels as peripherally as possible on the tibial plateau. This allows a more anatomic reduction and lessens the chance of the meniscus being reduced too centrally in the medial compartment. Third, the importance of the inside-out sutures cannot be overstated. At least 2 horizontal mattress sutures should be placed on the superior surface of the meniscus and 2 sutures on the inferior surface. From a risk standpoint, the greatest inherent risk related to crisscross radial meniscal repair, similar to all meniscal repair, is lack of healing of the repair construct. Failure to heal may be the result of poor biological factors and may necessitate a partial meniscectomy procedure. Table 2 details pearls and pitfalls of this technique.

An important observation with the 2-tunnel radial repair method is that this technique effectively anchors the medial meniscus to the medial tibial plateau. Although there may be some concerns that this configuration may limit medial meniscal motion after healing, it should be noted that the medial meniscus, as noted by various authors, inherently is effectively immobile on the proximal tibia because of meniscocapsular attachments as well as attachments to the deep portion of the medial collateral ligament.[18]

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