Technical Note

Anatomic Reinforced Medial Meniscal Root Reconstruction With Gracilis Autograft

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Abstract: Meniscal root tears, left untreated, result in accelerated progression of arthritis. Numerous techniques to repair medial meniscus posterior root tears have been presented in the literature. Direct repair of the meniscus to bone without reconstructive tissue may result in a nonanatomic and biologically weak construct with a significant number of structural repair failures. Re-creation of the ligament-like structures that fix the meniscal root to bone is critical to restoring normal knee biomechanics. We present an arthroscopic reconstructive technique using gracilis autograft with suture reinforcement for medial meniscus posterior root tears.

The menisci play important roles in knee force transmission, load distribution, stability, and proprioception.[1,2] Complete tears of the meniscal root essentially renders the meniscus nonfunctional, resulting in loss of hoop stresses and increased contact pressures comparable to a knee that has undergone a total meniscectomy.[3] If left untreated, it has been shown to strongly correlate with progressive symptomatic joint arthritis; therefore, meniscal root repair and/or reconstruction can be surgically performed in an attempt to re-establish the normal biomechanics of the knee.[4,5] Numerous studies have been performed on meniscal root anatomy and repair techniques; however, none recreate the normal meniscal root tensile strength at time 0, and repair techniques do not provide additional collagen to strengthen and stimulate biologic healing at the meniscus-bone interface.[6-8] Andrews et al.[9] identified a ligament-like structure that attaches the meniscal root to the tibial plateau and then transitions into the fibrocartilaginous meniscal body, thus grafting to recreate a ligamentous structure is a logical transition. Recently, Li et al.[10] showed in a rabbit model that tendon grafting reproduced the structural and chondroprotective properties of the meniscus, which reinforces a theoretical basis for tendon graft to meniscus healing and fibrocartilaginous metaplasia. Clinical results of medial meniscus posterior root tear repairs have been reported and show promising clinical improvements. Postoperative magnetic resonance imaging (MRI) and second-look arthroscopy studies show lower rates of complete healing, with repairs producing only partial healing.[11] Many repairs have not reversed or prevented meniscal extrusion; thus, the ideal repair or reconstruction technique remains elusive. Our focus is to create a high-strength anatomic construct with improved potential for biologic and structural healing. We present an anatomic, reinforced medial meniscal root reconstruction technique with gracilis autograft (Video 1).

Surgical Technique

Gracilis Tendon Harvest and Graft Preparation

Standard arthroscopic anterolateral, anteromedial, and optional posteromedial portals are created and a knee survey is done confirming the medial meniscus posterior root tear. There should be no greater than Outerbridge Grade II chondromalacia of the medial compartment to proceed with the root reconstruction. An additional central portal is created for suture management. A "pie crust" technique with an 18-gauge needle is used to release the superficial medial

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collateral ligament (MCL) to improve visualization. The gracilis tendon is harvested via a 2-cm longitudinal incision over the pes anserinus. The tendon is dissected and harvested with a tendon stripper. The graft is prepared and shortened to 8 cm. The ends are then whip-stitched with a No. 0 braided nylon suture (FiberLoop; Arthrex) and paired down in size to fit through 3-mm-diameter tunnels. The doubled graft diameter should fit through a 6-mm sizer, which is the size of the tibial tunnel. The graft is placed under tension and covered with saline-soaked gauze until further use.

Arthroscopic Tibial Tunnel Preparation

Viewing through the anterolateral portal, the torn meniscal root tissue is debrided from the meniscal root edge. Anatomic landmarks relevant to the insertion of the meniscal root are then identified: medial meniscus posterior root, insertion of the posterior cruciate ligament, medial tibial spine, and the tibial articular margins (Fig 1). Using an arthroscopic guide through the anteromedial portal either an anterior cruciate ligament (ACL) tibial tip—tip guide or meniscal root guide (Arthrex), a 6.0-mm retrograde reamer (FlipCutter; Arthrex) is drilled into the anatomic center of the meniscal root insertion. Initially, the tip—tip guide was used in practice, but recently the meniscal root guide has been used in an inverted fashion to locate the reamer in the anatomic footprint (Fig 2).

The guide is removed and the position of the guide wire/reamer is then checked to ensure proper position (Fig 3). The Flipcutter cutting fin is deployed and the 6.0-mm tibial tunnel is reamed in a retrograde fashion to a depth of 30 mm. Bony debris is cleared and shuttle suture is placed in the tibial tunnel and parked in the central portal.

Suture, Internal Brace, and Gracilis Autograft Passage and Fixation

A suture-passing device is used (Knee Scorpion; Arthrex) to allow passage of No. 0 suture shuttle

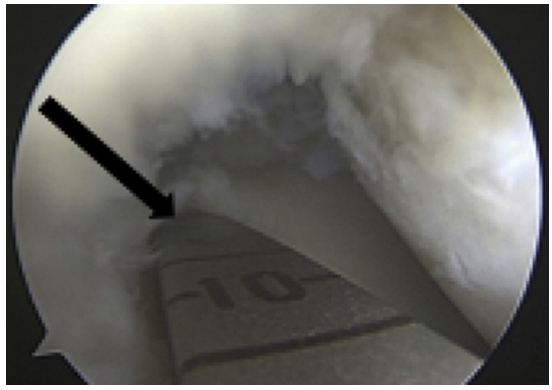

Fig 2. Viewing from the anterolateral portal of the right knee, the tip to tip guide (black arrow) is placed over the tibial spine at the medial meniscal posterior root insertion.

(FiberLink; Arthrex), which is used throughout the procedure to shuttle larger sutures (Figs 4 and 5). We use No. 2 suture tape (SutureTape; Arthrex) as an inverted horizontal mattress suture and collagen-coated braided nylon suture tape (InternalBrace; Arthrex) in vertical mattress fashion. The suture can be passed in the order the surgeon desires. We typically pass the InternalBrace, the SutureTape, and then the graft passage. The SutureTape is placed 4 to 5 mm from the torn end of the meniscus, and the internal brace is placed 4 to 5 mm medial to the SutureTape. It is imperative to accurately place the suture and to keep the internal brace 2 to 3 mm from the periphery of the meniscus for optimal fixation of the construct. The suture is shuttled into the tibial tunnel with a previously placed suture loop (Fig 6). When shuttling the sutures into the tibial tunnel, another suture loop is included for later shuttling of the graft sutures. A "soft tissue tunnel" is created for the graft in the medial meniscus. This tunnel is created 4 to 5 mm medial to the internal brace and placed at the periphery of the meniscus 2 to 3 mm from the meniscosynovial junction. The steps to create the

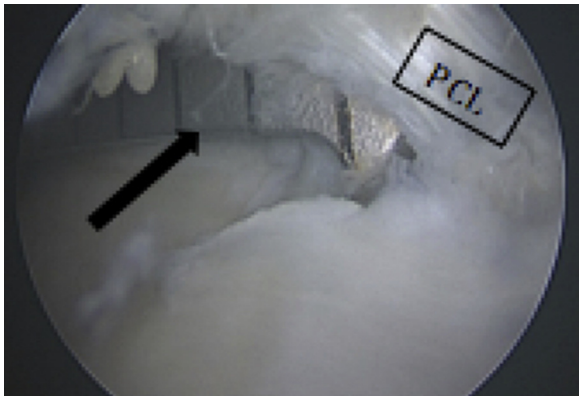

Fig 1. Viewing from a posteromedial portal of the right knee, the tip-to-tip guide (black arrow) is placed in close relationship to the PCL before reaming the tibial tunnel. (PCL, posterior cruciate ligament.)

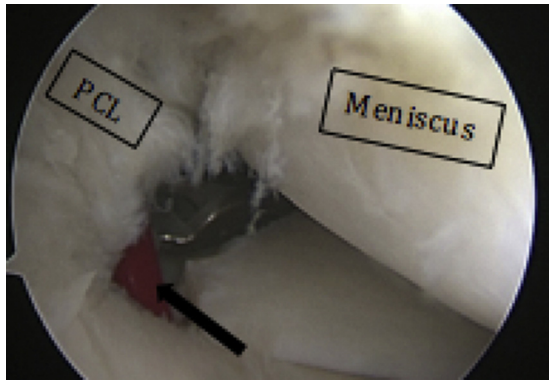

Fig 3. Viewing from the anterolateral portal of the right knee, the tunnel placement at the MMPR insertion is marked by a red Arthrex TigerStick (black arrow). (MMPR, medial meniscal posterior root; PCL, posterior cruciate ligament.)

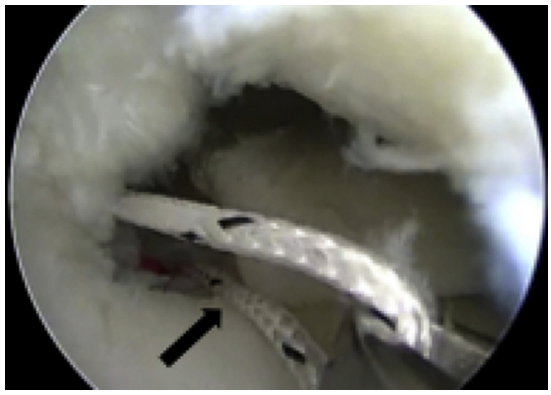

Fig 4. Viewing from the anterolateral portal of the right knee, the tibial tunnel shuttle suture (black arrow) is brought through the medial portal.

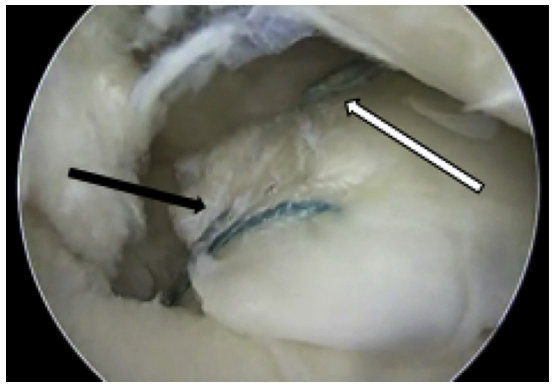

Fig 6. Viewing from the anterolateral portal of the right knee, the internal brace (white arrow) and suture tape (black arrow) have been shuttled into the tibial tunnel.

tunnel are as follows: (1) pass a No. 0 suture shuttle, (2) pass doubled No. 2 braided nylon (FiberWire; Arthrex) and saw back and forth to begin dilating, (3) pass quadrupled FiberWire with the same sawing motion, (4) pass single-braided nylon tape (FiberTape; Arthrex), and (5) pass doubled FiberTape once again with a back and forth sawing motion. The tunnel should now be ready to accept the graft. The graft is passed from superior to inferior through the meniscus (Fig 7). A shuttle is used to pull the suture through and the graft is teased through the meniscus until equal lengths inferiorly and superiorly are obtained. The graft sutures are passed down through the tibial tunnel and ready for fixation (Fig 8). A suture retriever or probe is used to position the sutures and graft in parallel and situated in the tibial tunnel. The knee is passed through numerous flexion–extension cycles to remove any slack and reduce creep. The suture tape/InternalBrace are fixed first with a 4.75-mm PEEK (polyether ether ketone) knotless suture anchor (SwiveLock; Arthrex) while simultaneously tensioning the sutures and arthroscopically visualizing the construct (Fig 9). The knee is typically in 30° of flexion for this step. Appropriate tension is placed on the graft, and the graft sutures are fixed in the same manner as described previously with a second suture anchor. The knee is passed through numerous flexion–extension cycles to make certain the construct remains properly tensioned. The knotless anchors allow retensioning if loosening occurs during the fixation process. Once the surgeon is pleased with the construct (Fig 10), the arthroscope is removed, wounds are closed, and dressings applied. Postoperatively, the patient is toe-touch weight bearing for 6 weeks in a hinged brace. Patients are allowed to increase their motion as tolerated with the physical therapist but no passive flexion beyond 90° in the first 6 weeks. The patient is weight bearing as tolerated after 6 weeks. Tables 1 and 2 outline important considerations for medial meniscal root reconstruction.

Discussion

Although it appears as a relatively innocuous injury on MRI, numerous authors have published on the long-

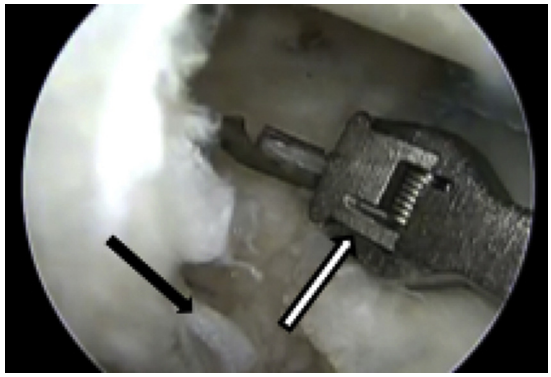

Fig 5. Viewing from the anterolateral portal of the right knee, the sutures and internal brace are shuttled through the meniscus using the suture shuttle passage with a Knee Scorpion (white arrow) and a white No. 0 FiberLink shuttle (black arrow).

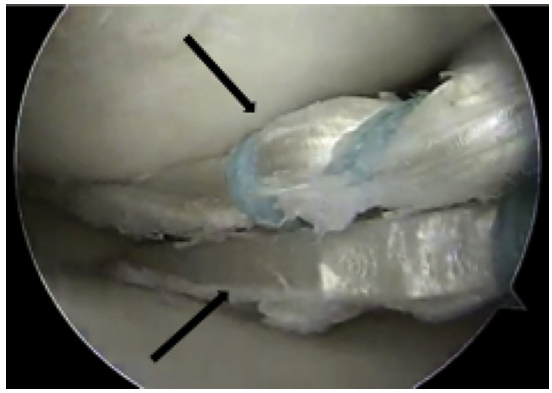

Fig 7. Viewing from the anterolateral portal of the right knee, the soft tissue tunnel for the graft is dilated with multiple passes of No. 2 suture and doubled FiberTape. The graft is passed superior to inferior and equal length tails are obtained (2 black arrows). The graft can now be shuttled into the tibial tunnel.

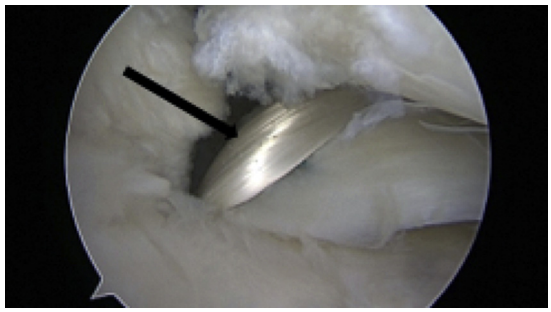

Fig 8. Viewing from the anterolateral portal of the right knee, the graft (black arrow) has been shuttled into the tibial tunnel and placed under tension.

term sequelae and severity of a posterior medial meniscus root injury with rapid progression to osteoarthritis in the involved compartment.[1-3] Numerous studies have been published on transtibial medial meniscus root repair techniques, clinical follow-up, and strength of repair. Short-term clinical results of these repairs have been promising; however, studies of the anatomic healing of the repair are lacking and second-look arthroscopy studies have shown a low rate of complete healing. Feucht et al.[12] reviewed available studies, with 30-month average follow-up, of meniscal root repairs finding that meniscal extrusion was reduced in 56% and complete healing by MRI or second-look arthroscopy was 62%. Suture anchor repair of meniscal roots has shown only 50% healing rate on MRI and increased meniscal extrusion in 59% at 1 year postoperatively by MRI.[11]

Our hypothesis is that adding additional collagenous tissue such as a tendon graft to the meniscal repair construct will facilitate a higher rate of complete meniscus-to-bone healing, improved chondroprotection, and reduced extrusion. In this report, we present an anatomic, reinforced reconstruction technique that has great potential to resist initial displacement and provide a biologic construct to allow for renewed ligamentization of the attachment to bone as Andrews et al.[9] described. In recent literature, Lee et al.[13] developed a similar meniscal root reconstruction technique using gracilis graft with the similar goal to recreate and reposition the meniscal root in anatomic position. Their technique solely focuses on the gracilis autograft without any type of suture or internal brace reinforcement. In addition, the preparation of the torn meniscus for graft passages differs from the atraumatic dilatation of the soft tissue tunnel as indicated previously.

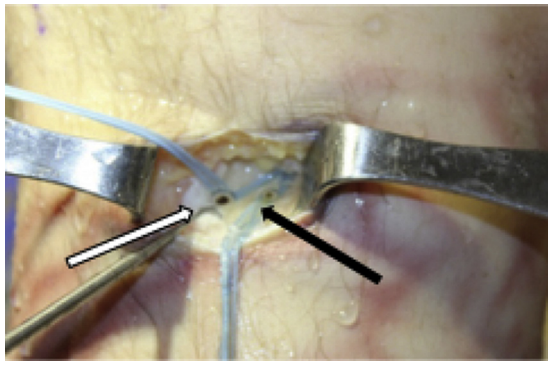

Fig 9. Anterior right tibial incision showing the suture tails of the suture tape and internal brace are tensioned and fixed with a SwiveLock knotless anchor (black arrow) to the tibial metaphysis. Subsequently, the suture tails of the graft (white arrow) are fixed. Arthroscopic visualization is maintained to ensure appropriate position and tension of the construct.

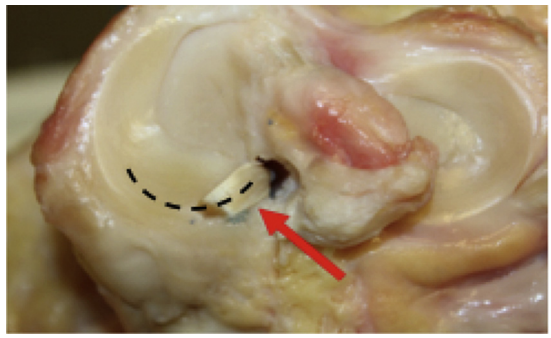

Fig 10. Disarticulated right knee viewed from above demonstrating anatomic reconstruction of medial meniscus posterior root tear (red arrow). Reinforcing sutures and internal brace are completely covered with graft and not exposed to articular surface of femur or tibia. The vector of the hoop stresses (dashed black arrow) of the meniscal root closely approximates the normal anatomy.

In our graft model at time 0, there is a collagen bridge from the bony tunnel to the meniscus itself. We propose that the tendinous graft will heal to meniscus and that the graft will heal into the bony tunnels to allow for sufficient contact surface area on both ends to allow healing. In the ACL model, there are volumes of data describing tendon to bone healing within a bony tunnel;

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
1. Release superficial MCL with an 18-gauge spinal needle using the "pie crust" technique.	1. Current root guides are imperfect at easily locating the meniscal root insertion.
2. Place the tibial tunnel in an anatomic footprint with a root guide and flip cutter.	2. Current meniscal suture passers are difficult to use in the thick, peripheral meniscus.
3. Dilate a "soft tissue tunnel" with a sequentially larger-diameter suture/suture tape.	
4. Pass the graft from superior to inferior.	
5. Always keep a shuttle in the tunnel until all sutures have been passed.	

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
1. Meniscal root reconstruction can restore meniscal anatomy, hoop tension, and provide chondroprotection.	1. Meniscal root reconstructions are more complex and require higher surgical skill than simple repairs.
2. The procedure provides reattachment to the anatomic footprint and cartilaginous graft to facilitate healing.	2. Donor site morbidity may occur from gracilis graft harvest.
3. Reinforcement of the graft with sutures and an internal brace provide greater initial strength.	3. Surgical time is increased.

therefore, there is a high level of confidence that that will occur with proper fixation. With regard to healing of the graft to the meniscus, Li et al.[10] demonstrated successful use of autograft semitendinosus for meniscal reconstruction in a rabbit model demonstrating metaplasia to fibrochondrocytes and similar strength of the healed reconstruction to native meniscus. Although this does not guarantee meniscus-to-graft healing, we believe there is a high likelihood of healing into a meniscal "root-like" structure. The limitations of this procedure lie primarily in its complexity and working in a tight medial joint space. It is no more complex than commonly performed reconstruction procedures such as ACL reconstruction or meniscal transplantation, however. In addition, with release of the superficial MCL, we have been able to obtain sufficient working space to complete the procedure and avoid posteromedial portal. In addition, we are working with first-generation meniscal root guides and suture passers. Second-generation instrumentation is being developed by multiple manufacturers, and we are optimistic they will significantly simplify this technique. Other limitations lie in the uncertainty of patient indications. It is our belief that arthrosis should be no greater than Outerbridge Grade II, but we currently have no limitations for meniscal extrusion. "Significant" bone edema on MRI may also be a contraindication, but there are no firm data to use for guidance. Risks of the procedure include all of those typical for arthroscopic knee reconstructive procedures, including risk of failure of this procedure to achieve meniscal healing.

In summary, this arthroscopic, anatomic, and reinforced meniscal root reconstruction is expected to yield improved healing rates and clinical results compared with direct repair techniques. Future study is warranted, and clinical studies including postoperative imaging studies are ongoing.

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References

1. Fukubayashi T, Kurosawa H. The contact area and pressure distribution pattern of the knee: A study of normal and osteoarthritic knee joints. *Acta Orthop Scand* 1980;51:871-879.
2. Starke C, Kopf S, Lippisch R, Lohmann CH, Becker R. Tensile forces on repaired medial meniscal root tears. *Arthroscopy* 2013;29:205-212.
3. Bhatia S, LaPrade CM, Ellman MB, LaPrade RF. Meniscal root tears: Significance, diagnosis, and treatment. *Am J Sports Med* 2014;42:3016-3030.
4. Kim SB, Ha JK, Lee SW. Medial meniscus root tear refixation: Comparison of clinical, radiologic, and arthroscopic findings with medial meniscectomy. *Arthroscopy* 2011;27:346-354.
5. Faucett SC, Geisler BP, Chahla J, et al. Meniscus root repair vs meniscectomy or non-operative management to prevent knee osteoarthritis after medial meniscus root tears: Clinical and economic effectiveness. *Am J Sports Med* March 1, 2018 [Epub ahead of print].
6. Feucht MJ, Grande E, Brunhuber J. Biomechanical evaluation of different suture materials for arthroscopic transtibial pull-out repair of posterior meniscus root tears [published online September 3, 2013]. *Knee Surg Sports Traumatol Arthrosc* September 3, 2013 [Epub ahead of print].
7. Kopf S, Colvin AC, Muriuki M, Zhang X, Harner CD. Meniscal root suturing techniques: Implications for root fixation. *Am J Sports Med* 2011;39:2141-2146.
8. Mitchell R, Matava M, Pitts R, Kim YM. Medial meniscus root avulsion: A biomechanical comparison of four different repair constructs. *Arthroscopy* 2013;29:e32.
9. Andrews SH, Rattner JB, Jamniczky HA, Shrive NG, Adesida AB. The structural and compositional transition of the meniscal roots into the fibrocartilage of the menisci. *J Anat* 2015;226:169-174.
10. Li C, Hu X, Meng Q, et al. The potential of using semitendinousis tendon autograft in rabbit meniscus reconstruction. *Sci Rep* 2017;7:7033.
11. Chung KS, Ha JK, Ra HJ, Nam GW, Kim JG. Pullout fixation of posterior medial meniscus root tears: Correlation between meniscus extrusion and midterm clinical results. *Am J Sports Med* 2017;45:42-49.
12. Feucht MJ, Kuhle J, Bode G, et al. Arthroscopic transtibial pullout repair for posterior medial meniscus root tears: A systematic review of clinical, radiographic, and second-look arthroscopic results. *Arthroscopy* 2015;31:1808-1816.
13. Lee DW, Haque R, Chung KS, Kim JG. Arthroscopic medial meniscus posterior root reconstruction using autogracilis tendon. *Arthrosc Tech* 2017;6:e1431-e1435.