

Knotless Medial Meniscus Posterior Root Repair

Sachin Ramchandra Tapasvi, M.B.B.S., M.S.(Ortho.), D.N.B., F.R.C.S.(Glasgow),
Anshu Shekhar, M.B.B.S., M.S.(Ortho.), and
Shantanu Sudhakar Patil, M.B.B.S., M.S.(Ortho.)



Abstract: Medial meniscus posterior root tears are common injuries, especially in the Asian world. This injury must be repaired where indicated to restore knee biomechanics and prevent arthritis. Suturing the meniscus using suture tapes provides good hold of the tissue. The use of a 70° arthroscope and creation of a transeptal portal improve visualization of the posterior compartment. Creation of a high posteromedial portal achieves the correct trajectory for the suture anchor insertion. A knotless suture anchor can be used to fix the posterior root at its anatomic attachment site. This obliterates the need for transtibial drilling for a suture pull-out repair or for knot tying and suture shuttling as for a conventional suture anchor.

Medial meniscus posterior root tears (MMPRT) are increasingly being diagnosed due to better understanding of the pathology, better imaging, and improved arthroscopic practice. The detrimental effect that this injury can have is accepted and is known to lead to an increase in peak contact pressure by 25%, akin to total medial meniscectomy, progressive arthritis, and instability.¹ The derangement of biomechanics of the medial compartment of the knee is due to extrusion of the meniscus. The degree of extrusion has recently been shown to increase progressively within a short duration of the root tear based on magnetic resonance imaging (MRI) evaluation.² The risk factors for an MMPRT include female sex, increased body mass index, lower sports activity level, severe varus deformity, increased posterior tibial slope, and anterior cruciate ligament deficiency.^{3,4}

There are 2 standard techniques for repairing the torn posterior root of the medial meniscus: either using pull-out sutures through a transtibial tunnel and tying the sutures over an implant or inserting suture anchors, passing the sutures through the meniscus and tying it down. Whether either technique restores normal knee biomechanics is a matter of debate, but securing attachment to bone until such time that healing occurs is important. We describe here our technique of MMPRT repair using suture tapes and a knotless suture anchor.

Indications for Surgery

Patients with MMPRT benefit from repair in terms of symptomatic relief and prevention of degenerative joint disease.⁵ Acute and chronic degenerative tears must be repaired to achieve these outcomes. Arthroscopic repair, however, is best reserved for patients with good cartilage status and relatively acute tear. Patients who are high risk due to medical comorbidities or advanced age can be managed nonsurgically.⁵ Another contraindication for repair is the presence of Outerbridge grade 3 or 4 chondral changes in the medial compartment as these patients have a poor outcome.⁶ Also, patients with varus malalignment must undergo a simultaneous or prior osteotomy to correct the alignment.⁷ A varus of 3° is probably acceptable.⁸

Surgical Technique

Diagnostic Arthroscopy and Preparing the Meniscus Bed

After induction of appropriate anesthesia, the patient is placed in the supine position. A high thigh tourniquet

From the Orthopaedic Specialty Clinic (A.S., S.R.T., S.S.P.), Pune; and Translational Medicine and Research, SRM Medical College and Hospitals, SRM University (S.S.P.), Kattankulathur, Tamil Nadu, India.

The authors report the following potential conflicts of interest or sources of funding: S.R.T. receives support from Zimmer Biomet India and Sanofi Biosurgery. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received October 26, 2017; accepted November 8, 2017.

Address correspondence to Shantanu Sudhakar Patil, M.B.B.S., M.S.(Ortho.), The Orthopaedic Speciality Clinic, 16 Status Chambers, 1221/A Wrangler Paranjpe Road, Pune 411004, India. E-mail: shantanusp@gmail.com

© 2017 by the Arthroscopy Association of North America. Published by Elsevier. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

2212-6287/171313

<https://doi.org/10.1016/j.eats.2017.11.002>

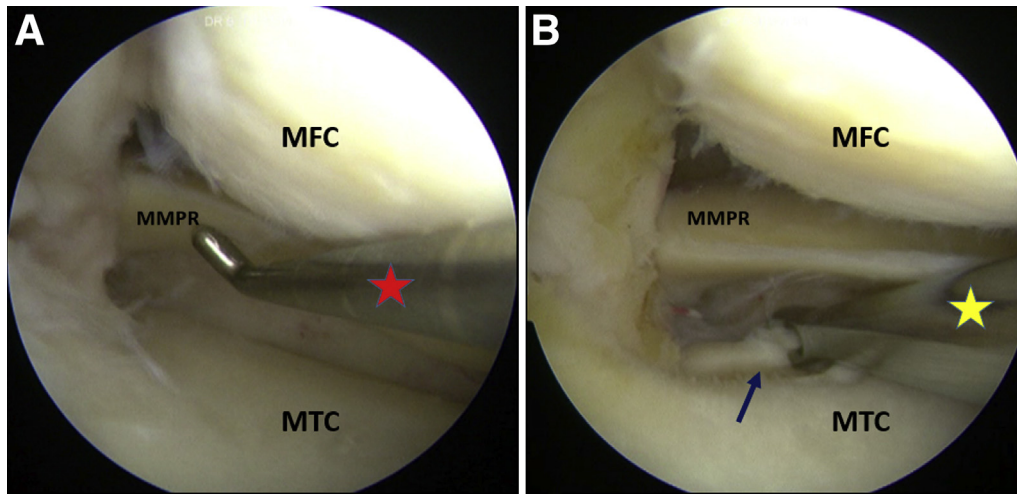


Fig 1. Arthroscopic diagnosis of a medial meniscus posterior horn tear and preparation of its bed for reattachment. (A) Right knee arthroscopy, viewing from the anterolateral portal with knee in 20° flexion and application of valgus, external rotation force. A hook probe (red star) is inserted from the anteromedial portal, and probing of the meniscus root is performed. This confirms the presence of the tear. (B) An arthroscopic curette (yellow star) is inserted from the anteromedial portal, while viewing from the anterolateral portal. The cartilage at the anatomic root insertion is removed to expose raw subchondral bone. (MFC, medial femoral condyle; MMPR, medial meniscus posterior root; MTC, medial tibial condyle.)

is applied with side support and table flat. After preparation, the tourniquet is inflated, a high anterolateral (AL) portal is created, and a diagnostic round is performed to assess the medial compartment chondral status, presence of root tear, and any ligamentous pathology with a 30° arthroscope. It is sometimes difficult to visualize the root, and this can be improved by pie crusting of the medial collateral ligament with an 18 FG hypodermic needle while a valgus, external rotation force is applied. A standard anteromedial (AM) working portal is created, and careful probing of the root is carried out to confirm a tear. Feasibility of repair is assessed by evaluation of the quality of meniscus tissue, site of tear, and cartilage status. An arthroscopic curette is inserted from the AM portal, and the cartilage at the root attachment site is removed to create a bed of raw subchondral bone while a valgus, external rotation force is applied with the knee in 20° flexion (Fig 1).

Suturing the Meniscus

The knee is kept in 20° flexion, a knee Scorpion (Arthrex, Naples, FL) self-suture retrieving device is loaded with no. 0 FiberWire (Arthrex), and a bite is taken in the meniscus near the root to obtain a simple stitch. The FiberWire is retrieved through the AM portal, and a SutureTape (Arthrex) is tied to one end. The other end of the FiberWire is pulled, and thus the SutureTape gets shuttled through the meniscus to obtain a simple loop stitch (Fig 2). This step is repeated to obtain 2 SutureTape passes through the meniscus root. The ends of the tape are retrieved through the AM portal, and hemostat is applied. A motorized shaver is

used to clear the septum (Fig 3A), and the scope is advanced transeptally to visualize the posteromedial (PM) compartment with the knee in 90° flexion as first described by Ahn et al.⁹ A high PM portal is then created about 4 cm proximal to the joint line by the outside-in technique using an 18 FG spinal needle, with the gastrocnemius fold acting as a landmark (Fig 3B), and an 8.0 mm cannula (Stryker, Kalamazoo, MI) is inserted over a Wissinger rod. The Wissinger rod is also used to confirm a straight trajectory from the PM portal to the root (Fig 4A). Each end of the tape is then shuttled posteriorly over a knot pusher inserted from the AM portal with the knee in 20° flexion while visualizing posteromedially with the scope passed transeptally from AL portal. The 4 tape ends are retrieved out of the PM portal using a suture grasper and parked there (Fig 4 B and C).

Fixation

All 4 ends of the suture tapes are loaded into the eyelet of a 4.75 × 19.1 mm BioComposite SwiveLock (Arthrex) suture anchor and clamped. The 30° arthroscope is replaced by a 70° arthroscope and is inserted through the AL portal. This allows a bird's-eye view of the meniscus root attachment site. The knee is kept in 90° flexion, and the scope is advanced transeptally to focus at the root attachment on the tibia, which was previously prepared. An awl for the SwiveLock anchor is inserted through the high PM portal, and a pilot hole is created at the root attachment site by gentle tapping (Fig 5A). The driver is then inserted through the PM portal, and traction is applied to all suture tapes to

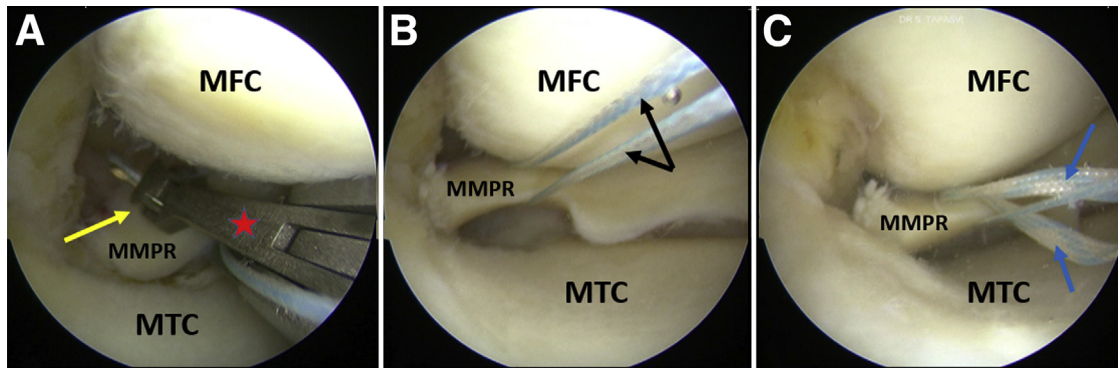


Fig 2. Suturing the meniscus root. (A and B) Right knee arthroscopy, viewing from the anterolateral portal with knee in 20° flexion and application of valgus, external rotation force. A knee Scorpion (Arthrex) self-suture retrieving device (red star) is loaded with no. 0 FiberWire (Arthrex) and inserted from the anteromedial portal, and a bite is taken in the meniscus near the root to obtain a simple stitch (black arrows). (C) A SutureTape (Arthrex; blue arrows) is tied to the previously passed suture and shuttled through the meniscus root to obtain a simple stitch. (MFC, medial femoral condyle; MMPR, medial meniscus posterior root; MTC, medial tibial condyle.)

remove any slack. It is gently tapped into the pilot hole until the anchor tip is seen. Gentle traction is applied to all the suture tapes, and the anchor is screwed in by turning in a clockwise direction completely under vision (Fig 5 B and C). The driver is removed, and the tip retention suture is pulled out. A 30° scope is again inserted from the AL portal, the attached root is visualized with the knee in 20° of flexion, and thorough probing is done from the AM portal to confirm the reduction and stability of the repair. The 3 portal site incisions are sutured, and sterile compression dressing is applied.

The arthroscopic surgical technique for right knee medial meniscus posterior root repair is explained in Video 1. The advantages of this technique to repair an MMPRT are enumerated in Table 1.

Rehabilitation

The initial priorities are pain relief, edema control, and quadriceps activation. The patient is mobilized non-weight bearing with the leg in a long knee brace in full extension. The meniscus translates posteriorly with flexion, especially beyond 60°, and this is detrimental for the repair.¹⁰ Knee flexion is restricted to 60° for the

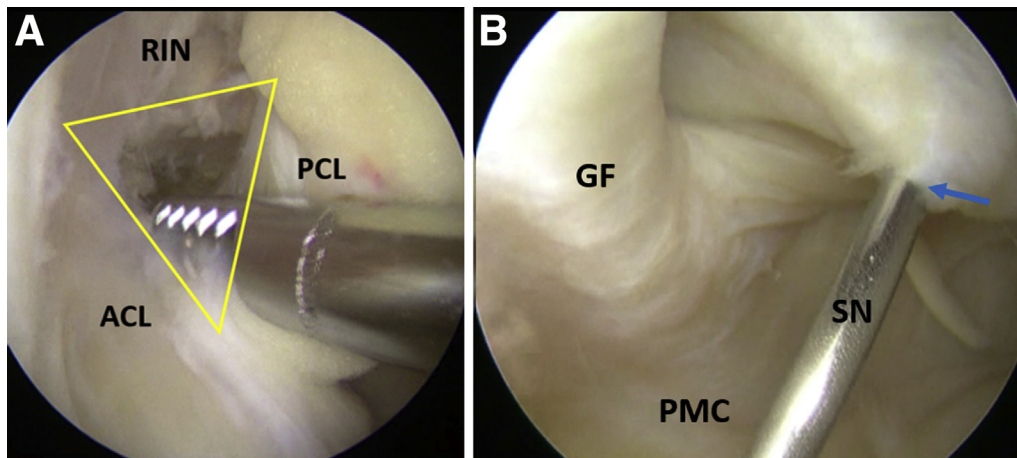


Fig 3. Creation of transeptal and high posteromedial portals. (A) Right knee arthroscopy, viewing from the anterolateral portal with knee in 90° flexion. A shaver is introduced from the anteromedial portal and advanced to the triangular area (yellow triangle) formed by the ACL, PCL, and roof of the intercondylar notch to clear the septum and allow passage of the arthroscope through this transeptal portal. (B) Right knee arthroscopy, viewing through the transeptal portal with knee in 90° flexion. The arthroscope is focused on the posteromedial capsule with the gastrocnemius fold acting as a landmark, and a high posteromedial portal is created, about 4 cm superior to the joint line. An 18 FG spinal needle is used to guide the creation of this high portal (blue arrow). (ACL, anterior cruciate ligament; GF, gastrocnemius fold; PCL, posterior cruciate ligament; PMC, posteromedial capsule; RIN, roof of intercondylar notch; SN, spinal needle.)

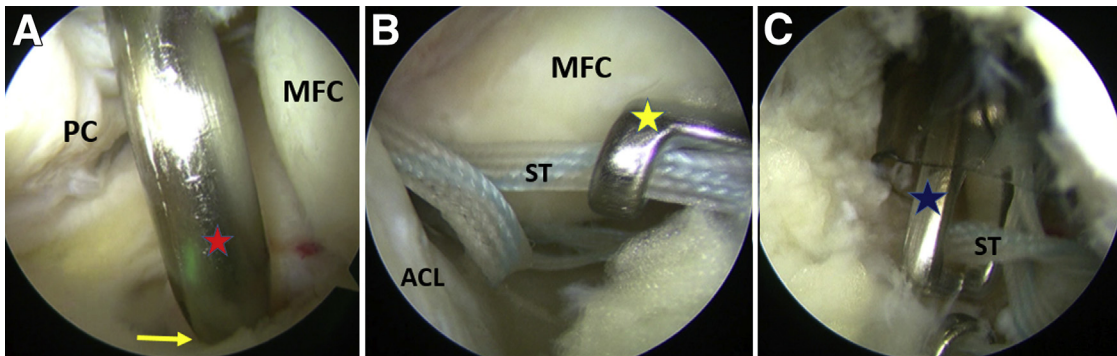


Fig 4. Shutting the sutures from anterior to posterior. (A) Right knee arthroscopy, viewing through the transeptal portal with knee in 90° flexion. After creation of the high posteromedial portal, a Wissinger rod (red star) is introduced through it and advanced to the previously prepared meniscus root bed (yellow arrow) to confirm a straight trajectory. This is important for easy anchor insertion. (B) Right knee arthroscopy, viewing through the anterolateral portal with knee in 90° flexion. Each SutureTape is sequentially loaded onto a knot pusher (yellow star), and this is advanced posteriorly into the posteromedial compartment. (C) Right knee arthroscopy, viewing through the transeptal portal with knee in 90° flexion. A suture retriever (blue star) is introduced through the high posteromedial portal, and each SutureTape is sequentially retrieved out of this portal to the external. (ACL, anterior cruciate ligament; MFC, medial femoral condyle; PC, posterior capsule; ST, SutureTape.)

initial 4 weeks, and full knee flexion is permitted only after 2 months, to protect the repair. Weight bearing generates hoop stresses, which can distract the repair and compromise healing.¹¹ Hence, patients are kept non-weight bearing for 4 weeks, followed by partial weight bearing for 2 weeks, and full weight bearing is allowed at the end of 6 weeks. Deep flexion activities like squatting are permitted only after 6 months.

Discussion

While comparing the various suture configurations for MMPRT repair in human menisci for maximum failure load, Kopf et al. found that the modified Kessler

stitch was stronger than the loop stitch, which in turn was stronger than 2 simple stitches for MMRT repair. No suture configuration recreated the strength of the native root.¹² In a similar study in porcine models, Feucht et al. found that modified Mason-Allen stitches provided the best biomechanical properties with regard to cyclic loading and load-to-failure testing. While 2 simple stitches were an alternative, a horizontal mattress suture and 2 loop stitches had lower stiffness and higher displacement during cyclic loading.¹³ However, application of complex suture configuration arthroscopically is extremely difficult in a small and tight area like the PM compartment of the knee. Using

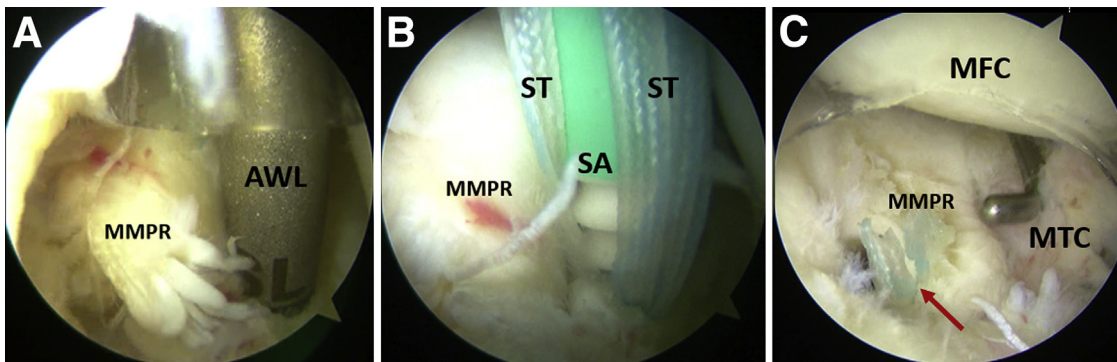


Fig 5. Fixation of the medial meniscus posterior root. (A) Right knee arthroscopy, viewing through the transeptal portal with knee in 90° flexion using a 70° arthroscope. An awl for the 4.75 mm SwiveLock suture anchor is introduced from the high posteromedial portal up to the prepared meniscus bed. The awl is tapped to the prescribed limit under vision to create a socket for suture anchor insertion. (B) Right knee arthroscopy, viewing through the transeptal portal with knee in 90° flexion using a 70° arthroscope. A 4.75-mm SwiveLock suture anchor that is loaded with the 2 suture tapes is introduced from the high posteromedial portal up to the socket. The tip of the anchor is tapped in, slack from all 4 ends of the suture tapes is removed, and the suture anchor is inserted by screwing motion until the meniscus root is fully dunked in. (C) Right knee arthroscopy, viewing through the posteromedial portal with knee in 90° flexion using a 70° arthroscope. The complete seating of the anchor is seen (red arrow), and a hook probe introduced from the posteromedial portal is used to probe the stability of the repair. (AWL, awl for the suture anchor; MFC, medial femoral condyle; MMPR, medial meniscus posterior root; MTC, medial tibial condyle; SA, suture anchor; ST, SutureTape.)

Table 1. Advantages of Knotless Anchor Medial Meniscus Posterior Root Tear Repair

1. No transtibial drilling and no incision over the shin, better cosmesis, and less pain.
2. Useful in association with ligament surgery by avoiding tunnel coalescence, especially in a multiligament reconstruction scenario.
3. Significantly reduced complexity when performed in association with high tibial osteotomy.
4. Firm fixation at point of attachment at or near the anatomic root.
5. No knotting issues as with knotted suture anchors.
6. Tapes provides better grip of meniscal tissue compared with sutures and avoid a “cheese cutter” effect.

appropriate suture material is also important. The ideal suture material should provide low displacement, high stiffness, and high maximum load to keep the root reattached while healing occurs.¹⁴ Feucht et al. evaluated various suture materials in porcine menisci, comparing biomechanical properties, and concluded that FiberWire (Arthrex) may be the preferred suture material for transtibial pull-out MMPRT repair due to comparably low displacement during cyclic loading and higher values for maximum stiffness and load. The 2 mm FiberTape (Arthrex) exhibited greater displacement, but this was a maximum of 1.46 mm, the clinical significance of which is unknown.¹⁵ The SutureTape (Arthrex) that has been used for this technique is narrower (1.3 mm) and causes less tissue trauma while passing.

There are 2 techniques of fixation of the sutured meniscus root to its bed on the tibia: either the pull-out technique through a transtibial tunnel or suture

anchors. Padalecki et al. have shown that in a cadaveric model, pull-out repair of root avulsions improved load distribution in the medial compartment at all angles of knee flexion. Their repair restored contact area and pressure to a level that was statistically similar to an intact meniscus state and reduced contact pressure while increasing contact area compared with a torn state.¹⁶ A similar conclusion has been arrived at by other investigators in cadaveric studies, and there is a strong basis to recommend repairing the torn root to restore normal joint biomechanics at all flexion angles.^{1,17} However, recognition of the arthroscopic anatomic landmarks for achieving an anatomic repair is crucial.¹⁸ A nonanatomic repair has been shown not to restore either the mean contact pressure or contact area to an intact meniscus or an anatomic repair state at all flexion angles in a cadaveric model.¹⁹ Stärke et al. have shown a narrow window for mechanically sufficient root repair in porcine models. A 3-mm displacement from the native attachment causes lower levels of meniscal hoop tension and increased cartilage deformation, indicating increased local stress in this study.²⁰

There are certain problems inherent in the transosseous repair technique, like the requirement of drilling a tunnel, which complicates associated ligament reconstruction; risk of suture abrasion within the tunnel prior to healing of the meniscus; and the possibility of creep within the suture reducing the strength of the repair.⁵ Arthroscopic repair of a MMPRT was perhaps first described by Engelsohn et al.²¹ a decade ago in

Fig 6. The healing of the meniscus root and reduction of extrusion has been confirmed on magnetic resonance imaging (MRI) scans for the described technique. (A) Right knee T2 weighted coronal MRI scan section showing the continuity of the meniscus root and site of suture anchor (yellow arrow). (B) Right knee proton density sagittal MRI section showing orientation of the suture anchor (red arrow) in the tibia.



Table 2. Pearls and Pitfalls

Pearls	Pitfalls
1. Adequate arthroscopic visualization of the posterior root is necessary, and pie crusting of the medial collateral ligament greatly improves this.	1. In the presence of advanced chondral changes or friable meniscus tissue detected intraoperatively, it is worthwhile to abandon the repair.
2. A high posteromedial portal created about 3-4 cm proximal to joint line is essential to allow straight trajectory for vertical placement of the suture anchor.	2. It is important to prevent soft-tissue bridges in between the sutures to prevent entanglement and laceration of the sutures through the meniscus.
3. Shuttling of the suture tape through the meniscus is easier when performed from inferior to superior surface.	3. It must be ensured that there is no slack in the suture tapes when the anchor is being inserted into the pilot hole.
4. A 70° arthroscope inserted transeptally allows excellent visualization of the posterior root attachment site while inserting the suture anchor.	4. Loosening and extrusion of the anchor prior to healing is a possibility, especially if rehabilitation is aggressive.

reports of 2 patients. Kim et al. compared the results of MMPRT repair by a pull-out suture and suture anchor, and there was no clinical or functional difference between these groups at a minimum follow-up of 2 years. However, there was statistically greater prevalence of incomplete healing on MRI in the pull-out repair group as well as greater meniscal extrusion in these patients. The progress of cartilage degeneration was also greater in this group of patients. The authors also noted the inadequate tensioning of the sutures due to the long distance in the pull-out repair technique.²² LaPrade et al.²³ have reported improvement in pain, function, and activity level following a transtibial double tunnel pull-out repair of the medial meniscus root, irrespective of age. However, Kaplan et al.²⁴ have found increased meniscal extrusion, worsening of medial compartment chondral status, and partial healing in a majority of patients at a mean follow-up of 2 years after transtibial MMPRT repair. The healing of meniscus root and reduction of extrusion has been confirmed on MRI scans by using this current technique (Fig 6). Feucht et al. performed a biomechanical comparison between the 2 repair techniques for MMPRT repair and found that although the suture anchor repair was superior biomechanically, neither technique could provide the strength of a native root attachment. The suture anchor construct provided significantly lower displacement and higher stiffness, and favorable biomechanical properties are important for healing of the repaired root and restoration of function. They proposed that the long suture-meniscus construct causes micromotion of the reattached meniscus, due to a bungee effect possibly compromising healing, besides problems like abrasion of suture in the tunnel and tunnel widening when a pull-out suture technique is employed.²⁵ This bungee effect has been refuted by Cerminara et al.,²⁶ who have demonstrated that the displacement at meniscus-suture interface was statically greater than that at the bone-button interface or suture elongation component for transtibial pull-out repair. The placement of suture anchors in the posterior compartment of the knee is challenging and requires shuttling of sutures, and there

exists the possibility of anchor loosening and displacement.²⁷ The use of knotless anchors eliminates one step of suture shuttling and knot tying, thus simplifying the process by a degree.

MMPRT is increasingly being diagnosed and repaired by arthroscopists. There is much controversy in the optimal management of MMPRTs as a repair does not restore knee function to that of a normal meniscal condition, and improved reparative technique can be one path to achieve this goal.⁸ However, a repair must be performed wherever indicated. The technique described here provides the surgeon with another method to repair an MMPRT without the need for drilling transosseous tunnels or the need to suture the meniscus to an anchor in the tight posterior space. Biomechanical evaluation must be performed for this technique of fixation prior to recommending its widespread use.

The pearls and pitfalls of this technique are discussed in Table 2.

References

- Allaire R, Muriuki M, Gilbertson L, Harner CD. Biomechanical consequences of a tear of the posterior root of the medial meniscus. *J Bone Joint Surg Am* 2008;90:1922-1931.
- Furumatsu T, Kamatsuki Y, Fujii M, et al. Medial meniscus extrusion correlates with disease duration of the sudden symptomatic medial meniscus posterior root tear [published online September 22, 2017]. *Orthop Traumatol Surg Res*. doi:10.1016/j.otsr.2017.07.022.
- Hwang B-Y, Kim S-J, Lee S-W, et al. Risk factors for medial meniscus posterior root tear. *Am J Sports Med* 2012;40:1606-1610.
- Cho S-D, Youm Y-S, Kim J-H, Cho H-Y, Kim K-H. Patterns and influencing factors of medial meniscus tears in varus knee osteoarthritis. *Knee Surg Relat Res* 2016;28:142-146.
- Bhatia S, LaPrade CM, Ellman MB, LaPrade RF. Meniscal root tears: significance, diagnosis, and treatment. *Am J Sports Med* 2014;42:3016-3030.
- Moon H-K, Koh Y-G, Kim Y-C, Park Y-S, Jo S-B, Kwon S-K. Prognostic factors of arthroscopic pull-out

- repair for a posterior root tear of the medial meniscus. *Am J Sports Med* 2012;40:1138-1143.
7. Chahla J, Moulton SG, LaPrade CM, Dean CS, LaPrade RF. Posterior meniscal root repair: the transtibial double tunnel pullout technique. *Arthrosc Tech* 2016;5: e291-e296.
 8. Lee DW, Ha JK, Kim JG. Medial meniscus posterior root tear: a comprehensive review. *Knee Surg Relat Res* 2014;26: 125-134.
 9. Ahn JH, Wang JH, Yoo JC, Noh HK, Park JH. A pull out suture for transection of the posterior horn of the medial meniscus: using a posterior trans-septal portal. *Knee Surg Sports Traumatol Arthrosc* 2007;15:1510-1513.
 10. Thompson WO, Thaete FL, Fu FH, Dye SF. Tibial meniscal dynamics using three-dimensional reconstruction of magnetic resonance images. *Am J Sports Med* 1991;19:210-216.
 11. Gao J, Wei X, Messner K. Healing of the anterior attachment of the rabbit meniscus to bone. *Clin Orthop Relat Res* 1998;348:246-258.
 12. 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.
 13. Feucht MJ, Grande E, Brunhuber J, Burgkart R, Imhoff AB, Braun S. Biomechanical evaluation of different suture techniques for arthroscopic transtibial pull-out repair of posterior medial meniscus root tears. *Am J Sports Med* 2013;41:2784-2790.
 14. Feucht MJ, Kühle 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.
 15. Feucht MJ, Grande E, Brunhuber J, et al. Biomechanical evaluation of different suture materials for arthroscopic transtibial pull-out repair of posterior meniscus root tears. *Knee Surg Sports Traumatol Arthrosc* 2013;23:132-139.
 16. Padalecki JR, Jansson KS, Smith SD, et al. Biomechanical consequences of a complete radial tear adjacent to the medial meniscus posterior root attachment site. *Am J Sports Med* 2014;42:699-707.
 17. Marzo JM, Gurske-DePerio J. Effects of medial meniscus posterior horn avulsion and repair on tibiofemoral contact area and peak contact pressure with clinical implications. *Am J Sports Med* 2009;37:124-129.
 18. Johannsen AM, Civitarese DM, Padalecki JR, Goldsmith MT, Wijdicks CA, LaPrade RF. Qualitative and quantitative anatomic analysis of the posterior root attachments of the medial and lateral menisci. *Am J Sports Med* 2012;40:2342-2347.
 19. LaPrade CM, Foad A, Smith SD, et al. Biomechanical consequences of a non-anatomic posterior medial meniscal root repair. *Am J Sports Med* 2015;43:912-920.
 20. Stärke C, Kopf S, Grobel KH, Becker R. The effect of a nonanatomic repair of the meniscal horn attachment on meniscal tension: a biomechanical study. *Arthroscopy* 2010;26:358-365.
 21. Engelsohn E, Umans H, Difelice GS. Marginal fractures of the medial tibial plateau: possible association with medial meniscal root tear. *Skeletal Radiol* 2007;36:73-76.
 22. Kim J-H, Chung J-H, Lee D-H, Lee Y-S, Kim J-R, Ryu K-J. Arthroscopic suture anchor repair versus pullout suture repair in posterior root tear of the medial meniscus: a prospective comparison study. *Arthroscopy* 2011;27:1644-1653.
 23. LaPrade RF, Matheny LM, Moulton SG, James EW, Dean CS. Posterior meniscal root repairs: outcomes of an anatomic transtibial pull-out technique. *Am J Sports Med* 2016;45:884-891.
 24. Kaplan DJ, Alaia EF, Dold AP, et al. Increased extrusion and ICRS grades at 2-year follow-up following transtibial medial meniscal root repair evaluated by MRI [published online November 2, 2017]. *Knee Surg Sports Traumatol Arthrosc*. doi:10.1007/s00167-017-4755-8.
 25. Feucht MJ, Grande E, Brunhuber J, et al. Biomechanical comparison between suture anchor and transtibial pull-out repair for posterior medial meniscus root tears. *Am J Sports Med* 2014;42:187-193.
 26. Cerminara AJ, LaPrade CM, Smith SD, Ellman MB, Wijdicks CA, LaPrade RF. Biomechanical evaluation of a transtibial pull-out meniscal root repair: challenging the bungee effect. *Am J Sports Med* 2014;42:2988-2995.
 27. Jung YH, Choi NH, Oh JS, Victoroff BN. All-inside repair for a root tear of the medial meniscus using a suture anchor. *Am J Sports Med* 2012;40:1406-1411.