Recent Advances in Posterior Meniscal Root Repair Techniques

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Abstract

Posterior root avulsions of the medial and lateral menisci result in decreased areas of tibiofemoral contact and increased tibiofemoral contact pressures. These avulsions may lead to the development of osteoarthritis. Therefore, two surgical techniques, the transtibial pullout repair and the suture anchor repair, have recently been developed to restore the native structure and function of the meniscal root attachment. Compared with the historical alternative of partial or total meniscectomy, these techniques allow for meniscal preservation and anatomic reduction of the meniscal roots, with the goal of preventing the development and progression of osteoarthritis. However, early biomechanical and clinical studies have reported conflicting results on the effectiveness of both techniques with regard to resisting displacement and facilitating healing. Although there is currently a lack of consensus on which is the superior technique, transtibial pullout and suture anchor repairs are increasingly used in clinical practice.

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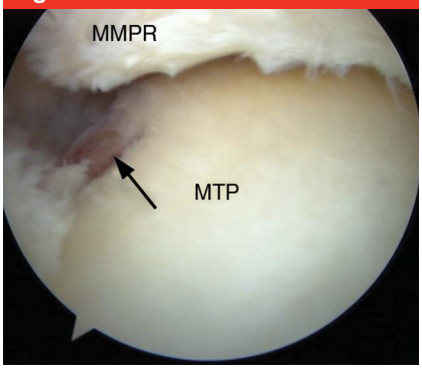
The anterior and posterior meniscal roots anchor the medial and lateral menisci to the tibial plateau. Posterior root pathology is often caused by either acute injury or chronic degeneration[1] and leads to altered tibiofemoral contact mechanics and the inability to convert axial loads into transverse hoop stresses[2-6] (Figure 1). In one series, posterolateral meniscal root tears were observed in 8% of anterior cruciate ligament tears.[7] Another study reported that up to 21.5% of medial meniscal tears may be located at the posterior root.[8]

The natural history of untreated meniscal root avulsions is poorly understood. On imaging studies, complete or partial posteromedial meniscal root avulsions have been associated with >3 mm of meniscal extrusion.[9] Extrusion >3 mm has been linked to substantially increased articular cartilage loss and osteophyte formation.[9] In addition, a comparison study of partial meniscectomy and meniscal repair for vertical longitudinal or bucket-handle tears of the medial meniscus reported a significant increase in osteoarthritis progression associated with partial meniscectomy at an 8-year follow-up.[10] Historically, partial meniscectomy was used to manage meniscal root avulsions, and it is possible that similar effects would be seen in meniscal root avulsions treated with meniscectomy. Therefore, preservation of meniscal tissue and restoration of meniscal continuity is becoming the standard of care for posterior meniscal root pathology.[11-13]

Not all patients are candidates for root repair, however. Repair is indicated in active patients (typically aged <50 years) following acute or chronic injury with no significant osteoarthritis (Outerbridge grade 3 or 4), joint-space narrowing, and malalignment.[1,14] Moon et al[14] examined the prognostic factors for

Figure 1



Arthroscopic image demonstrating a posterior root avulsion (arrow) of the medial meniscus from its native attachment on the posterior aspect of the medial tibial plateau (MTP) of the right knee. MMPR = medial meniscus posterior horn

Figure 2

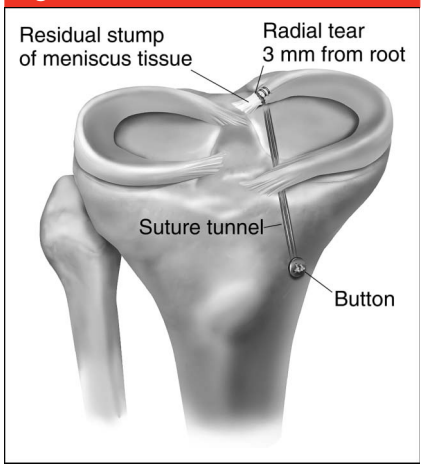


Illustration of the transtibial pullout repair technique for a tear of the posteromedial meniscal root of the right knee. A complete radial tear is located 3 mm from the bony attachment. The two simple stitches method of suture fixation is demonstrated. In the meniscal body, two sutures are passed from anterior to posterior 5 mm medial to the root tear. The sutures are then shuttled down a small tunnel reamed at the attachment site of the root. The sutures are then tied over a surgical button with the knee flexed at 90° to secure the root repair. (Reproduced with permission from Padalecki JR, Jansson KS, Smith SD, et al: Biomechanical consequences of a complete radial tear adjacent to the medial meniscus posterior root attachment site: In-situ pullout repair restores derangement of joint mechanics. *Am J Sports Med* 2014;42[3]:699-707.)

pullout repair of posterior root tears of the medial meniscus and found that patients with Outerbridge grade 3 or 4 cartilage lesions had substantially worse clinical outcomes after meniscal root repair.

Over the past few years, numerous advances have been made in the development and refinement of posterior meniscal root repair techniques. The transtibial pullout and suture anchor repairs have evolved as alternatives to meniscectomy, with the goal of restoring the meniscal root to an anatomic and secure attachment to bone.[11,15]

Repair Techniques

Transtibial Pullout Repair

The use of transtibial pullout repair for the medial and lateral posterior meniscal roots has been described, with side-to-side variations in surgical technique. For repair of either posterior root, the patient is positioned with the knee in 90° of flexion. Medial and lateral parapatellar arthroscopic portals are created. If necessary, an accessory posteromedial or posterolateral portal may be created to facilitate suture passage.[1] An anterior cruciate ligament aiming device is used to position a guide pin, which is inserted through an incision over the anteromedial aspect of the tibia and exits at the anatomic tibial attachment of the medial or lateral posterior meniscal root.[3,5]

Once the position of the guide pin is anatomic and has been confirmed with direct arthroscopic visualization or fluoroscopy, a transtibial tunnel is reamed over the guide pin. Although tunnels of various sizes have been used,[2-6] we prefer a tunnel with a diameter of 5 mm because of the relative ease with which the sutures can be pulled out of the tunnel. The accessory portal is used to place an arthroscopic grasper to firmly hold the torn root and to more effectively position it toward the suture passer.[1] No. 2 nonabsorbable sutures are passed in a superior-to-inferior direction through the substance of the meniscal root, shuttled down the transtibial tunnel, and secured over the anteromedial tibial cortex (Figure 2).[5] Although screw and washer suture fixation has been described,[6] we prefer the cortical button fixation method because it is less invasive and has less potential for irritation.[1,5]

Several different suture fixation techniques for meniscal root tears have been biomechanically evaluated.[16,17] Although complex techniques are associated with higher ultimate failure loads, we believe the ability to resist displacement of the root is the most clinically important parameter[11,16,17] because 3 mm of nonanatomic displacement significantly alters meniscal function.[13] Therefore, we prefer the two simple stitches technique[16] because of its ability to resist displacement and its decreased technical complexity; the technique allows for accurate suture placement in a confined joint space (Figure 2).

Suture Anchor Repair

Although variations of this procedure have been described, suture anchor repair of a meniscal root tear generally involves an all-inside technique using one suture anchor with two sutures secured in the cortical bone at the native attachment site.[11,15,18] The repair is performed using standard medial and lateral parapatellar portals. For repair of the posterior root of the medial meniscus, a posteromedial portal is also created and placed higher than normal (approximately 2 to 4 cm proximal to the

joint line) to allow for more vertical placement of the suture anchor while avoiding the posterior convexity of the medial femoral condyle (Figure 3). The suture anchor is placed at the site of the native anatomic attachment of the posteromedial meniscal root. Sutures attached to the suture anchor are then passed through the substance of the root, shuttled between portals, and arthroscopically tied using a knot pusher while adequate tension is maintained to complete the repair[11,15,18] (Figure 4).

Postoperative Restrictions

For both transtibial pullout and suture anchor repairs, postoperative restrictions include partial weight-bearing in a knee immobilizer for the first 6 weeks, with daily range-of-motion exercises performed without the immobilizer. Progressive advancement to full weight-bearing begins at 8 weeks, allowing adequate healing time before resuming load-bearing activities.[1] These restrictions are recommended because biomechanical studies have reported that common methods of suture fixation fail secondary to suture cutout of the meniscus at levels of tension close to those exerted on the medial meniscal root during partial weight-bearing.[17,19]

Biomechanical Evidence

Studies have evaluated the biomechanical effects of avulsions of the medial and lateral posterior meniscal roots and subsequent transtibial pullout repairs (Table 1). They have reported a decrease in tibiofemoral contact areas and an increase in peak and mean contact pressures following an avulsion of the posterior root of both the medial and lateral menisci.[2-6] However, the ability of the transtibial pullout repair to restore the contact areas varies between the medial[2,4,5] and lateral[3,6] menisci.

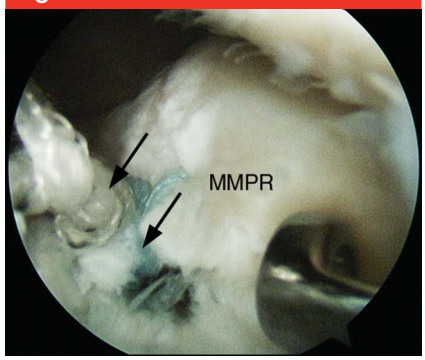
Figure 3

Intraoperative photograph of the right knee demonstrating placement of a high posteromedial arthroscopic portal for suture anchor repair of a posteromedial meniscal root avulsion. The portal is located approximately 2 to 4 cm proximal to the joint line to facilitate proper angulation of the instruments and to allow shuttling of sutures into the posteromedial compartment.

Repair of posteromedial meniscal root avulsions and radial tears 3 mm and 6 mm from the root attachment can restore the contact area to intact levels at all angles;[2,5] however, repair of posterolateral meniscal root avulsion at 3 mm and 6 mm from the root have been less successful, resulting in contact areas that are substantially less than those of intact roots when pooled across all angles.[3]

Descriptions of the biomechanical properties of suture anchor repair are limited. In a porcine model, Feucht et al[11] reported significantly less displacement following cyclic loading after suture anchor repair compared with displacement after the transtibial pullout repair ($P < 0.001$). However, there was no significant difference between the two techniques in terms of the ultimate failure loads. Compared with an intact posteromedial meniscal root, both repair techniques failed to restore the ultimate failure loads or prevent displacement of the root attachment.[11]

Figure 4



Arthroscopic image of the right knee following suture anchor repair of the posteromedial meniscal root demonstrating anatomic reduction and suture fixation (arrows) at the native attachment site of the meniscus root during probing. MMPR = medial meniscus posterior root

Clinical Outcomes

Conflicting clinical and structural outcomes after medial meniscal root repairs have been reported. This may be attributed to the fact that clinical studies that have evaluated the transtibial pullout or suture anchor repairs are limited to case-control studies or case series that included patients with an average age >50 years.[12,14,15,18,20] Two studies also included patients who had osteoarthritis classified as grade 3 or 4 on the Kellgren-Lawrence or Outerbridge scales.[14,15] Increased age and advanced osteoarthritis (grade 3 or 4) are common contraindications for root repair because of the probability of a poor healing response and decreased clinical outcome scores.[1,14]

Although all clinical studies reported substantial improvement in subjective outcome measures at 2 to 3 years after transtibial pullout or suture anchor repair,[12,14,15,18,20] structural outcomes evaluated with MRI or second-look arthroscopy have revealed conflicting results. Kim et al[15] reported a decrease in meniscal extrusion following both

Table 1

Summary of Studies of the Biomechanical Properties of the Knee After Transtibial Pullout Repair of Medial or Lateral Posterior Meniscal Root Tears

Study	Type of Posterior Meniscal Root Tear	Compressive Load (N)	Testing Groups	Methods	Pertinent Results and Conclusions
Allaire et al[2]	Medial	1,000	Intact root, root avulsion, root repair, and total medial meniscectomy	Loading performed at 0°, 30°, 60°, and 90° of knee flexion	Root repair restored the peak contact pressures, contact areas, external rotation, and lateral tibial translation to those of the intact state.
LaPrade et al[3]	Lateral	1,000	Intact root, footprint tear of supplemental fibers, root avulsion, root repair, complete radial tears at 3 mm and 6 mm from root attachment, and subsequent repair at 3 mm and 6 mm	Loading performed at 0°, 30°, 45°, 60°, and 90° of knee flexion	Repair restored the mean contact pressures to those of the intact state for all repairs at all angles. Mean contact pressures were significantly decreased compared with those of the torn states. After root repair, the contact area was indistinguishable from that of the intact state; however, repairs at 3 mm and 6 mm from the root attachment had significantly lower contact areas than those of the intact state.
Marzo and Gurske-DePerio[4]	Medial	1,800	Intact root, root avulsion, and root repair	Loading performed at 0° of knee flexion	No difference between root repair and the intact state in terms of contact area and peak contact pressure. Increased contact area and decreased peak contact pressure were noted after root repair.
Padalecki et al[5]	Medial	1,000	Intact root, root avulsion, root repair, complete radial tear at 3, 6, and 9 mm from the root attachment, and subsequent repair at 3, 6, and 9 mm	Loading performed at 0°, 30°, 45°, 60°, and 90° of knee flexion	Repair of the root avulsion and radial tears restored the mean contact pressures to the intact state for all angles beyond 0° and when pooled across flexion angles. Repair of all tears resulted in contact areas that were indistinguishable from those of the intact state. At all flexion angles beyond 0°, repair resulted in restored contact areas and peak contact pressures.
Schillhammer et al[6]	Lateral	NR (simulated 5 gait cycles)	Intact root, root avulsion, and root repair	Gait cycle duration was 20 s. Measurements taken during fourth gait cycle.	Root repair resulted in mean and peak contact pressures that were not significantly different from those of the intact state. Root repair resulted in significantly lower mean and peak contact pressures than those associated with the avulsion. Root repair resulted in a maximum contact area that was significantly lower than that of the intact state, whereas average contact area was not significantly different from that of the intact state.

NR = not reported

root repair techniques, and Jung et al[18] reported no change in meniscal extrusion after suture anchor repair. In contrast, Moon et al[14] reported an increase in meniscal extrusion with the transtibial pullout technique. However, the patient population included patients with severe osteoarthritis and a relatively high average age (59 years); therefore, these poor structural outcomes may be partially explained by patient selection.

Second-look arthroscopy has also been used to evaluate outcomes. Lee et al[20] performed second-look arthroscopy in 10 knees treated with transtibial pullout repair and found that all patients had complete healing 2 years after surgery. Seo et al[12] evaluated healing on second-look arthroscopy after repairs of posterior root tears in 11 patients and found that none had complete healing by 1 year postoperatively. However, 82% of the injuries were chronic tears, which are believed to have poor healing potential.[1,12] In addition, Seo et al[12] and Moon et al[14] allowed full weight-bearing at 6 weeks. Improved healing was reported by other authors who restricted full weight-bearing until 8 weeks after surgery.[15,18,20]

Several biomechanical studies have demonstrated the risk of nonanatomic displacement during cyclic loading before healing of the meniscal tissue associated with both repair techniques.[11,16,17] In a prospective comparison study of suture anchor and pullout suture repairs in 45 patients (23 suture anchor and 22 pullout suture repairs), Kim et al[15] reported that 14% of patients had incomplete healing of the meniscal root repair after suture anchor repair on MRI. In contrast, Jung et al[18] reported that 5 of 10 patients (50%) treated with suture anchor repair experienced partial or no healing. Kim et al[15] reported that incomplete structural healing after transtibial pullout repair was higher than that following suture anchor repair; however, no other differences between clinical or structural outcomes were noted.

Because early clinical data have been inconclusive, further research must be conducted before conclusions can be drawn with greater certainty. In effect, the current reports may be validating poor outcomes following treatment of patients with contraindications for root repair. Future outcome studies should use inclusion and exclusion criteria that are more representative of patient populations that typically undergo meniscal root repairs. Although biomechanical studies have reported promising results, enthusiasm for repair must be tempered until clinical improvement is documented through clinical outcome studies with higher levels of evidence.

Comparison of Techniques

The transtibial pullout technique facilitates anatomic repair with a high degree of accuracy and reproducibility. Although the procedure is technically demanding, attention to detail and accurate placement of the arthroscopic portals helps to simplify anatomically accurate positioning of the posterior meniscal root on the tibial plateau. In addition, transtibial tunnel drilling may enhance meniscal healing due to a biologic augmentation effect caused by the influx of progenitor cells and growth factors from the bone marrow into the intra-articular space.[11]

There are also unresolved biomechanical, technical, and clinical issues related to this technique. First, the suture fixation techniques for the transtibial pullout repair yield a significantly weaker repair construct compared with the native roots, and postoperative rehabilitation must proceed with caution.[17,19] The transtibial pullout repair may also result in a bungee effect, which is best described by Feucht et al[11] as micromotion of the root repair caused by the long length of the meniscus-suture construct. Feucht et al[11] reported that the transtibial pullout repair construct resulted in 2.2 mm of displacement under cyclic loading in a porcine model. Because nonanatomic meniscal root displacement reportedly has a substantial effect on meniscal function,[13] the bungee effect likely will be a significant focus of further investigation.

The suture anchor technique consists of an all-inside meniscal root repair at the native root attachment site and eliminates the need for tunnel drilling. In addition, micromotion associated with transtibial pullout repair, which is caused by the long meniscus-suture construct, is minimized because the suture repair construct is short and less prone to micromotion. However, there are also challenges associated with the suture anchor technique. Placing a suture anchor in a small arthroscopic space while ensuring accurate anatomic placement is technically demanding, particularly in cases without concurrent medial collateral ligament injury. Once the anchor is placed, shuttling sutures between portals can be difficult in a patient with a large thigh or a high body mass index. Finally, Jung et al[18] reported that the suture anchor may loosen and protrude into the joint over time. Similar to the transtibial pullout repair, the suture anchor technique allowed displacement under cyclic loading in a porcine model; however, the displacement (1.3 mm ± 0.3 mm) was less than that associated with the transtibial pullout technique (2.2 mm ± 0.5 mm).[11]

Summary

Repair of a posterior meniscal root tear is essential because of the consequences related to meniscal root deficiency.

Biomechanical studies have provided early indications that root repair, specifically the transtibial pullout repair, is able to restore tibiofemoral contact mechanics. However, further optimization of the transtibial pullout and suture anchor techniques should focus on eliminating nonanatomic displacement following repair. Preliminary clinical outcomes studies reveal conflicting results, which may be attributed in part to the inclusion of atypical patient populations for meniscal root repair. A meniscal root repair should be considered for patients with meniscal root injuries who do not have osteoarthritis (grade 3 or 4), joint-space narrowing, or malalignment. Our preferred technique is the transtibial pullout repair because of the decreased technical difficulty and the ability to facilitate an anatomic root repair with what we believe to be a greater degree of accuracy and reproducibility. Further biomechanical studies should focus on optimizing both the transtibial pullout and suture anchor repair techniques. Prospective comparative studies of clinical outcomes are essential for evaluating the effectiveness of current and future iterations of these techniques.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 8, 10, and 15 are level III studies. References 7, 9, 12, 14, 18, and 20 are level IV studies.

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