Arthroscopic Repair of Meniscal Root Injuries

Ahmad Raafat Abdel-latif, Abdelsalam Mohamed Hefny, Ahmed Abdel-Aziz Ahmed, Ahmed Hatem Farhan

Orthopedic Surgery Department, Faculty of Medicine, Zagazig University, Egypt

Corresponding author: Ahmad Raafat Abdel-latif

E-mail: Ahmadorthopedic87@gmail.com

Conflict of interest: None declared

Funding: No funding sources

Abstract

The menisci are fibrocartilaginous structures that help maintain the knee joint by absorbing shock, transferring loads, and stabilising the knee. If you want to transform axial loading pressures across your knee into circumferential hoop stresses, you need meniscus root integrity. By enhancing meniscal extrusion and diminishing its intrinsic load-sharing capability, meniscus root tears destabilise tibiofemoral contact mechanics. Accordingly, these injuries hasten the deterioration of the knee joint and have been compared to a total meniscectomy in terms of biomechanics and functionality. The clinical presentation determines the best course of treatment for meniscus root tears: nonoperative or surgical. Researchers have found that meniscus root restoration reduces the risk of osteoarthritis (OA) and slows the progression to arthroplasty compared to partial meniscectomy and nonsurgical treatment. With its biomechanical robustness, the transtibial pull-through repair technique provides surgeons with a safe and successful repair strategy that utilizes common arthroscopy ports. In an effort to improve upon current methods by decreasing postoperative meniscal extrusion, arthroscopic centralization has recently gained attention as a cutting-edge healing procedure.

Keywords: Arthroscopic Repair, Meniscal Root Injuries

Tob Regul Sci.™ 2023;9(1): **6391 - 6408**

DOI: doi.org/10.18001/TRS.9.1.448

Introduction

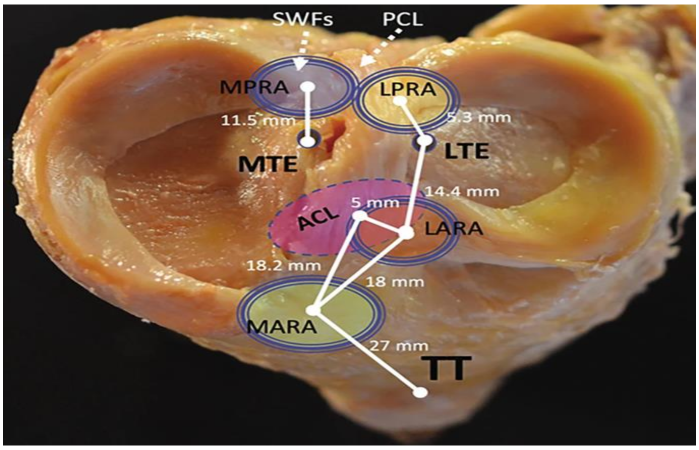
The meniscus plays an important role in the knee by absorbing impact, supporting the joint biomechanically, and preserving it for the future [1, 2]. A meniscus tear accounts for 12–14% of all knee orthopaedic complaints [3], making it one of the most prevalent knee ailments. Radial tears within 1 cm of the meniscus root attachment or avulsion of the meniscus root itself are known as meniscus root tears, and they can happen in as many as 10–20 percent of patients having an arthroscopic meniscectomy [2,3,4,5]. The mechanics of the knee are changed, the pressure between the tibia and the hip is increased, and the affected compartment's cartilage might deteriorate quickly if the root attachment is disrupted. As a result, if left untreated, these tears can lead to OA, severe functional impairments, and the eventual need for total knee arthroplasty in some cases [3, 5].

Nonoperative or partial meniscectomy was the initial treatment for meniscus tears, which often occurred in the 40s and 50s. Nevertheless, the meniscus's pivotal function in preserving joint integrity has been better understood. Since nonoperative treatment or partial meniscectomy leads to worse outcomes, the clinical approach to meniscus root tears has changed as a result of this insight [3, 6]. In order to prolong the life of joint cartilage and delay the necessity of TKA, the emphasis has changed to preservation and anatomic restoration. Improved knee contact pressures, kinematics, and patient reported outcome scores are among the encouraging outcomes that have been observed thus far in relation to meniscal healing and development of cartilage degeneration following root repair [3, 6, 7, 8, 9].

2 Anatomy

2.1 Meniscus

Here we will go over some of the more recent methods for fixing meniscal root tears, with an emphasis on arthroscopic techniques.



According to cadaveric investigations, the MTE and LTE are well-established landmarks where the distance to the meniscal root attachments can be quantified. Reducing menisci to their anatomical positions requires expert knowledge of meniscal root anatomy. Abbreviations: The acronyms MPRA, LPRA, LARA, MARA, ACL, TT, MTE, and LTE stand for medial posterior root attachment, lateral posterior root attachment, medial anterior root attachment, tibial tubercle, and medial cruciate ligament, respectively. The posterior cruciate ligament (PCL) and the shiny white fibres of the posterior medial meniscus root (SWFs) are one and the same (Reproduced with permission from Ref. [12])

2.1.1 Anterior Roots

Generally speaking, the front horn of the medial meniscus leaves the strongest imprint, while the anterior roots are able to withstand more stress before failing than the posterior roots [11]. Its insertion is vulnerable to disruption during intramedullary tibial nailing because it lies 18.2 mm anteromedial to the tibial ACL attachment [12]. Lateral meniscus anterior root attachment accounts for 63.2% of the insertion location on the tibia, while ACL insertion accounts for 40.7% [13]. Because the root fibres go so deeply under the ACL connection, iatrogenic damage is practically inevitable while repairing the ACL. It is not yet understood what this means for clinical practise [14, 15].

2.1.2 Posterior Roots

Among the meniscus roots, the posterior lateral one is said to be the weakest, followed by the posterior medial one [14]. A fibrous growth called shiny white fibres (SWFs) is located in the posterior horn of the medial meniscus. These SWFs serve as anatomical landmarks during procedures such as posteromedial meniscus root repair and PCL restoration [16]. The posterolateral root is located 12.7 mm in front of the closest point on the PCL footprint and 5.3 mm posteromedial to the apex of the lateral tibial eminence [17].

2.2 Articular Cartilage

The smooth surface for articulation provided by the joint is articular cartilage, which is made up of hyaline cartilage type II collagen fibres [18]. Restored interest in restorative treatments has been met with the substantial pain and morbidity linked to articular cartilage injuries [19, 20]. It is not uncommon for meniscus root injuries to occur alongside articular cartilage destruction, with variations noted in the degree of damage detected on either side. Medial root rips are more common in the elderly and are associated with widespread deterioration of the medial compartment. When a young, active person sustains a lateral root rupture, it is common for them to have ligamentous and cartilaginous injuries as well, but there may be less degenerative changes overall [21]. Because of its physiologic features and lack of blood vessels, articular cartilage has a low healing capacity [22]. Consequently, OA is greatly accelerated in cases where chondral injury occurs as a result of root rips. In a study of 197 knees that had total knee arthroplasty, the researchers found that 78% of patients had posterior medial meniscal root tears. These patients were all younger than 60 years old. There was a correlation between the severity of OA and meniscus root tears [23]. In conclusion, articular cartilage injury occurs frequently, does not heal well, and increases the likelihood of developing OA.

3 Clinical Presentation and Diagnosis

Upon initial examination, meniscus root tears are frequently misdiagnosed. This occurs because the rip itself may not be seen on imaging, the physical exam may not be able to elicit pain, and there are no telltale signs like locking, catching, or giving way [1, 12, 24]. The presentation of a meniscal root tear can be confusing, so it's important for clinicians to know what to look for in order to make a right diagnosis.

3.1 Patient Symptoms and Physical Exam Findings

3.1.1 Lateral Meniscus Root Tears (LMRT)

Concomitant ligamentous injury from trauma or sports is a common occurrence in LMRTs. Loss of cartilage and reduced MRI extrusion are characteristics of younger male patients with lateral rips rather than medial ones [21]. The posterior lateral meniscus root, in particular, acts as a supplementary stabiliser of anterior tibial translation in the knee of an ACL deficient patient, according to biomechanical investigations [15, 25]. Thus, a simultaneous ACL and lateral meniscus posterior root rupture could be indicated by a 3+ Lachman and 3+ pivot shift on physical examination [12].

3.1.2 Medial Meniscus Root Tears (MMRT)

One study found that MMRTs are more prevalent in the elderly [3]. Degenerative root tears account for almost 70% of all posterior medial meniscus tears. The start of pain might be mild but severe, and patients often do not report an initiating event [15]. Minor trauma, such getting up from a chair or squatting deeply, is believed to be the cause. The most typical physical exam findings are discomfort along the joint lines and pain felt when bending down deeply at the knee; a positive McMurray's test, although not very sensitive, may be useful in this regard [1, 12, 15]. Finally, clinical evidence of posterior root avulsion of the medial meniscus includes pain during a varus stress test in full knee extension, according to some experts. The extruded meniscus, which becomes noticeable under varus stress but goes away when the knee is back in its usual position, is to blame for this [26].

3.2 Imaging

Meniscus root tears are best detected on T2-weighted scans, and magnetic resonance imaging (MRI) is the imaging modality of choice for detecting these injuries [1, 3]. A meniscus root tear can be suspected based on some noticeable visual indicators. Figure 2 shows a "ghost sign" where part of the meniscus is not visible on sagittal or coronal imaging. Another sign is a "cleft sign" where a high signal runs horizontally or vertically through the meniscus on sagittal or coronal imaging. The third sign is a "truncation sign" where the triangular root of the meniscus is abruptly cut off on sagittal or coronal imaging [28,29,30]. Even though magnetic resonance imaging (MRI) technology is constantly improving, recent studies have shown that MRI often fails to detect posterior root tears [31]. Up to 67% of posterior LMRTs go undetected by preoperative MRI, according to research by Krych and colleagues. Therefore, in cases where the root cannot be positively detected, the authors suggest that radiologists state that "the root is poorly visible" so that surgeons can assess the anatomy correctly after surgery [31].

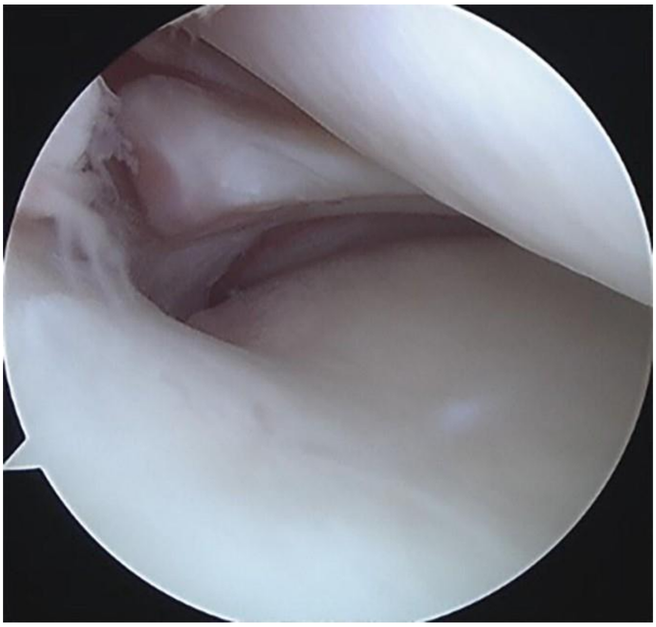
Fig. 2

Coronal T2-weighted MRI showing medial meniscus posterior root tear (red arrow) with associated meniscus extrusion (white arrow)

3.3 Classification

In order to aid surgeons in the diagnosis and treatment of meniscus root tears, these injuries are classified according to tear morphology. When it comes to meniscus root tears, the LaPrade system is by far the most popular [30, 32]. The types of tears are as follows: Type 1, which contains partial and stable tears, accounts for 7.0 percent of all tears; Type 2, depicted in Figure 3, comprises complete radial tears less than 9 mm from the root attachment, which accounts for 67.6 percent of all tears; Type 3, which contains bucket-handle tears with a root detachment, for 5.6% of all tears; Type 4, which comprises complete oblique tears less than 9 mm from the root attachment, for 9.9% of all tears; and Type 5, which represents avulsion fractures of the root attachment, for 9.9% of all tears [32]. According to the location of the tear in relation to the root attachment, Type 2A tears were categorised as less than 3 mm, Type 2B tears were classified as between 3 mm and less than 6 mm, and Type 2C tears were identified as 6-9 mm [30, 32].

Fig. 3



Arthroscopic view of a complete medial meniscus posterior root tear (Type 2)

3.4 Extrusion

A lot of recent research on meniscal root restoration has focused on meniscus extrusion. When the meniscus protrudes beyond the tibial plateau on magnetic resonance imaging (MRI), it is classified as extrusion [33,34,35]. Researchers have discovered that extrusion is a risk factor for tibiofemoral cartilage degeneration and is linked to posterior meniscus root injuries. Nevertheless, the specific sequence in which root rips and meniscus extrusion manifest is still a mystery [34,35,36]. An extruded meniscus and meniscotibial ligament failure may increase stresses to the point where a root tear occurs, according to a recent study [37]. It appears that the degree of meniscus extrusion after repair determines the rate of articular cartilage deterioration; a larger chondroprotective advantage is linked with less extrusion. It has not been demonstrated that extrusion can be fully remedied by early repair techniques that solely concentrated on anatomic root healing [7, 35, 38]. When the meniscus's mid-body is "centralised" by anchoring it onto the lip of the tibial plateau, it can reduce meniscal extrusion, according to meniscus centralization [39, 40]. Initial research has shown promising results, supporting the hypothesis that centralising meniscus root restoration provides more cartilage protection [41].

4 Natural History

The development of osteoarthritis (OA) without treatment is accelerated in meniscus root tears, which have a dismal prognosis and are functionally identical to meniscectomy [42]. Thirteen percent of the group underwent TKA an average of thirty months after diagnosis, and an eighty-seven percent failure rate was based on patient reported outcomes and radiographic progression in a recent study that highlighted the natural history of patients with symptomatic MMRTs treated nonoperatively. Arthroplasty rates were greater and subjective scores were lower among females. At 5-year follow-up, nonoperative management is generally linked to increasing arthritis, poor clinical results, and a relatively high prevalence of arthroplasty [43].

Additionally, subchondral insufficiency fractures of the knee (SIFK)—previously known as spontaneous insufficiency fractures of the knee (SONK)—may be influenced by increased tibiofemoral contact pressures caused by root tears. These fractures were originally believed to be idiopathic [29, 30, 44, 45]. These injuries have serious consequences, including frequent need for surgical procedures and total knee arthroplasty (TKA) [46]. The goal of the validated predictive model developed by Pareek et al. was to improve the quantification of independent risk factors and the prediction of TKA progression in patients with SIFK. According to their findings, the following factors are significant predictors of LMRT conversion to TKA: medial meniscus extrusion, lateral meniscus extrusion, Kellgren-Lawrence (K-L) Grade 4, and SIFK of the medial femoral condyle [47]. It has been noted in the literature that SIFK can arise following arthroscopy and is anticipated to occur in 50-100 percent of individuals with posterior meniscus tears [44, 45]. Meniscectomy was the most common arthroscopic surgery in a group of 28 individuals with post-arthroscopy SIFK (89%), with 75% of these patients having a body mass index (BMI) greater than 35. On average, 54% of the group underwent arthroplasty after one year, and 75% of patients experienced either a meniscal root or radial tear [48]. For meniscal root rips that are irreversible and do not respond to nonoperative treatment, arthroplasty is still a viable option for some individuals. Knee arthroplasty for secondary OA from root pathology is associated with comparable reductions in pain, activity level, comorbidities, and reoperation rates compared to primary OA, according to a recent matched case-control comparison research [49].

Articular cartilage lesions are rather prevalent after meniscal injuries and can cause a lot of discomfort and illness [19, 50]. Acute meniscal root tears and chronic changes in tibiofemoral contact pressures are two potential causes of articular cartilage degradation [36]. Though not covered in this chapter, there are a number of cartilage restoration methods that can be used to repair tiny, acute cartilage defects, including chondroplasty, microfracture, and osteochondral autograft transfer [19]. One key process in the development of severe knee OA is the progressive deterioration of the joint after an articular cartilage injury. Because of this, orthopedists performing meniscus root repairs should be alert for any acute cartilage lesions that might be amenable to treatment [19].

5 Outcomes

Preventing or delaying the progression of progressive knee OA and enabling patients to resume exercise are the main objectives of meniscus root tear treatment. Progressive joint degeneration is a common complication of nonoperative treatment for meniscus root tears, as mentioned before. In addition to nonoperative care, partial meniscectomy is a historical treatment method that has been associated with similar outcomes [51] and is a major risk factor for osteoarthritis [1, 42, 52]. The effectiveness of partial meniscectomy in treating 52 MMRTs was compared to a matched group that did not have surgery, according to Krych et al. After 54 months on average, 54% of meniscectomy patients underwent total knee arthroplasty (TKA) during the 5-year follow-up. Neither group differed significantly from the other in terms of patient-reported outcomes, K-L grade progression, or arthroplasty progression. Clinical and radiological results were poorer in cases when the patient was female, had a higher body mass index, or had meniscus extrusion [51]. Root repairs are more effective than nonoperative therapy and meniscectomy, according to mounting data [6, 53]. This leads to fewer cases that warrant removal.

There has been promising early research on the effectiveness of meniscus root restoration [6, 35, 53]. At an average follow-up of 7 years, Chung et al. detailed clinical outcomes and survival rates after transtibial pull-through repair of MMRTs. There was a 92% overall survival rate at 8 years, with just one patient (1.1%) advancing to TKA, and the investigators found a statistically significant improvement in Lysholm scores from 51.8 to 83.0 [54].

Nonoperative therapy (n=15), partial meniscectomy (n=15), and transtibial pull-through repair (n=15) were the three treatment options assessed in a more recent study by Bernard et al. for 45 patients with MMRTs who were age-, sex-, and preoperative K-L grade matched. There was a marked decrease in OA and total knee arthroplasty (TKA) progression in the repair group as compared to the nonoperative treatment and partial meniscectomy groups [53]. Chung et al. [55] tracked 37 patients for at least 10 years following MMRT repair to try to find out what factors lead to clinical failure after surgical root repair in the long run. The two groups of patients were classified by whether or not they progressed to TKA, the clinical failure criterion. Considerations for clinical failure following root restoration were postoperative meniscal extrusion (OR=1.5) and preoperative varus alignment >4° (OR=3.7), according to the final analysis.

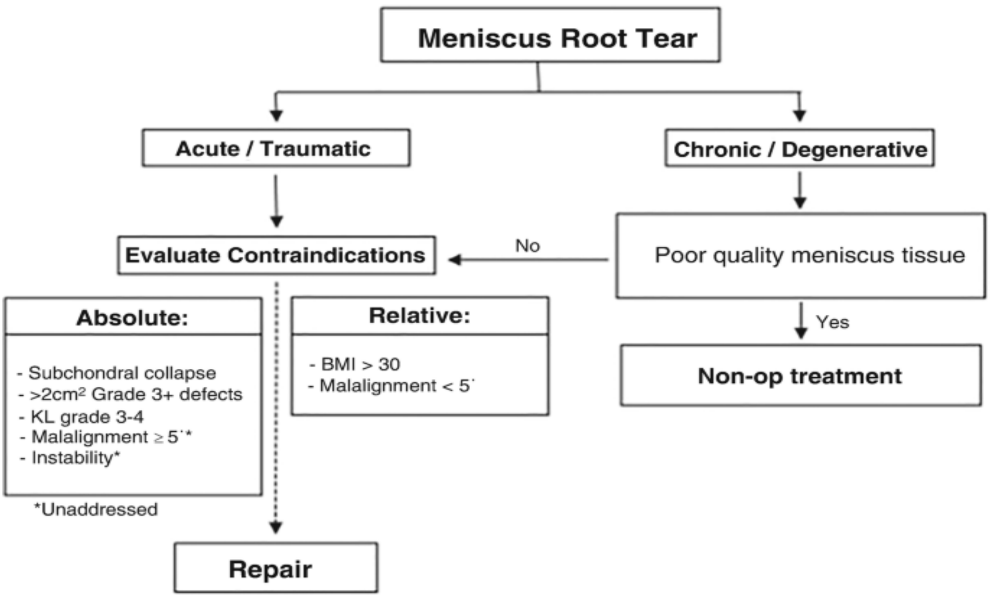
Surgery to heal a root tear may have different results depending on how soon after the injury occurs. A recent study found that patients who received pullout repair within 13 weeks of their arthritis symptoms improving clinically, with less extrusion and less arthritis progression at 2-year follow-up [56].

Over the past 20 years, our understanding of root rips and the factors that increase the likelihood of healing failure has greatly improved. However, there are still many open questions that require further research to answer [5]. Having excess weight or a tibiofemoral joint misalignment of 5 degrees or less increases the likelihood of a failed repair [51]. When compared to earlier treatment choices, modern repair procedures have shown a considerable improvement in OA progression delay. Nevertheless, there are strong correlations between meniscus extrusion and the development of osteoarthritis, and current treatments have not been able to adequately address both the extrusion itself and the OA that develops alongside it [7, 35, 38, 57]. Using serial MRI, Krych et al. tracked the development of root rips in the medial meniscus over time. Progressive meniscus extrusion and medial compartment articular cartilage deterioration were observed in patients with these tears within one year of diagnosis [36]. At 1-year follow-up, patients with less meniscus extrusion had considerably better K-L grades and clinical scores, and joint space narrowing was dramatically improved, according to a comparative root repair study by Chung et al. [35]. Significant improvements in postoperative clinical scores were observed at final follow-up in both repair groups [8]. In an attempt to tackle extrusion head-on and restore joint contact mechanics, Koga et al. [39, 40] detailed meniscus centralization as a method to supplement root restoration. The preliminary data on meniscus centralization is promising, however small-scale [38, 58,59,60]. The extrusion ratio improved significantly at final follow-up, according to a previous study that reported satisfactory clinical outcomes at 2-year follow-up after MMRT repair reinforced by centralization [41]. Reports of similar results following LMRT repairs enhanced with centralization have been made [58]. The future of meniscus extrusion treatment will be influenced by the long-term clinical outcomes of this approach [30].

6 Repair Options

We believe that repairs should be performed in young patients with acute injuries and otherwise healthy knees. It is critical to correct underlying issues at the time of repair, such as malalignment and ligamentous/cartilage injuries, in effort to prevent repair failures and progression to OA. Patients with generalized OA and varus malalignment >5° are unlikely to benefit from repair [5, 29]. However, there have been reports of equivocal outcomes in select patients treated with root repair with underlying mild to moderate (5–10°) varus alignment [61]. Obesity and malalignment ≤5° both place additional stress on the meniscus and are risk factors for potential repair failure [51]. Accordingly, our group has strict inclusion criteria for patients undergoing root repair (Fig. 4). Although not absolute contraindications, careful patient selection is required inpatient cohorts with obesity or varus malalignment 5–10°. Contraindications include K-L grade ≥ 3 on X-ray, grade 3 chondromalacia or worse at time of arthroscopy, subchondral bone collapse, varus malalignment >10°, or in patients unable or not willing to utilize crutches for 6 weeks [3, 21].

Fig. 4



Flowchart showing indications and contraindications for meniscus root tear repair. (Reproduced with permission from Ref. [3])

6.1 Transtibial Pull-Through Repair

The transtibial pull-through technique employs meniscus sutures that are passed through a tibial bone tunnel that anchor the meniscus root to the tibial plateau [1, 29]. These sutures are secured to the anterior tibial cortex [1]. Our preferred technique is described in more detail below.

6.2 Suture Anchor Repair

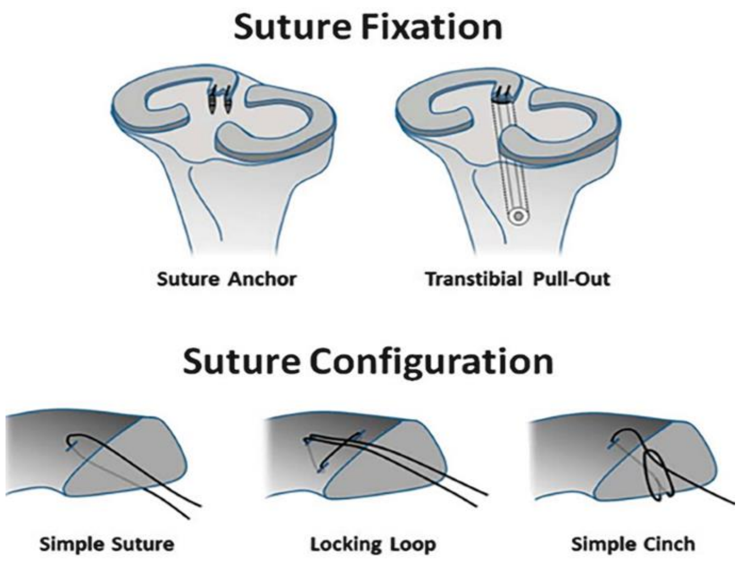
The suture anchor technique was initially developed to facilitate root repair without creating tibial bone tunnels in the setting of patients with multiligamentous knee injury [1]. Engelsohn et al. first described the suture anchor technique with an all arthroscopic approach to root repair utilizing a posteromedial portal. This technique requires a dedicated, curved guide and working through a portal adjacent to the neurovascular bundle. Aside from operating near critical structures, gaining arthroscopic access to the meniscal root may not be practical in ligamentously intact knees [62, 63]. This approach may be an advantage in a skeletally immature patient or when performing a concomitant proximal tibial osteotomy.

7 Authors' Preferred Surgical Technique

7.1 Transtibial Pull-Through

Repair of meniscus root tears has been described using sutures pulled through a transtibial tunnel or using direct fixation with suture anchors (Fig. 5). Although outcome data support the efficacy of both suture anchor and transtibial constructs, with satisfactory and comparable structural healing and patient-reported outcome scores, the suture anchor technique is technically challenging, requires a posterior portal adjacent to the neurovascular structures, and uses specialized suture-passing devices for constrained passing within the knee. With this in mind, the authors are proponents of transtibial fixation using standard and familiar arthroscopy portals, which has an established record of positive midterm to long-term results [8, 30, 54, 64].

Fig. 5



Depiction of suture anchor and transtibial pull-through techniques with simple suture, locking loop, and simple cinch suture configurations for meniscal fixation. (Reproduced with permission from Ref. [3])

Our preferred technique of meniscal root repairs has previously been described in detail [3, 30, 65]. Key steps, pearls, and pitfalls are summarized in Tables 1 and 2 [66]. Standard knee arthroscopy portals are used, including a portal ipsilateral to the tear to allow for direct visualization of the posterior root. The attachment of the meniscus horn is inspected and palpated with a probe, which is of clinical significance because of the high rate of incomplete tear visualization on preoperative MRI [31]. In cases where it is difficult to obtain adequate visualization of the posterior meniscus roots and their respective compartments, we recommend consideration of (reverse) notchplasty or "pie crusting" of the medial collateral ligament to provide satisfactory arthroscopic access [67]. Given that lateral meniscus root tears are challenging to identify preoperatively, including in the setting of both primary and revision ACL reconstruction, surgeons must always thoroughly inspect the meniscus attachments and be ready to repair detected root tears.

After establishment of optimal portals and working space, attention is turned to tibial socket preparation. Given the importance of anatomic socket location, our preference is to use a root-specific tibial guide placed through the ipsilateral arthroscopy portal and centered on the meniscus root footprint. However, this can also be achieved with a standard ACL guide and drill. Subsequently, a 6-mm all-in-one guide pin/reamer is introduced into the joint through an incision on the proximal and medial tibia and deployed so that a shallow 6-mm socket is formed to provide fixation access to healing vascular subchondral bone. This can also be achieved with the standard 6-mm drill; however, this leads to greater bone loss along the length of the entire tibial tunnel compared with selective inside-out drilling with all-in-one instrumentation.

For meniscus fixation, a free No. 0 nonabsorbable suture is passed through the torn meniscus in a simple cinch configuration using a self-retrieving suture-passing device. A total of 2–3 locking sutures are placed, depending on the tissue size and quality, and then individually tightened, with the knee cycled to remove creep from the system. Subsequently, the sutures are tensioned through the tibial socket to reduce the meniscus root back to the native bony root attachment. Tibial fixation is subsequently obtained using a 5.5-mm anchor or, as classically described, a tibial button, with the knee in 90° of flexion (Fig. 6).

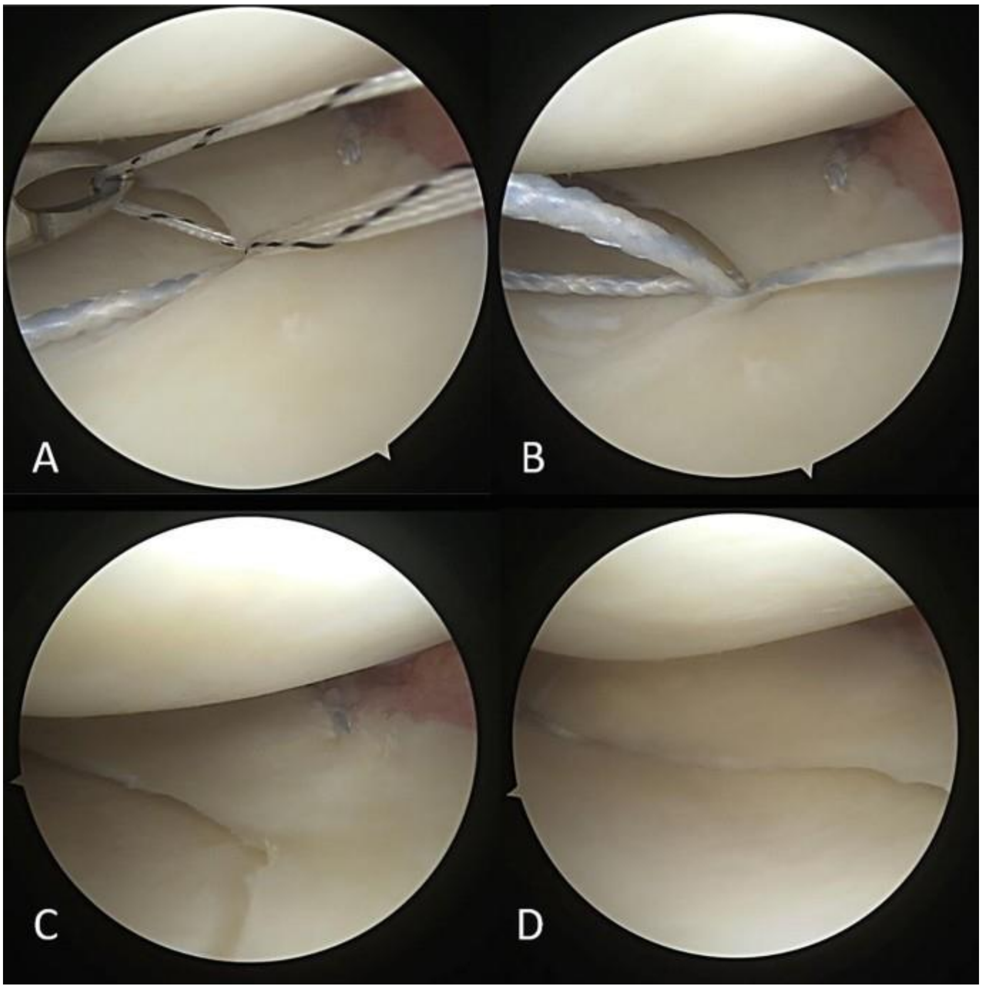
Fig. 6

Arthroscopic images of a right knee viewed from the anterolateral portal showing (**a**) the location of the tibial tunnel through the meniscal root anatomic footprint, (**b**) transosseous tensioning of the simple cinch sutures, and (**c**) subsequent meniscal root reduction to the anatomic bony attachment, establishing the final repair

7.2 Arthroscopic Centralization

Our preferred technique combines transtibial pull-through and centralization sutures [30, 66]. Meniscus centralization is completed prior to the transtibial pull-through method described above. Similarly, beginning with a diagnostic arthroscopy is fundamental to understanding the pathology prior to carrying out the surgical plan. Create an accessory medial portal that is proximal and medial to the standard anteromedial portal, to allow for the correct angulation of instruments. Using a curved elevator, perform a release of the meniscotibial ligaments off the periphery of the tibial plateau. Next, the anteromedial portal is utilized to place a knotless suture anchor just central to the peripheral rim of the tibial articular surface. With a self-retrieving suture passing device, via the anterolateral portal, pass the repair suture through the meniscocapsular junction in a mattress fashion. Tension the centralization suture down with an arthroscopic knot pusher or with a pusher-cutter device (Fig. 7). Repeat this process to create a total of 2–3 centralization sutures. Once the meniscus centralization is complete, move on to the transtibial root repair.

Fig. 7



(**a**) Deployed suture anchor placed at the periphery of the medial tibial plateau with shuttle sutures exiting the accessory anteromedial (AM) portal (right knee viewing from AM portal). (**b**) Suture placement before tensioning anchor with arthroscopic knot pusher or pusher-cutter device. (**c**) Oblique mattress suture after tensioning. (**d**) Final construct of root repair and centralization

8 Postoperative Management

Establishing a sound postoperative rehabilitation protocol for meniscus root repair is critical to the success of the operation. Throughout the first several months, the optimal healing environment for the meniscus occurs when the knee remains free of loading of events, especially in deep flexion. The postoperative management recommendations detailed below should be considered for a patient following an isolated root repair. Patient-specific alterations should be considered when patients undergo additional procedures such as a concomitant osteotomy or ligament reconstruction (i.e., ACL reconstruction), which can influence optimal range of motion, weight-bearing, and timeline considerations. Consequently, communication between the patient, surgeon, and physical therapist should be prioritized.

Patients are required to wear a hinged knee brace full-time for the first 6 weeks following the procedure. Knee range of motion is permitted from full extension to 90° of flexion. Weight-bearing is limited to toe-touch weight-bearing with the knee in full extension.

After 6 weeks, the knee brace may be discontinued. Patients may practice unrestricted knee range of motion through an unloaded joint and can progressively increase their weight-bearing as tolerated. Patients must wait until at least 4 months from surgery before placing loads across their knees when flexed beyond 90°.

The point at which patients return to sport is influenced by the clinical timeline and the physical readiness of the patient. By 3 months, patients are allowed to slowly increase physical activity. After 4–6 months of recovery, those who have attained normal strength with symmetric gaits are able to gradually begin participating in sporting activities. The typical timeline from isolated root repair to full return to sporting activities is 6–9 months.

9 Conclusion

The posterior horn meniscus root attachments are essential for knee joint integrity. Root tears are often missed at initial presentation due to a lack of classic symptoms and difficulty in imaging detection. When unrepaired, root tears lead to notable functional limitations, rapid cartilage deterioration, and subsequent OA [68]. Studies show that meniscus root repair is superior to nonoperative management as well as meniscectomy and should be considered first-line treatment in select patient populations [6, 53]. While repair with both suture anchor and transtibial pull-through techniques shows satisfactory outcomes, the robust, safe, and technically less challenging transtibial pull-through method remains the authors' preferred technique. Additionally, meniscus centralization is a newer technique that is recognized as a method to decrease meniscus extrusion. It is performed prior to root repair by securing or "centralizing" the mid-body of the meniscus onto the rim of the tibial plateau. Early studies hypothesizing that meniscus root repair augmented with centralization would offer additional cartilage protective benefits have demonstrated encouraging results [39,40,41].

No Conflict of interest.

References:

[1] Bhatia S, LaPrade CM, Ellman MB, LaPrade RF. Meniscal root tears: significance, diagnosis, and treatment. Am J Sports Med. 2014;42(12):3016–30.

[2] Papalia R, Vasta S, Franceschi F, D'Adamio S, Maffulli N, Denaro V. Meniscal root tears: from basic science to ultimate surgery. Br Med Bull. 2013;106:91–115.

[3] Krych AJ, Hevesi M, Leland DP, Stuart MJ. Meniscal root injuries. J Am Acad Orthop Surg. 2020;28(12):491–9.

[4] Kim SB, Ha JK, Lee SW, Kim DW, Shim JC, Kim JG, et al. Medial meniscus root tear refixation: comparison of clinical, radiologic, and arthroscopic findings with medial meniscectomy. Arthroscopy. 2011;27(3):346–54.

[5] Krych AJ. Editorial commentary: knee medial meniscus root tears: "you may not have seen it, but It's seen you". Arthroscopy. 2018;34(2):536–7.

[6] Faucett SC, Geisler BP, Chahla J, Krych AJ, Kurzweil PR, Garner AM, et al. Meniscus root repair vs meniscectomy or nonoperative management to prevent knee osteoarthritis after medial meniscus root tears: clinical and economic effectiveness. Am J Sports Med. 2019;47(3):762–9.

[7] Krych AJ, Nauert RF 3rd, Song BM, Cook CS, Johnson AC, Smith PA, et al. Association between transtibial meniscus root repair and rate of meniscal healing and extrusion on postoperative magnetic resonance imaging: a prospective multicenter study. Orthop J Sports Med. 2021;9(8):23259671211023774.

[8] Chung KS, Ha JK, Yeom CH, Ra HJ, Jang HS, Choi SH, et al. Comparison of clinical and radiologic results between partial meniscectomy and refixation of medial meniscus posterior root tears: a minimum 5-year follow-up. Arthroscopy. 2015;31(10):1941–50.

[9] LaPrade CM, LaPrade MD, Turnbull TL, Wijdicks CA, LaPrade RF. Biomechanical evaluation of the transtibial pull-out technique for posterior medial meniscal root repairs using 1 and 2 transtibial bone tunnels. Am J Sports Med. 2015;43(4):899–904.

[10] Fox AJ, Wanivenhaus F, Burge AJ, Warren RF, Rodeo SA. The human meniscus: a review of anatomy, function, injury, and advances in treatment. Clin Anat. 2015;28(2):269–87.

[11] Kennedy MI, Strauss M, LaPrade RF. Injury of the meniscus root. Clin Sports Med. 2020;39(1):57–68.

[12] LaPrade RF, Floyd ER, Carlson GB, Moatshe G, Chahla J, Monson JK. Meniscal root tears: solving the silent epidemic. J Arthrosc Surg Sports Med. 2021;1:47–57.

[13] LaPrade CM, Ellman MB, Rasmussen MT, James EW, Wijdicks CA, Engebretsen L, et al. Anatomy of the anterior root attachments of the medial and lateral menisci: a quantitative analysis. Am J Sports Med. 2014;42(10):2386–92.

[14] Ellman MB, LaPrade CM, Smith SD, Rasmussen MT, Engebretsen L, Wijdicks CA, et al. Structural properties of the meniscal roots. Am J Sports Med. 2014;42(8):1881–7.

[15] Pache S, Aman ZS, Kennedy MI, Nakama G, Moatshe G, Ziegler C, et al. Meniscal root tears: current concepts review. Arch Bone Jt Surg. 2018;6:250–9.

[16] Chahla J, Nitri M, Civitarese D, Dean CS, Moulton SG, LaPrade RF. Anatomic double-bundle posterior cruciate ligament reconstruction. Arthrosc Tech. 2016;5(1):e149–56.

[17] 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(10):2342–7.

[18] Carballo CB, Nakagawa Y, Sekiya I, Rodeo SA. Basic science of articular cartilage. Clin Sports Med. 2017;36(3):413–25.

[19] Camp CL, Stuart MJ, Krych AJ. Current concepts of articular cartilage restoration techniques in the knee. Sports Health. 2014;6(3):265–73.

[20] Redondo ML, Naveen NB, Liu JN, Tauro TM, Southworth TM, Cole BJ. Preservation of knee articular cartilage. Sports Med Arthrosc Rev. 2018;26(4):e23–30.

[21] Krych AJ, Bernard CD, Kennedy NI, Tagliero AJ, Camp CL, Levy BA, et al. Medial versus lateral meniscus root tears: is there a difference in injury presentation, treatment decisions, and surgical repair outcomes? Arthroscopy. 2020;36(4):1135–41.

[22] Patil S, Tapasvi SR. Osteochondral autografts. Curr Rev Musculoskelet Med. 2015;8(4):423–8.

[23] Choi ES, Park SJ. Clinical evaluation of the root tear of the posterior horn of the medial meniscus in total knee arthroplasty for osteoarthritis. Knee Surg Relat Res. 2015;27(2):90–4.

[24] Matheny LM, Ockuly AC, Steadman JR, LaPrade RF. Posterior meniscus root tears: associated pathologies to assist as diagnostic tools. Knee Surg Sports Traumatol Arthrosc. 2015;23(10):3127–31.

[25] Frank JM, Moatshe G, Brady AW, Dornan GJ, Coggins A, Muckenhirn KJ, et al. Lateral meniscus posterior root and meniscofemoral ligaments as stabilizing structures in the ACL-deficient knee: a biomechanical study. Orthop J Sports Med. 2017;5(6):2325967117695756.

[26] Seil R, Duck K, Pape D. A clinical sign to detect root avulsions of the posterior horn of the medial meniscus. Knee Surg Sports Traumatol Arthrosc. 2011;19(12):2072–5.

[27] Lee SY, Jee WH, Kim JM. Alvusi of the medial meniscal root: reliability and accuracy of MRI for diagnosis. AJR Am J Roentgenol. 2008;191(1):81–5.

[28] Harper KW, Helms CA, Lambert HS 3rd, Higgins LD. Radial meniscal tears: significance, incidence, and MR appearance. AJR Am J Roentgenol. 2005;185(6):1429–34.

[29] Krych AJ, Hevesi M, Leland DP, Stuart MJ. Meniscal root injuries. J Am Acad Orthop Surg. 2019.

[30] Ozeki N, Seil R, Krych AJ, Koga H. Surgical treatment of complex meniscus tear and disease: state of the art. J Isakos. 2021;6(1):35–45.

[31] Krych AJ, Wu IT, Desai VS, Murthy NS, Collins MS, Saris DBF, et al. High rate of missed lateral meniscus posterior root tears on preoperative magnetic resonance imaging. Orthop J Sports Med. 2018;6(4):2325967118765722.

[32] LaPrade CM, James EW, Cram TR, Feagin JA, Engebretsen L, LaPrade RF. Meniscal root tears: a classification system based on tear morphology. Am J Sports Med. 2015;43(2):363–9.

[33] Costa CR, Morrison WB, Carrino JA. Medial meniscus extrusion on knee MRI: is extent associated with severity of degeneration or type of tear? AJR Am J Roentgenol. 2004;183(1):17–23.

[34] Krych AJ, Bernard CD, Leland DP, Camp CL, Johnson AC, Finnoff JT, et al. Isolated meniscus extrusion associated with meniscotibial ligament abnormality. Knee Surg Sports Traumatol Arthrosc. 2020;28(11):3599–3605. https://doi.org/10.1007/s00167-019-05612-1.

[35] 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(1):42–9.

[36] Krych AJ, Johnson NR, Mohan R, Hevesi M, Stuart MJ, Littrell LA, et al. Arthritis progression on serial MRIs following diagnosis of medial meniscal posterior horn root tear. J Knee Surg. 2018;31(7):698–704.

[37] Krych AJ, LaPrade MD, Hevesi M, Rhodes NG, Johnson AC, Camp CL, et al. Investigating the chronology of meniscus root tears: do medial meniscus posterior root tears cause extrusion or the other way around? Orthop J Sports Med. 2020;8(11):2325967120961368.

[38] Daney BT, Aman ZS, Krob JJ, Storaci HW, Brady AW, Nakama G, et al. Utilization of transtibial centralization suture best minimizes extrusion and restores tibiofemoral contact mechanics for anatomic medial meniscal root repairs in a cadaveric model. Am J Sports Med. 2019;47(7):1591–600.

[39] Koga H, Muneta T, Yagishita K, Watanabe T, Mochizuki T, Horie M, et al. Arthroscopic centralization of an extruded lateral meniscus. Arthrosc Tech. 2012;1(2):e209–12.

[40] Koga H, Watanabe T, Horie M, Katagiri H, Otabe K, Ohara T, et al. Augmentation of the pullout repair of a medial meniscus posterior root tear by arthroscopic centralization. Arthrosc Tech. 2017;6(4):e1335–e9.

[41] Mochizuki Y, Kawahara K, Samejima Y, Kaneko T, Ikegami H, Musha Y. Short-term results and surgical technique of arthroscopic centralization as an augmentation for medial

meniscus extrusion caused by medial meniscus posterior root tear. Eur J Orthop Surg Traumatol. 2021;31(6):1235–41.

[42] Allaire R, Muriuki M, Gilbertson L, Harner CD. Biomechanical consequences of a tear of the posterior root of the medial meniscus: similar to total meniscectomy. JBJS. 2008;90(9):1922–31.

[43] Krych AJ, Reardon PJ, Johnson NR, Mohan R, Peter L, Levy BA, et al. Non-operative management of medial meniscus posterior horn root tears is associated with worsening arthritis and poor clinical outcome at 5-year follow-up. Knee Surg Sports Traumatol Arthrosc. 2017;25(2):383–9.

[44] Robertson DD, Armfield DR, Towers JD, Irrgang JI, Maloney WJ, Harner CD. Meniscal root injury and spontaneous osteonecrosis of the knee: an observation. J Bone Joint Surg Am. 2009;91-B(2):190–5.

[45] Hussain ZB, Chahla J, Mandelbaum BR, Gomoll AH, LaPrade RF. The role of meniscal tears in spontaneous osteonecrosis of the knee: a systematic review of suspected etiology and a call to revisit nomenclature. Am J Sports Med. 2019;47(2):501–7.

[46] Pareek A, Parkes CW, Bernard C, Camp CL, Saris DBF, Stuart MJ, et al. Spontaneous osteonecrosis/subchondral insufficiency fractures of the knee: high rates of conversion to surgical treatment and arthroplasty. J Bone Joint Surg Am. 2020;102(9):821–9.

[47] Pareek A, Parkes CW, Bernard CD, Abdel MP, Saris DBF, Krych AJ. The SIFK score: a validated predictive model for arthroplasty progression after subchondral insufficiency fractures of the knee. Knee Surg Sports Traumatol Arthrosc. 2020;28(10):3149–55.

[48] Barras LA, Pareek A, Parkes CW, Song BM, Camp CL, Saris DBF, et al. Post-arthroscopic subchondral insufficiency fractures of the knee yield high rate of conversion to arthroplasty. Arthroscopy. 2021;37(8):2545–53.

[49] Tagliero AJ, Kurian EB, LaPrade MD, Song BM, Saris DBF, Stuart MJ, et al. Arthritic progression secondary to meniscus root tear treated with knee arthroplasty demonstrates similar outcomes to primary osteoarthritis: a matched case-control comparison. Knee Surg Sports Traumatol Arthrosc. 2021;29(6):1977–82.

[50] Heir S, Nerhus TK, Rotterud JH, Loken S, Ekeland A, Engebretsen L, et al. Focal cartilage defects in the knee impair quality of life as much as severe osteoarthritis: a comparison of knee injury and osteoarthritis outcome score in 4 patient categories scheduled for knee surgery. Am J Sports Med. 2010;38(2):231–7.

[51] Krych AJ, Johnson NR, Mohan R, Dahm DL, Levy BA, Stuart MJ. Partial meniscectomy provides no benefit for symptomatic degenerative medial meniscus posterior root tears. Knee Surg Sports Traumatol Arthrosc. 2018;26(4):1117–22.

[52] Salata MJ, Gibbs AE, Sekiya JK. A systematic review of clinical outcomes in patients undergoing meniscectomy. Am J Sports Med. 2010;38(9):1907–16.

[53] Bernard CD, Kennedy NI, Tagliero AJ, Camp CL, Saris DBF, Levy BA, et al. Medial meniscus posterior root tear treatment: a matched cohort comparison of nonoperative management, partial meniscectomy, and repair. Am J Sports Med. 2020;48(1):128–32.

[54] Chung KS, Noh JM, Ha JK, Ra HJ, Park SB, Kim HK, et al. Survivorship analysis and clinical outcomes of transtibial pullout repair for medial meniscus posterior root tears: a 5- to 10-year follow-up study. Arthroscopy. 2018;34(2):530–5.

[55] Chung KS, Ha JK, Ra HJ, Kim JG. Preoperative varus alignment and postoperative meniscus extrusion are the main long-term predictive factors of clinical failure of meniscal root repair. Knee Surg Sports Traumatol Arthrosc. 2021;29(12):4122–4130. https://doi.org/10.1007/s00167-020-06405-7.

[56] Moon HS, Choi CH, Jung M, Lee DY, Hong SP, Kim SH. Early surgical repair of medial meniscus posterior root tear minimizes the progression of meniscal extrusion: 2-year follow-up of clinical and radiographic parameters after arthroscopic transtibial pull-out repair. Am J Sports Med. 2020;48(11):2692–702.

[57] Kim SJ, Choi CH, Chun YM, Kim SH, Lee SK, Jang J, et al. Relationship between preoperative extrusion of the medial meniscus and surgical outcomes after partial meniscectomy. Am J Sports Med. 2017;45(8):1864–71.

[58] Koga H, Muneta T, Watanabe T, Mochizuki T, Horie M, Nakamura T, et al. Two-year outcomes after arthroscopic lateral meniscus centralization. Arthroscopy. 2016;32(10):2000–8.

[59] Ozeki N, Koga H, Matsuda J, Kohno Y, Mizuno M, Katano H, et al. Biomechanical analysis of the centralization procedure for extruded lateral menisci with posterior root deficiency in a porcine model. J Orthop Sci. 2020;25(1):161–6.

[60] Ozeki N, Muneta T, Kawabata K, Koga H, Nakagawa Y, Saito R, et al. Centralization of extruded medial meniscus delays cartilage degeneration in rats. J Orthop Sci. 2017;22(3):542–8.

[61] Moon HS, Choi CH, Yoo JH, Jung M, Lee TH, Jeon BH, et al. Mild to moderate varus alignment in relation to surgical repair of a medial meniscus root tear: a matched-cohort controlled study with 2 years of follow-up. Am J Sports Med. 2021;49(4):1005–16.

[62] Engelsohn E, Umans H, Difelice GS. Marginal fractures of the medial tibial plateau: possible association with medial meniscal root tear. Skelet Radiol. 2007;36(1):73–6.

[63] Lee SK, Yang BS, Park BM, Yeom JU, Kim JH, Yu JS. Medial meniscal root repair using curved guide and soft suture anchor. Clin Orthop Surg. 2018;10(1):111–5.

[64] Woodmass JM, Mohan R, Stuart MJ, Krych AJ. Medial meniscus posterior root repair using a transtibial technique. Arthrosc Tech. 2017;6(3):e511–e6.

[65] Hevesi M, Stuart MJ, Krych AJ. Medial meniscus root repair: a transtibial pull-out surgical technique. Oper Tech Sports Med. 2018;26(3):205–9.

[66] Leafblad ND, Smith PA, Stuart MJ, Krych AJ. Arthroscopic centralization of the extruded medial meniscus. Arthrosc Tech. 2021;10(1):e43–e8.

[67] Bert JM. First, do no harm: protect the articular cartilage when performing arthroscopic knee surgery! Arthroscopy. 2016;32(10):2169–74.

[68] Krych AJ, Hevesi M, Leland DP, Stuart MJ. Meniscal root injuries. JAAOS-J Am Acad Orthop Surgeons. 2020;28(12):491–9.