Review Article

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Meniscal Repair

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The meniscus has several important roles, such as transmission of the load, absorption of the shock in the knee joint, acting as a secondary anteroposterior stabilizer of the knee joint, and contributing to proprioception of the knee joint. Degenerative changes of the knee joint develop in the long-term follow-up even after partial meniscectomy. Thus, there has been growing interest in meniscal repair. In addition, with increased understanding of the important roles of the meniscal root and advancement of diagnostic methods, efforts have been made to ensure preservation of the meniscal roots. In this review article, we will discuss operative techniques and clinical outcomes of arthroscopic repair of the meniscus and the meniscal root and postoperative rehabilitation and complications as well.

Keywords: **Knee, Meniscus, Repair**

Introduction

The meniscus is responsible for load transmission and shock absorption of the tibiofemoral joint in the human knee[1,2]. In addition, it acts as a secondary anteroposterior stabilizer of the knee joint, contributing to proprioception of the knee joint, lubrication, and nutrition supply to the articular cartilage[3-5].

Meniscal tears are the most common knee injuries and seen in patients of all ages due to several causes: degeneration, trauma, and discoid meniscus[6]. The indications and surgical techniques for excision of torn menisci have been controversial. In addition, increasing degenerative changes have been noted in long-term follow-ups after excision of torn menisci, especially after total meniscectomy[7,8]. In biomechanical studies, peak contact pressure was shown to increase by up to 235% after total meniscectomy[9,10] and by up to 165% even after partial meniscectomy[10]. In contrast, the contact pressure after meniscal repair decreases almost down to the intact level[10-12]. In terms of clinical outcomes, meniscectomy has been associated with lower clinical outcome scores than meniscal repair[13-15].

Complete removal of the meniscus is justified only when it is irreparably torn, and the meniscal rim should be preserved if at all possible[16,17]. The indications for partial meniscectomy are central, intra-substance meniscal lesions, unstable lesions in the white-white zone, irreducible displaced inner edge in bucket-handle tears, the flaps in flap tears, and the flaps in oblique tears[16,18,19]. Meniscectomy still remains as a common orthopaedic procedure although meniscal repairs are increasingly performed over meniscectomies, especially in young or adolescent patients[20,21]. The indications for meniscal repair have remained controversial. However, the ideal indication for meniscal repair is an acute 1 to 2 cm longitudinal peripheral tear that can be repaired in conjunction with anterior cruciate ligament (ACL) reconstruction in young patients[16,22-24]. Nevertheless, some authors reported good clinical results after repair of meniscus tears extending into the avascular zone in patients less than 20 years of age[25]. Other investigators performed meniscal repairs in patients with meniscal tears including those with more than 60 years of age, and they recommended meniscal repair wherever possible regardless of age[26-30]. The reparability of meniscal tears depends on several factors, such as vascularity, type of tear, chronicity, and size[16]. A longitudinal tear on red-red zone in an acute setting has a preferable reparability than a radial or a flap tear on white-white zone

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in a chronic setting[16]. Meniscal repair can be performed either with an open or arthroscopic technique. Arthroscopic meniscal repair has advantages over open repair in terms of minimal incision, early recovery, and rehabilitation[31-33]. Arthroscopic repair techniques can be divided into 4 categories: inside-out techniques, outside-in techniques, all-inside techniques, and hybrid techniques that combine multiple techniques[16]. A meniscal tear on mid-third horn or a peripheral capsule area can be repaired with inside-out technique. Repair of a meniscal tear on anterior horn or an attempt to reduction of bucket-handle tear can be performed with outside-in technique. All-inside technique can be used in a meniscal tear on posterior horn[16].

In this review article, we will describe the operative methods and clinical outcomes of arthroscopic repair techniques. In addition, we will discuss operative methods and clinical outcomes of meniscal root repair because of the growing interest in the importance of the meniscal root, and rehabilitations and complications after meniscal repair as well.

Inside-Out Repair Technique

1. Operative Method

The inside-out technique can be performed using double-armed needles with an absorbable or non-absorbable suture passing through single-lumen zone-specific repair cannulas. Before meniscal repair, tear debridement and perisynovial tissue abrasion with a meniscal rasp or motorized shaver should be performed to stimulate a proliferative fibroblastic healing response[16]. First, a 4 to 5 cm skin incision and dissection are made along the posterior border of the collateral ligaments. For medial meniscal repair, the fascia is opened and the hamstrings and medial gastrocnemius are retracted posteriorly. A popliteal retractor can be placed in the interval between the medial head of the gastrocnemius and the posterior capsule of the joint to protect the popliteal vessels and to aid in passing the needles[16]. For lateral meniscal repair, the knee joint should be brought to 90° of flexion so that the peroneal nerve drops more inferiorly and is protected, and the iliotibial tract is retracted upwards and the biceps tendon downwards. Then, careful dissection should be performed to reflect the lateral gastrocnemius head off the posterior capsule. After this dissection, suturing is performed by passing a long needle with a suture attached through the cannula and then through the meniscus to exit laterally. After the first needle is passed, the cannula is repositioned at the inferior or superior articular surface of the meniscus and then a second needle is passed and retrieved (Fig. 1). After passing the needles, the sutures for the medial meniscus are tied over the joint capsule with the knee in 20° of flexion[34], the sutures for the lateral meniscus are tied over the joint capsule with the knee in 90° of flexion[16,35].

2. Clinical Outcomes

There are several studies to report clinical outcomes of meniscal repairs using an inside-out technique. Horibe et al.[35] reported that 113 of 120 patients showed clinically successful results at a mean of 8-month follow-up. However, only 73% of the patients had healed completely on a second-look arthroscopy. Steenbrugge et al.[30] reported that 85% of patients showed excellent or good results at a mean of 13.2-year follow-up, and no poor results were observed. Logan et al.[36] studied 45 elite athletes who underwent meniscal repairs with 83% of them having a concomitant ACL reconstruction. Eighty-one percent of the patients returned to their pre-injury level sports at a mean of 10.4-month follow-up. Seven of 11 failures after meniscal repairs were associated with a new injury. They also concluded that medial meniscal repairs

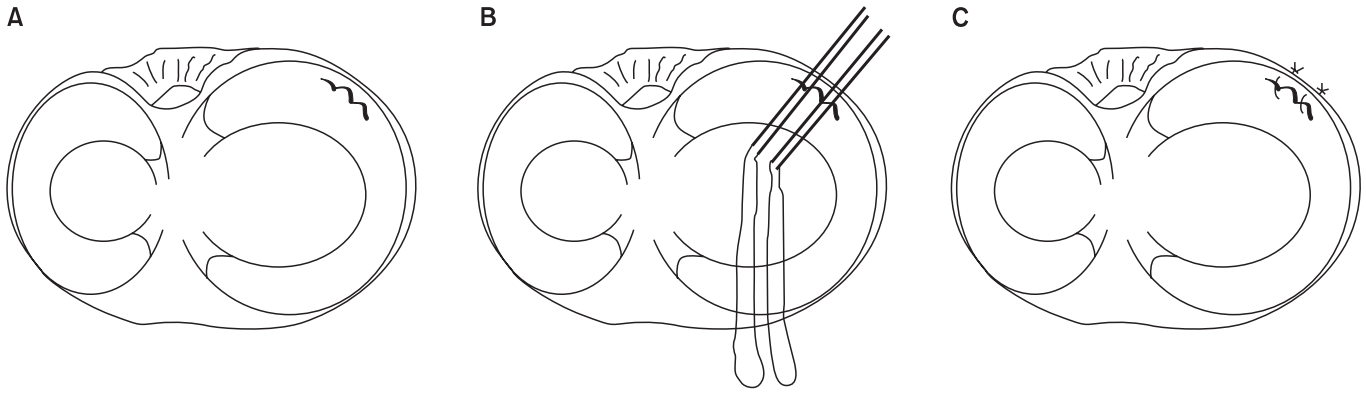

Fig. 1. Inside-out repair technique. (A) A longitudinal tear is identified. (B) Long needles with sutures attached are passed through appropriate cannulas superior and inferior to the tear site. (C) Vertical sutures are tied over the joint capsule.

were significantly more likely to fail than lateral meniscal repairs. Vanderhave et al.[23] compared 31 cases of inside-out meniscal repairs with concomitant ACL reconstruction in young athletes with 14 cases of meniscal repairs without ACL reconstruction. Forty-three of the 45 patients showed excellent clinical outcomes at a mean of 27-month follow-up. They reported no significantly different clinical results were observed between the medial and lateral meniscus groups. However, patients with ACL reconstruction had significantly longer return-to-activity periods and significantly lower Tegner activity scores than patients without ACL reconstruction. Ra et al.[37] reviewed inside-out repair of complete radial tears of the meniscus with a fibrin clot. Eleven of 12 cases showed complete healing on magnetic resonance imaging (MRI) and 6 of 7 patients who underwent a second-look arthroscopic examination showed completely healed meniscus at a mean of 30.3-month follow-up. Haklar et al.[38] studied inside-out repair of radial lateral meniscus tear by double horizontal sutures. They reported all patients showed completely healed meniscus on MRI and returned to their former level of activity at a mean of 31-month follow-up and concluded that repairing rather than resecting radial lateral meniscus tears extending into the capsular zone improved activity level. In systematic reviews, 62% of patients showed complete healing, 20% showed incomplete healing, 18% showed failed meniscal repair at a second-look arthroscopy[13], and the overall clinical failure rate was 17%[39].

Outside-In Repair Technique

1. Operative Method

Warren[40] introduced the outside-in meniscal repair technique to decrease the risk of injury to the peroneal nerve during the procedure of lateral meniscal repair. The peroneal nerve could be protected during meniscal repair because the starting point for needle entry is controlled by the surgeon[41]. The outside-in technique can be used for most of the meniscal tears patterns and locations, especially tears located in the anterior horn. It can also be

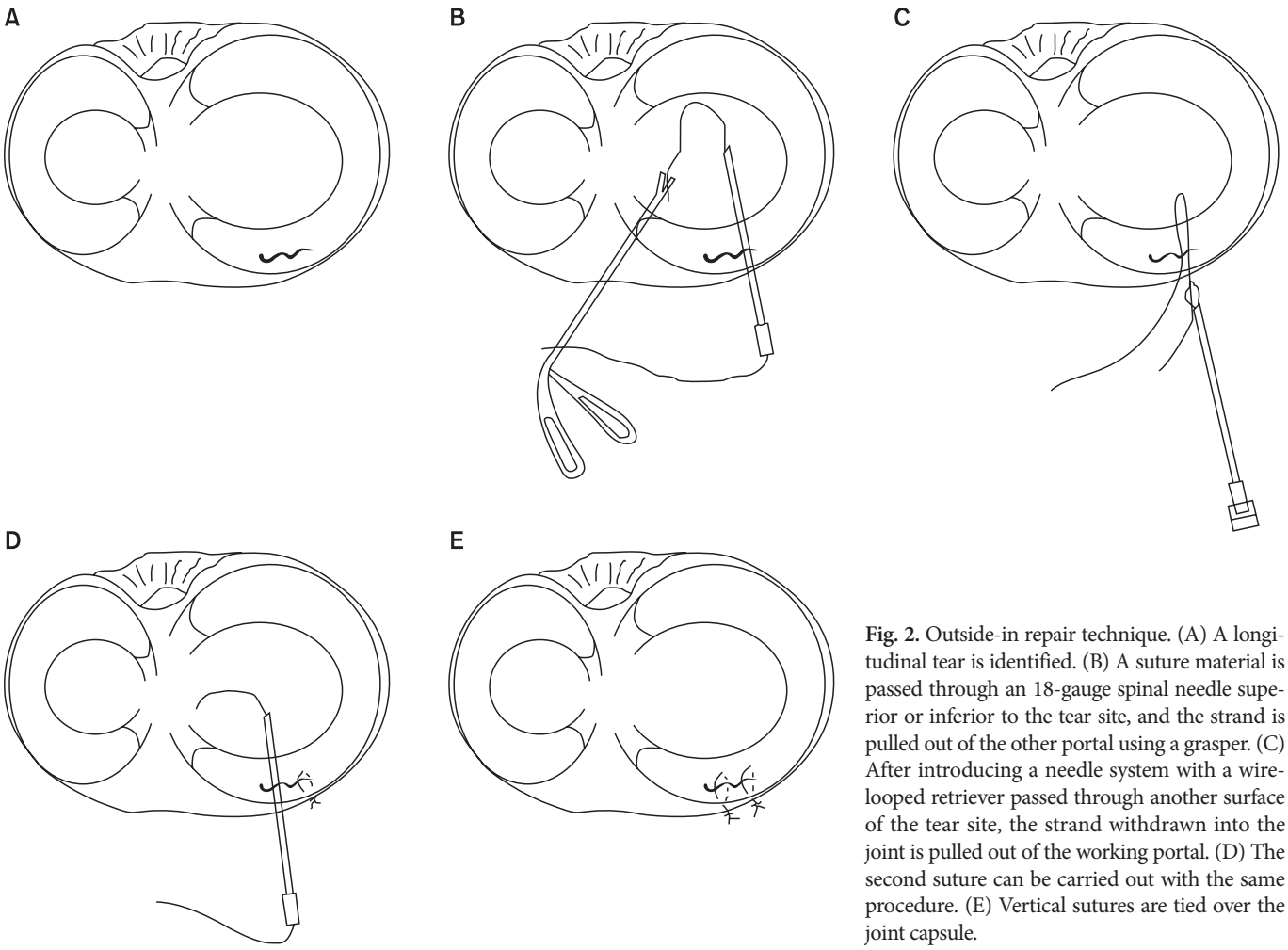

Fig. 2. Outside-in repair technique. (A) A longitudinal tear is identified. (B) A suture material is passed through an 18-gauge spinal needle superior or inferior to the tear site, and the strand is pulled out of the other portal using a grasper. (C) After introducing a needle system with a wire-looped retriever passed through another surface of the tear site, the strand withdrawn into the joint is pulled out of the working portal. (D) The second suture can be carried out with the same procedure. (E) Vertical sutures are tied over the joint capsule.

used to fix a transplanted meniscal allograft to the joint capsule[42]. The technique can be carried out using an 18-gauge spinal needle or a corresponding suture-passing needle system with a wire-looped retriever. For posteromedial repairs, the knee should be flexed to 10°–20° to allow the sartorial nerve to lie anterior to the repair site. For anteromedial repairs, the knee should be flexed to 40°–50° to allow the sartorial branch of saphenous nerve to lie posterior to the repair site. For lateral meniscal repairs, the knee should be in 90° of flexion to allow the common peroneal nerve to lie posterior to the repair site. A needle is passed from outside to inside through the tear site. Then, an absorbable or nonabsorbable suture is passed through the needle and pulled out of the anterior portal using a grasper. Then a suture-passing needle system is passed from outside to inside on the either inferior or superior articular surface of the meniscus, and a wire-looped retriever is introduced through this system. After this procedure, the first suture is withdrawn back into the joint using a grasper, and delivered through the wire loop (Fig. 2). Then, the suture is pulled out of the suture passer and tied over the joint capsule[16]. Horizontal mattress suture can be performed with the same method.

2. Clinical Outcomes

Majewski et al.[43] reported that 64 of 88 patients achieved a mean Tegner activity score of 6 points and a mean Lysholm score of 94 points at a mean of 10-year follow-up. However, failure rates were 23.9% because of re-tear of the repaired meniscus. Venkatachalam et al.[44] reported that 78.6% of patients showed clinically successful outcomes at a mean of 21-month follow-up. Mariani et al.[31] studied 22 meniscal repairs with concomitant ACL reconstruction for a mean of 28 months. The authors reported that 77.3% of the patients showed good clinical results. However, complete healing on MRI was observed in 45.5% of the patients, thus MRI findings were not associated with the clinical symptoms. Morgan et al.[45] reported that 65% of patients showed complete healing, 19% showed asymptomatic incomplete healing, and 16% showed failed meniscal repair at a second-look arthroscopy. All failures were associated with ACL deficiencies. van Trommel et al.[46] reported that 45% healed completely, 32% healed partially, and 24% failed on MRI or at second-look arthroscopy at a mean of 15-month follow-up. In a systematic review, the overall reoperation rate after outside-in meniscal repair was 25%[13].

All-Inside Repair Technique

1. Operative Method

The all-inside repair technique can be used for repairing posterior horn tears. All-inside repairs have been traditionally carried out using suture hooks[47]. Since the introduction of self-adjusting suture devices representing the next generation of all-inside meniscal repair devices, the surgeon can use these devices for meniscal repair (Fig. 3). Currently, various suture-based fixators are available, and most of the fixators are based on a reverse-barbed fishhook design that maintains apposition and reduction

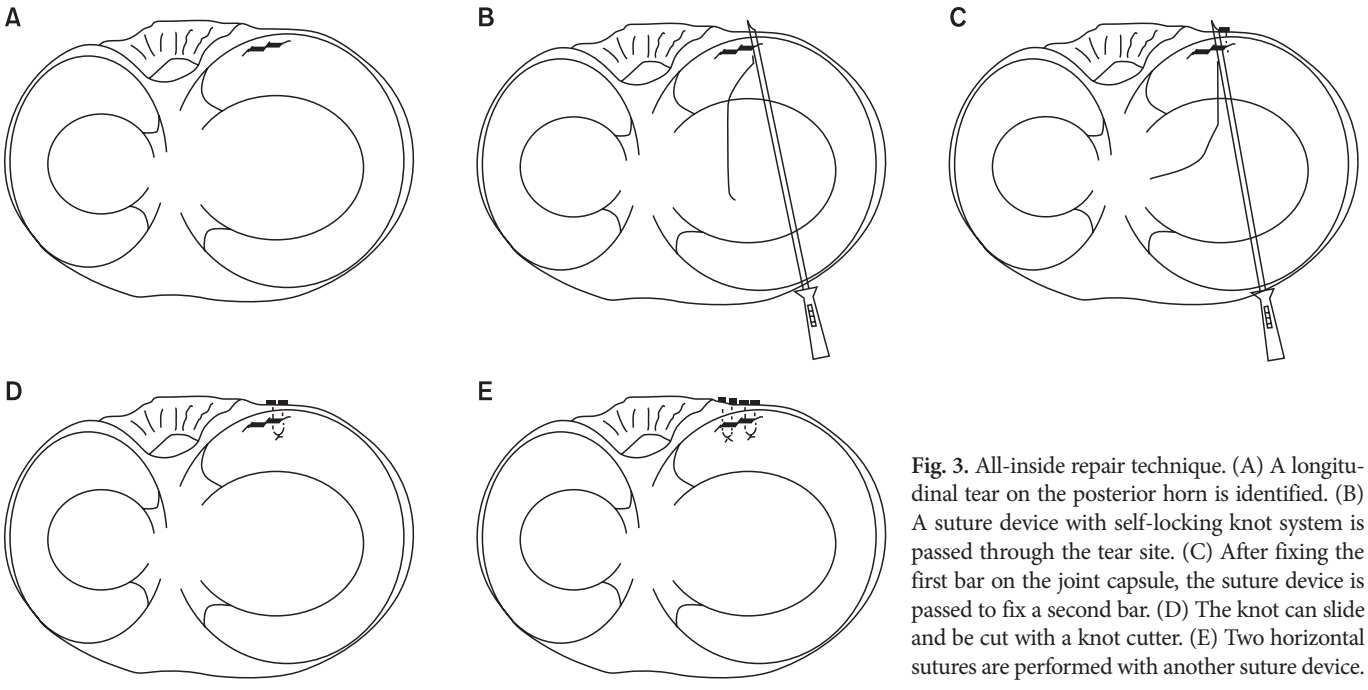

Fig. 3. All-inside repair technique. (A) A longitudinal tear on the posterior horn is identified. (B) A suture device with self-locking knot system is passed through the tear site. (C) After fixing the first bar on the joint capsule, the suture device is passed to fix a second bar. (D) The knot can slide and be cut with a knot cutter. (E) Two horizontal sutures are performed with another suture device.

of the torn fragments[34]. The principle is the same as that of the inside-out repair technique. The advantages of all-inside repair with suture devices include ease of use, avoidance of an accessory incision, shorter operating time, and less risk to neurovascular structures[48]. The disadvantages are meniscal or chondral damage from manipulation of the devices, implant migration, foreign body reactions, and higher cost[16,49]. The same methods used with all-inside repair devices can be applied to inside-out techniques. It is important to ensure enough meniscal tissue on both sides of the torn fragment to obtain sufficient tissue purchase[34]. Care must be taken while introducing the fixator to aim needle away from neurovascular structures and to set the needle depth penetration at 14 or 16 mm using a depth penetration limiter[16,50].

2. Clinical Outcomes

Ahn et al.[47] studied 39 all-inside repair using a suture hook in ACL-deficient knees for a mean of 19 months. They reported 82.1% complete healing and 15.4% asymptomatic incomplete healing at second-look arthroscopy. Haas et al.[50] reported that 86% of patients who underwent meniscal repairs by FasT-Fix device (Smith & Nephew, Andover, MA, USA) showed excellent or good clinical results at a mean of 24.3-month follow-up. Kotsovolos et al.[51] studied 61 meniscal repairs using FasT-Fix device with 62% of them undergoing concomitant ACL reconstruction over 18 months. They reported that the success rate was 90.2% and simultaneous ACL reconstruction did not affect the clinical outcomes. Kocabey et al.[52] reviewed 52 meniscal repairs using T-Fix (Smith & Nephew) with 62% of concomitant ACL reconstruction. They reported that 96% of patients showed excellent clinical results at a mean of 10.3-month follow-up. Asik et al.[53] also studied 47 meniscal repairs using T-Fix for a mean of 26 months. They reported that 89.4% of patients showed excellent or good clinical results, and 83% of patients who underwent second-look arthroscopy showed healing. Quinby et al.[54] reviewed 54 meniscal repairs using RapidLoc (DePuy Mitek Inc., Raynham, MA, USA) with concomitant ACL reconstruction. They reported that 90.7% of patients showed clinically successful results. However, Hantes et al.[55] reported only 65% of patients showed clinically successful results at a mean of 22-month follow-up. Spindler et al.[56] reviewed 85 meniscal repairs using Meniscus Arrow (Bionx, Blue Bell, PA, USA) with concomitant ACL reconstruction, and reported a 89% success rate over a 3-year follow-up period. Lee and Diduch[57] reviewed 32 meniscal repairs using Meniscus Arrow with concomitant ACL reconstruction. They reported that there was a clinical success rate of 90.6% at a mean follow-up of 2.3 years which deteriorated to 71.4% at 6.6 years of follow-up. In a systematic review, the overall clinical failure rate was 19%[39].

Meniscal Repairs in Medial Meniscal Root Tears

Meniscal root tears are radial tears or avulsions that occur at the insertion of the meniscus. Patients with meniscal root tears can complain of only minimal mechanical symptoms or discomfort with full flexion, and some patients may feel just a 'pop' in the knee joint at the moment of avulsion[26,58]. If torn fragments get caught in the knee joint during flexion, then patient can feel locking or pain in the knee. There is a growing concern over meniscal root tears because of the appreciation of the important physiological role played by the meniscal root as well as the advancement in various diagnostic tools[59,60]. According to biomechanical studies, meniscal root tears cause significant increases in tibiofemoral contact pressure which can be similar to that in the totally meniscectomied knee[60,61]. In addition, meniscal root tears can cause meniscal extrusion, chondral injury, and progressive osteoarthritis[62,63].

While lateral meniscal root tears are commonly associated with acute ACL injuries, medial meniscal root tears often occur secondary to degenerative joint changes[58,59,64]. Shelbourne and Heinrich[65] recommended nonoperative treatment for lateral meniscus tears, such as posterior horn tears and peripheral or posterior third tears that does not extend further than 1 cm in front of the popliteus tendon. Ahn et al.[66] reported good clinical outcomes and complete healing at second-look arthroscopy after all-inside meniscal repairs using a suture hook for the lateral meniscus tears combined with ACL injuries. Unstable root tears of the posterior horn of the medial meniscus can be treated either by the aforementioned all-inside repair techniques or by the pull-out repair. The pull-out repair principle is that the meniscus should be repaired to a freshened posterior bony bed. A posteromedial portal or posterior tran-septal portal can be used for additional visualization of the medial meniscal root and its insertion site[67]. If the introduction of an ACL guide is limited because of the medial femoral condyle (MFC) and soft tissue overlying the posterior cruciate ligament, notchplasty for removal of the synovium and 3 to 5 mm of the articular cartilage from the posterior aspect of the MFC can be performed[59]. Drilling is carried out from the anterolateral tibia to the base of the root footprint using an ACL guide and then sutures are passed through the meniscus using a suture shuttle device, pulled out through the bone tunnel, and tied anteriorly (Fig. 4)[16]. Lee et al.[26] reported that all patients were able to return to their previous life activities with little or no limitation at a mean of 31.8-month follow-up and all the patients

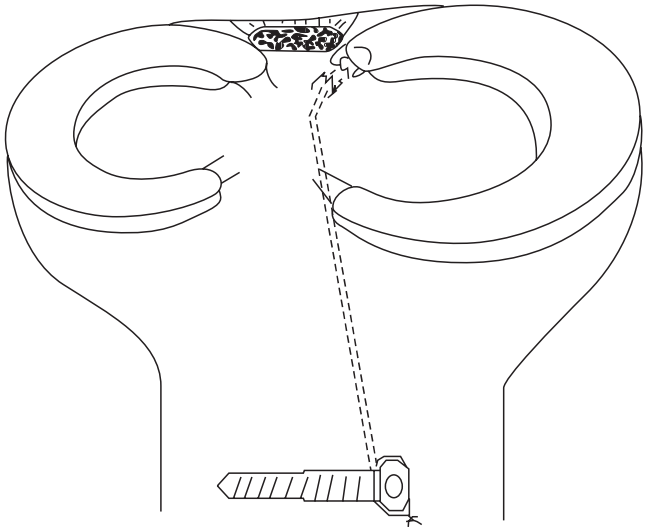

Fig. 4. Illustration of the pull-out repair of the posterior root of the medial meniscus.

who underwent second-look arthroscopy showed complete healing. Kim et al.[28] reviewed 22 meniscal root repairs using a pull out technique for a mean of 25.9 months. They observed significant improvement in functional scores and significant decreases in meniscal extrusions on MRI. However, only 64.7% of the patients who underwent follow-up MRI showed complete healing of the meniscus on MRI. Seo et al.[68] reviewed 21 meniscal root repairs with pull out techniques for 13.4 months. They reported that complete healing was not observed in any of the patients who underwent second-look arthroscopy regardless of the improvement in subjective clinical scores.

Rehabilitations after Meniscal Repair

There has been no generally accepted consensus regarding rehabilitation protocols after meniscal repairs. While some authors recommend accelerated rehabilitations with early range of motion (ROM) exercises and weight bearing[31,69-71], other authors recommend restricted rehabilitation. Haklar et al.[38] suggested immobilization with non-weight bearing for 6 to 8 postoperative weeks. Squatting beyond 120° and running activities were not allowed for 4 postoperative months. After 4 to 5 months, sporting activities were permitted. Horibe et al.[35] recommended immobilization for 1 to 2 postoperative weeks, and full-weight bearing was permitted after 5 to 6 weeks. After 4 to 6 months, vigorous activities were allowed. Most authors agree that patients who have meniscal repairs in complex tear patterns need restricted rehabilitation protocols: patients can return to sports or strenuous work activities when the clinical examination reveals a non-tender joint line, absence of pain and effusion, full ROM, especially full extension, and restored muscle strength[34].

Complications after Meniscal Repair

Many complications associated with meniscal repair are documented in the literatures[72]. Iatrogenic chondral, meniscal, or neurovascular injuries can occur during the procedure. According to a systematic review, chondral damage due to rigid meniscal implants occurred in 23% of the patients who underwent second-look arthroscopy after meniscal repair; however, this reported prevalence could have been overestimated because most second-look arthroscopies were performed in symptomatic patients[39]. Neurapraxia of the saphenous or peroneal nerve developed in 3 of the 191 patients (2%) with all-inside implants[51,73,74] and 16 of the 142 patients (11%) with inside-out repair[30,55,56,73,75]. Theses nerve symptoms also resolved spontaneously without severe complications. Meniscal repairs can fail because of improperly placed or tensioned sutures or devices. Postoperative pain can remain persistent because of soft tissue irritation, foreign body reaction or inflammation, and postoperative arthrofibrosis. Overall, local irritative symptoms by all-inside implants were found in 14% of patients, which resolved spontaneously over time (within 12 months) in most cases without leaving behind major sequela[51,74,76]. On the other hand, all-inside suture materials had to be removed because of persistent irritative symptoms in some cases[55,76-78]. Two mid- to long-term follow-up studies using a meniscus arrow for meniscal repair reported unsatisfactory outcomes because of high failure rates of healing and persistent irritation by the arrow[57,77]. In other studies, one superficial infection after 20 inside-out repairs required antibiotic treatment[30] and 2 deep infections after 34 inside-out repairs that occurred in one with an isolated meniscal tear and the other with concomitant ACL reconstruction were treated with arthroscopic synovectomy and resection of the meniscus[73]. Majewski et al.[43] reported 2 infections in 50 patients after meniscal repair using an outside-in technique, but they did not indicate if the infection was superficial or deep. Spindler et al.[56] observed 2 cyclops lesions in 85 patients who underwent all-inside meniscal repair using a meniscus arrow, arthroscopic debridement was the treatment of choice. Kotsovolos et al.[51] reported that 4 patients who underwent all-inside meniscal repair using FasT-Fix system with concomitant ACL reconstruction had difficulty in gaining full flexion of the knee joint after operation, one of which required an arthroscopic arthrolysis.

Conclusions

Meniscal repair should be aggressively considered in young patients to enhance functional recovery and durability of the knee joint, if the meniscus is reparable. It should be considered as an option even in patients aged 60 years or older, if the meniscus is reparable. It is important for the surgeon to be equipped with familiarity with the operative indications and techniques and full knowledge of the anatomy and prescribe appropriate rehabilitation to produce good outcomes and avoid complications.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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