Chapter

Medial Meniscus Root Tear: Current Update Review

Thun Itthipanichpong and Songthai Moonwong

Abstract

This chapter mainly focuses on medial meniscus posterior root tear which is the point of attention nowadays because it is the common degeneration process and can lead to early-onset osteoarthritis of the knee without treatment. The biomechanics of the medial meniscus root tear is similar to total meniscectomy. Hence, early detection and diagnosis will lead to better outcome. Most cases with medial meniscus root tear also have degenerative change of the knee. Meniscal extrusion is a common finding in magnetic resonance imaging (MRI) which represent impairing of hoop stress function of the meniscus. Patient selection and understanding of the natural history of the disease is a particularly important. Options for the treatment including conservative treatment, surgical treatment such as partial meniscectomy, meniscus root repair, or reduction of meniscal extrusion. Outcome of these treatments are variable depending on the condition of the patients. Long term outcome of surgical treatment revealed lower rate of knee replacement compared with conservative treatment.

Keywords: Meniscus root tear, Medial meniscus root tear, Medial meniscus tear, Meniscus extrusion

1. Introduction

Meniscus is a fibrocartilaginous structure which provides many functions to the knee joint such as distributing load to the knee, increased stability of the tibiofemoral articulation, lubrication, provides nutrient and a strong shock absorption. Without the meniscus, load to the articular cartilage will increase and progress to osteoarthritis. Meniscus root tear is one of the tear patterns which are increasingly important due to an increasing number of patients and the rapid progression of the osteoarthritis similar to total meniscectomy [1]. Hence, early detection and treatment may improve outcome of the patient.

1.1 Definition

The bone which avulsed from the attachment at tibial plateau which represent meniscus root tear, was first described in 1935 by Weaver by plain radiograph [2]. However, ligament or soft-tissue injury at the insertion site of meniscal root on tibial plateau was described later after the use of magnetic resonance imaging (MRI). In 1991, Pagnani reported a medial subluxation of the meniscus associated with an avulsion injury to the posterior horn medial meniscus in an athlete [3]. The modern

definition commonly used for "meniscus root tear" is defined as avulsion of the meniscal attachments to the tibia or radial tears within 1 cm from the bony insertion [4].

1.2 Epidemiology

In the past, medial meniscus root tear has been neglected due to difficulties in diagnosis. The prevalence might be lower than it should be. With increasing recognition of the medial meniscus root tear, the prevalence is higher. In a study by Matheny et al., in 673 arthroscopic surgeries, they found 50 patients with meniscus root tear equivalent to 7% [5]. Another study by Ozkoc et al. found that prevalence of radial tear of the posterior horn of the medial meniscus in 7,148 patients who underwent partial menisectomy of the knee was about 10% (722 patients) [6]. The prevalence may be up to 15% in Asia which is a more common injury [7]. In case of traumatic knees, a study by Ho Jong Ra found 7 medial meniscus posterior root tear out of 51 patients who had multiple ligaments knee injury [8]. Most of the medial meniscus root tear were degenerative change. However, traumatic tear of the medial meniscus root is also common. The incidence of medial meniscus posterior root tear was up to 78% in patient underwent total knee arthroplasty. In addition, severity and varus deformity correlated with the root tear [9].

1.3 Natural history

As we know meniscus is a strong shock absorber. Without meniscal root attachment, hoop stress is lost and can lead to rapid progression of osteoarthritis [10]. Five-year follow up study of non-operative treatment in 52 patients with posterior meniscus root tear revealed association with low functional outcome and 31% of the patients need conversion to total knee arthroplasty [11]. In case of partial meniscectomy of the meniscus, long term follow up (5-8 years) also showed osteoarthritis progression about one-third of the patients [7]. The meniscus extrusion in a sign that showed impairment of the meniscus function and the degree of extrusion might be associated with severity of osteoarthritis [9, 12]. The longer the symptom, the degree of extrusion might be worse. According to a study by Furumatsu et al., in early period (<1 month) mean extrusion was 3.0 mm. In subacute (1-3 months) and chronic (3-12 months), the mean extrusion was 4.2 and 5.8 mm respectively [13]. The increasing rate of meniscus extrusion was studied by okazaki et al. which reviewed MRI of 33 patients who were diagnosed with medial meniscus posterior root tear and had done MRI twice at a mean interval of 48 days, the mean extrusion increased from 3.4 mm to 4.5 mm. The progression of the extrusion rate was 0.02 mm per day [14]. There is also an association between the presence of medial meniscus root tears and articular cartilage damage of the knee with an Outerbridge grade 2 or greater changes. Patients with a medial root tear were approximately five times more likely to also have an articular cartilage defect of the knee with an Outerbridge grade 2 score or higher [5]. In addition, osteonecrosis, bone contusion, and subchondral insufficiency fracture are commonly associated with the medial meniscus root tear [10, 15].

1.4 Biomechanics

As mentioned above, the complete medial meniscus posterior root tear had similar biomechanics with total meniscectomy due to impairment of hoop stress function of the meniscus (**Figure 1**). Normal load to the meniscus is about 50% of body weight and the other 50% transfers directly to the articular cartilage [16].

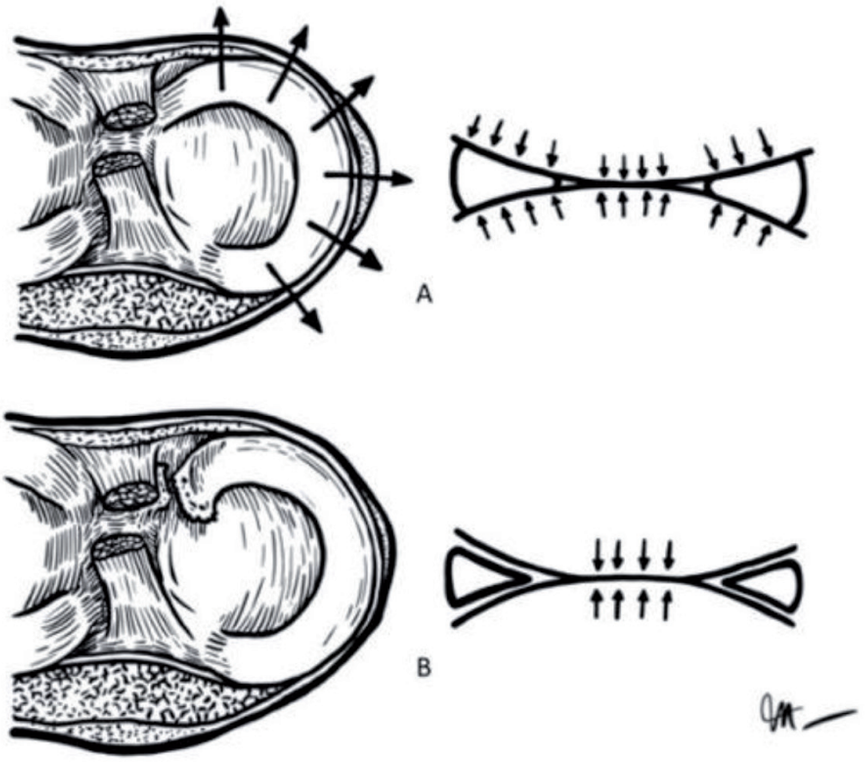

Figure 1.
Hoop stress function of meniscus. (A) Normal load distribution of meniscus with intact meniscal root. (B) With meniscal root tear, load is directly transferred to the articular cartilage.

Figure 2.
Fairbank phenomenon after meniscectomy. Finding included narrowing of joint space, squaring of femoral condyle and antero-posterior osteophyte.

The body and posterior horn of the medial meniscus take most of the force applied to the medial compartment and are the least mobile parts. With knee flexion, the pressure to the posterior horn of meniscus is the highest this is due to the femoral roll back mechanism of the knee. That explains why posterior horn and posterior root injuries have been found to be more common compared to the anterior horn injury [17]. In case of torn medial meniscus posterior root or total menisectomy, the peak pressure to the medial articular cartilage increased 25% [1, 18]. Hence, this may lead to osteoarthritis change which was called "Fairbank's phenomenon" [19] (**Figure 2**). The biomechanics test of medial meniscus posterior root repair can restore the tibiofemoral contact pressure compared with intact meniscus knee [20, 21].

2. Anatomy

Medial Meniscus is a fibrocartilaginous structure composed of collagen fiber that orientates in radial and circumferential fiber. These fibers provided hoop stress function of the meniscus. The width of the medial meniscus being about 1 cm and bigger at the posterior part compared to the anterior part. The semi-lunar shape is divided into 3 segments: anterior horn, body, and posterior horn. In anatomical landmark, meniscus may divide into 5 anatomical zone; the anterior root (zone 1); the anteromedial zone (zone 2a and 2b); the medial zone (zone 3); the posterior zone (zone 4); and the posterior root (zone 5) [22]. The attachment of the medial meniscus to the tibia at the anterior horn and posterior horn are called "medial meniscus anterior root" and "medial meniscus posterior root" respectively. The root of the meniscus itself is not a fibrocartilaginous structure but more like a ligament which serves as an anchor to the tibia. The medial meniscus posterior root attaches to the posterior intercondylar fossa between the attachments of the posterior root of the lateral meniscus and posterior cruciate ligament. The attachment is about 9.6 mm posterior to the apex of medial tibial eminence and 3.5 mm lateral to medial tibial plateau articular cartilage (**Figure 3**) [23–25].

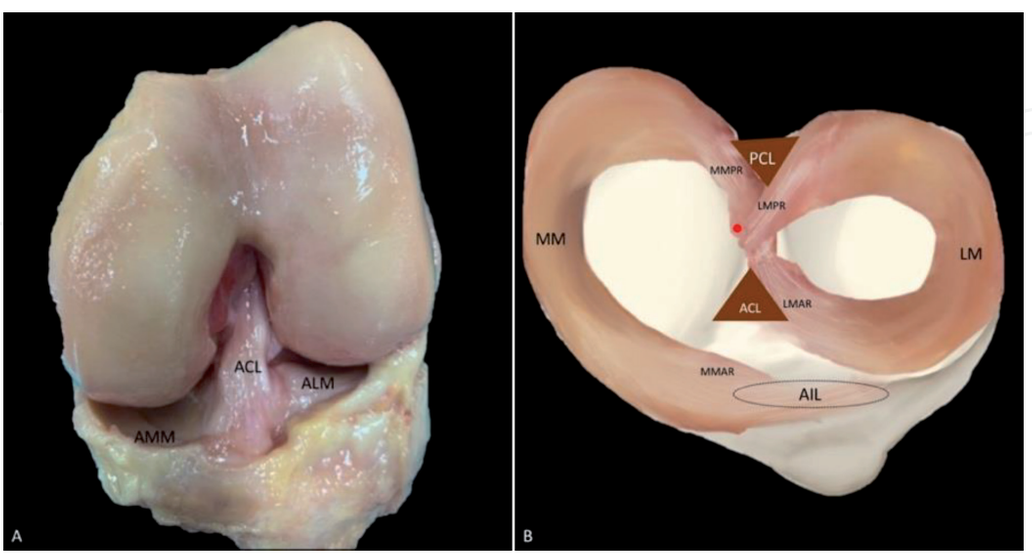

Figure 3.
Anatomy of left knee meniscus A: Intact ACL and meniscus knee. B: Drawing axial anatomy of meniscus. The red dot represented the apex of medial tibial spine. The MMPR attached behind this spot about 9.6 mm. ACL = anterior cruciate ligament, PCL = posterior cruciate ligament, AMM = anterior horn medial meniscus, ALM = anterior horn lateral meniscus, AIL = anterior intermeniscal ligament, MM = medial meniscus, LM = lateral meniscus, MMAR = medial meniscus anterior root, MMPR = medial meniscus posterior root, LMAR = lateral meniscus anterior root, LMPR = lateral meniscus posterior root.

3. Clinical presentation

There were 2 presentations of patients with meniscal root tear.

1. Traumatic event: In this group were younger patients who had major traumatic event such as a road traffic accident, or sports accidents. They were likely to have associated ligamentous injury [8].

2. Minor or non-traumatic event: Most of the patients with medial meniscus root tear especially medial meniscus posterior root tear fall in this group. Patients usually are in their fifth or sixth decade of life. Some patients had history of a "pop" sound while doing daily activity such as squatting and had sudden pain. The painful popping sound indicates a high chance of isolated medial meniscus posterior root injury [26]. Some patients had progressive medial knee pain without trauma history and the symptoms were similar to osteoarthritis [27].

Meniscus root tear's diagnoses is challenging. Patient might not have a problem of locking or catching knee. Medial knee pain and joint line tenderness are the most common symptom and sign especially at the posteromedial of the knee joint. Deep flexion of the knee might provoke the pain. Meniscus specific test such as Mcmurray's test was positive in 57%. Joint effusion presented in 14% [28]. Compared to other meniscus injuries, medial meniscus root tears are common in Asian populations, in particular, females and higher Body Mass Index (BMI > 30 kg/m^2 – 4.9 fold increase) patients. If patient had a varus mechanical axis, the risk of medial meniscus posterior root tear increased by 3.3-fold [29]. Generally, we recommend further investigation such as, an MRI in patients with progressive medial joint knee pain with no or mild osteoarthritis to rule out medial meniscus posterior root tear.

4. Imaging

The first imaging that detected medial meniscus root bony avulsion was in 1935 by plain radiograph [2]. We recommended to do plain radiograph in all patients suspected of medial meniscus root tear to evaluate degree of osteoarthritis change and axis deformity. The Kellgren and Lawrence (K-L) classification was a common and popular method to classify the severity of osteoarthritis change [30]. They classified 5 grades (**Figure 4**).

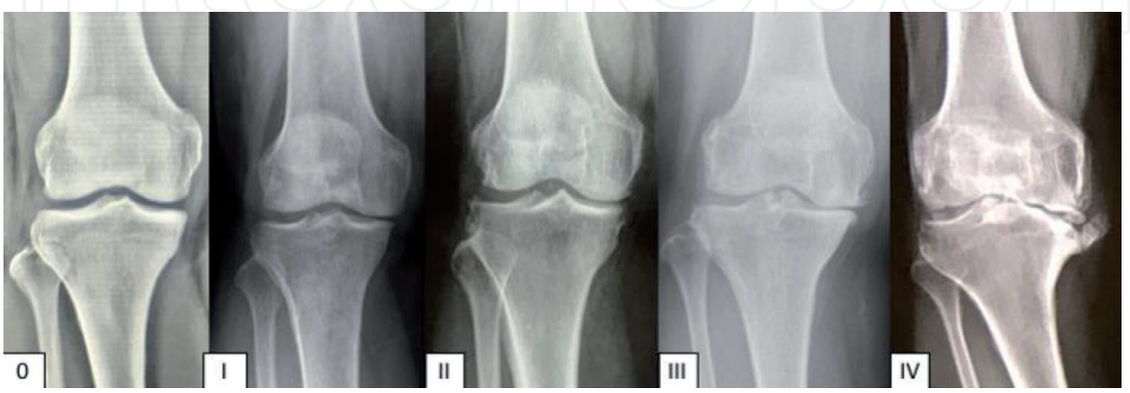

Figure 4.
Kellgren and Lawrence (K-L) classification, Grade 0 (none): definite absence of x-ray changes of osteoarthritis, Grade I (doubtful): doubtful joint space narrowing and possible osteophytes, Grade II (minimal): definite osteophytes and possible joint space narrowing, Grade III (moderate): moderate multiple osteophytes, definite narrowing of joint space and some sclerosis and possible deformity of bone ends, Grade IV (severe): large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone ends.

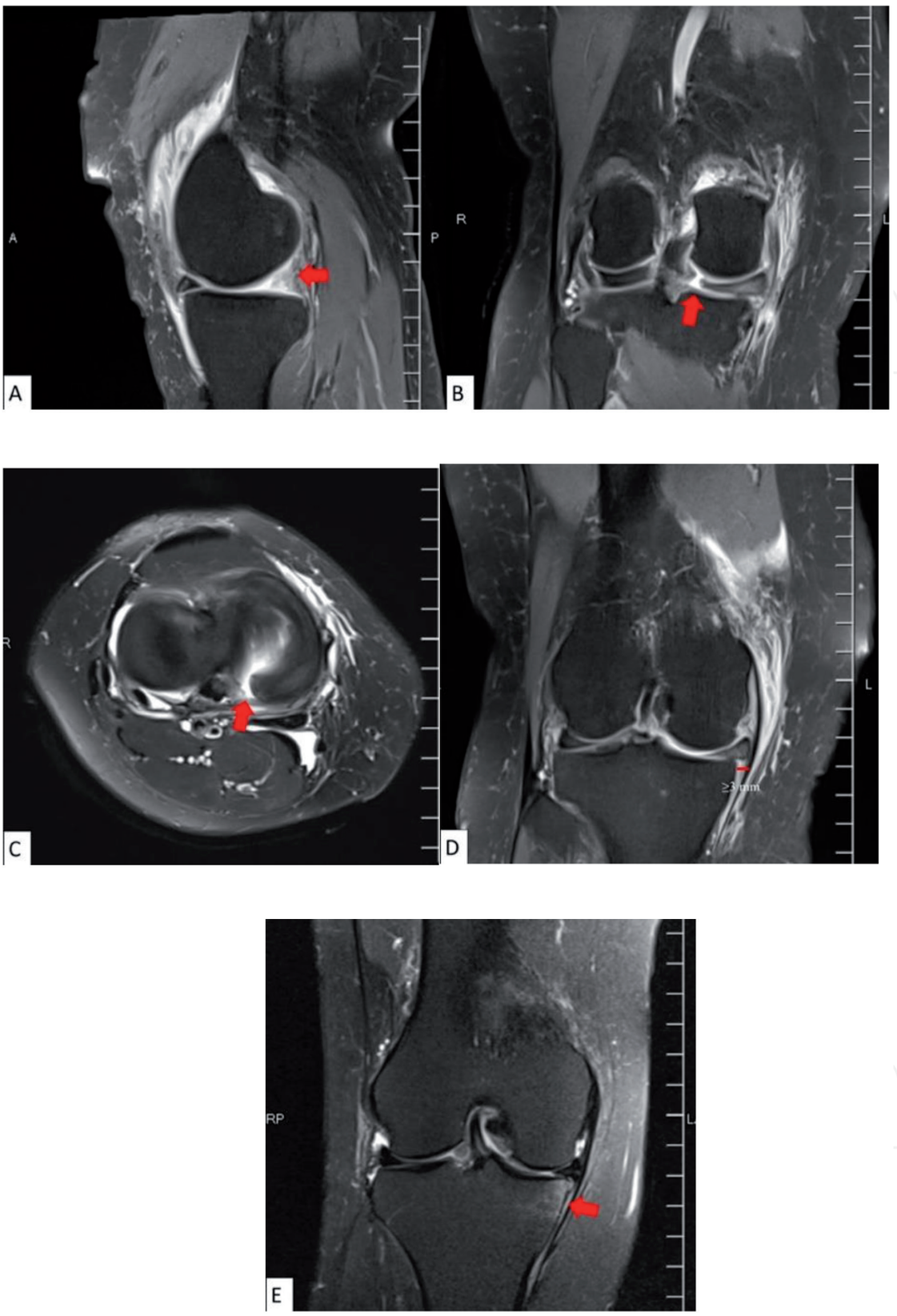

Figure 5.
MRI finding of meniscal root tear. A: Ghost sign (absent of posterior horn medial meniscus), B: Cleft sign (vertical linear defect on coronal images), C: Radial linear defect on axial image, D: Medial meniscus extrusion (≥3 mm), E: Bone contusion at the articular bearing area which is associated with medial meniscus root tear.

However, with popularize of MRI, soft tissue that avulsed from the attachment of the meniscus to the tibia could be easier to detect. Hence, MRI is now the goal standard in detecting medial meniscus root tear because of high sensitivity

(93.3%) and specificity (100%) [31]. Finding from MRI included absent of posterior horn meniscus called "ghost sign" on sagittal imaging adjacent to posterior cruciate ligament, vertical linear defect on coronal images called "cleft sign", radial linear defect on axial image, and medial meniscus extrusion (≥3 mm) on coronal image. Medial meniscus extrusion less than 3 mm could be found in general populations [32] (**Figure 5**). Medial meniscus that extruded usually larger and thicker than normal meniscus due to swelling and degeneration of meniscal tissue. The MRI study Okazaki showed that 3D MRI could estimate volume and thickness of extruded medial meniscus more precisely when compared to conventional 2D MRI [33].

Medial meniscus posterior root tear had an association with multiple findings including spontaneous osteonecrosis of the knee (SONK), subchondral insufficiency fracture, cartilage injury especially at the medial femoral condyle, and osteoarthritis change [34, 35].

5. Classification

There were many classifications for medial meniscus root tear mostly based on anatomic classification. For the medial meniscus anterior root attachment according to Berlet et al. there were four patterns of insertion of the anterior root [36].

Type I has the insertion located in the flat intercondylar region of the tibial plateau.
Type II (most common) has more medial insertion, closer to articular tibial surface.
Type III has a more anterior insertion, which is on the downslope of tibia.
Type IV shows no solid fixation.

For medial meniscus posterior root tear the most popular classification was classified by Laprade. The classification was based on the morphology of the tear and was classified into 5 types [37] (**Figure 6**).

Type I: partial stable root tear
Type II: complete radial tear within 9 mm from the bony root attachment.
Type III: bucket-handle tear with complete root detachment.
Type IV: complex oblique or longitudinal tear with complete root detachment.
Type V: bony avulsion fracture of the root attachment.

There was an arthroscopic classification by Bin et al. which developed a classification base on extrusion of the medial meniscus on MRI and finding of the torn site displacement. They were divided into 3 types; type A: non-displaced, type B: overlapped (the torn tissue overlap on each other), and type C: widely displaced [38] (**Figure 7**).

They found that the widely displaced group had a 4° greater varus deformity, and higher rates of meniscus extrusion, grade III or IV chondral wear in the medial femoral condyle and medial compartment osteoarthritis than did the nondisplaced or overlapped group.

Another classification by Kim et al. was made based on tear gap (**Figure 8**) of the medial meniscus posterior root in arthroscopic finding. The higher the tear type

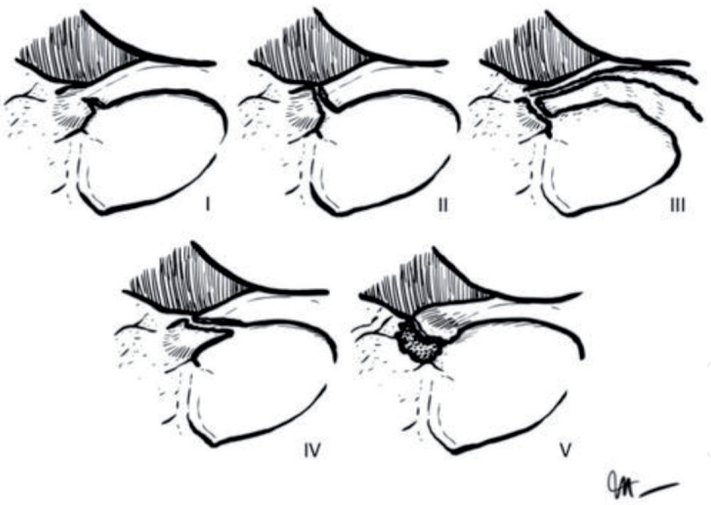

Figure 6.
Laprade's classification for medial meniscus root tear. Type I: Partial stable root tear. Type II: Complete radial tear within 9 mm from the bony root attachment. Type III: Bucket-handle tear with complete root detachment. Type IV: Complex oblique or longitudinal tear with complete root detachment. Type V: Bony avulsion fracture of the root attachment (redrawn from LaPrade et al. [37]).

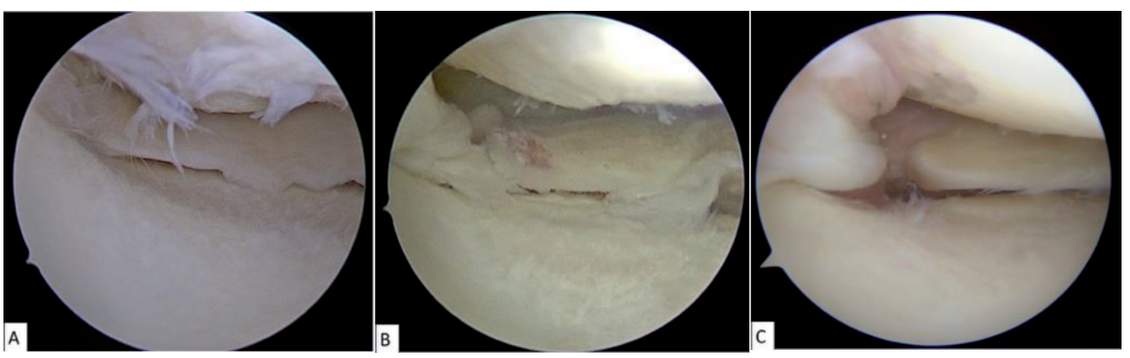

Figure 7.
A–C: Bin classification base on arthroscopic finding of meniscal tear and gap. A: Non-displaced, B: Overlapped and C: Widely displaced.

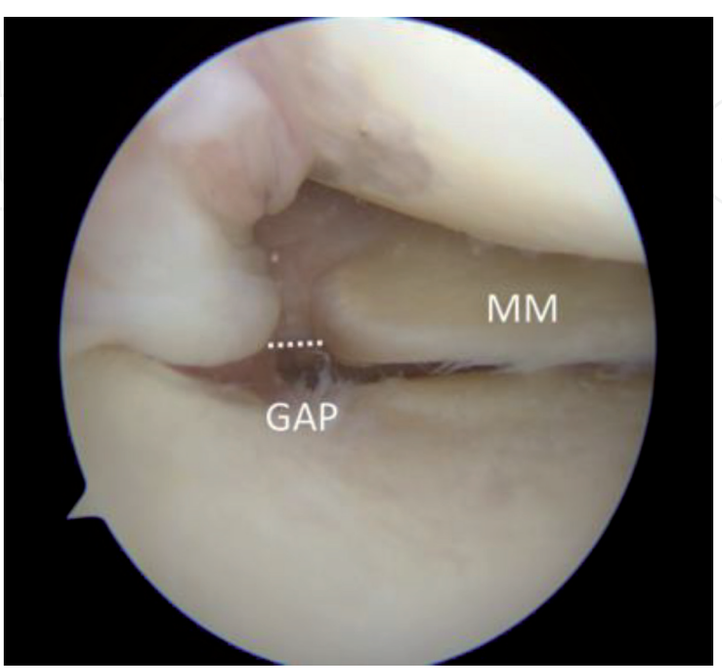

Figure 8.
Tear gap measurement from an arthroscopic view. MM = medial meniscus.

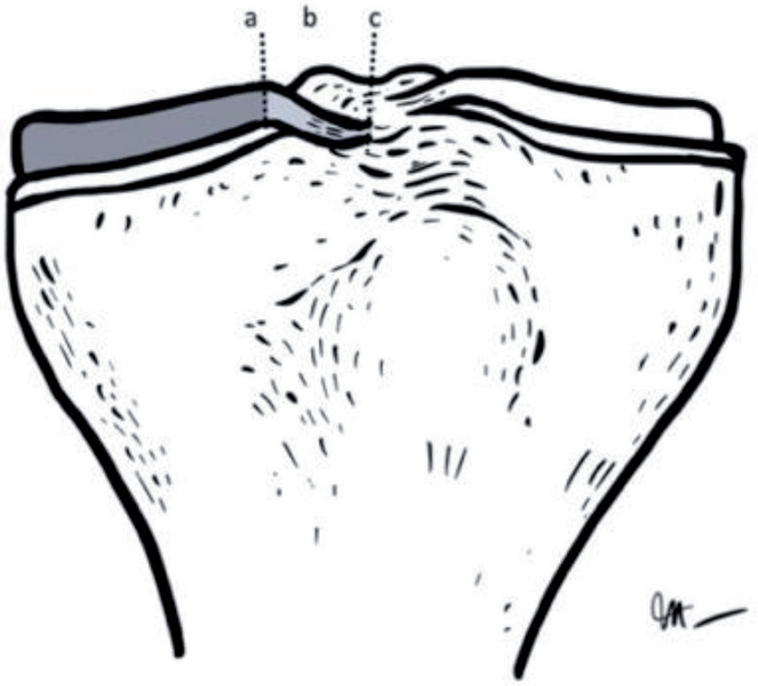

Figure 9.
Classification of medial meniscus posterior root tear based on MRI by Choi et al. posterior medial meniscus root ligament was defined as from tibial attachment point of root ligament to just lateral from articular cartilage inflection point of medial tibial plateau. Ligament was subcategorized into three zones: (a) transition to posterior horn of medial meniscus at junction between root and posterior horn, (b) midsubstance within root ligament proper, and (c) entheseal at tibial attachment point of root ligament (redrawn from Choi et al. [24]).

(increasing displacement of the tear gap in arthroscopic surgery), the higher association with degree of meniscal extrusion, chondral wear, and severity of arthritis. They were classified in to 5 types [39].

Type I: incomplete root tear.
Type 2: complete root tear with no gap or overlapped;
Type 3: complete root tear with gap measuring 1-3 mm.
Type 4: complete root tear with gap measuring 4-6 mm.
Type 5: complete root tear with gap measuring 7 mm.

There is an MRI classification based on the attachment of posterior medial meniscus root ligament. The term ligament is used because of the different of tissue component. This classification included both degenerative change and tear of the medial meniscus posterior root. They classified into 3 types; type a: Tear at transition to posterior horn of medial meniscus at junction between root and posterior horn, type b: Tear at midsubstance within root ligament proper, and type c: Tear at entheseal at tibial attachment point of root ligament [24] (**Figure 9**).

6. Treatment

According to the natural history of medial meniscus root tear, without proper treatment, there was a higher chance of progression of meniscal extrusion and osteoarthritis. Besides, the choice of treatment was still controversy because there were many factors which might lead to poor outcome. We divided the treatment into 2 categories: nonoperative and operative treatment.

6.1 Nonoperative treatment

The nonoperative treatment of medial meniscus posterior root tear was preserved for 1. Patients whose conditions were unfavorable for surgery. 2. Patients with advanced osteoarthritis of the knee (K-L grade III-IV) 3. Relieve pain before surgery. 4. Patients who could not follow the post-operative protocol. There were many methods of conservative treatment including taking non-steroidal anti-inflammatory drugs, cortisone injections, use of unloader knee brace, physical therapy, gait aid (cane or crutch) use, and orthotic use. We recommend using gait aid and hinge knee brace to prevent further damage to the meniscus and reduced the pain in acute setting. However, the use of cortisone injection should be avoided in patients who were planned for surgical repair of the meniscus due to the risk of infection and possibility of interference with the healing of the meniscal tissue. Nonoperative treatment provided symptomatic relief but could not prevent the progression of osteoarthritis in long term follow up [7, 40]. The physical therapy could improve functional score and reduce the pain especially from degenerative meniscal root tear [41]. From the meta-analysis by Faucett et al., the 10 years progression of osteoarthritis was about 95% and 45% conversion rate to knee replacement surgery [42]. Conversion to total knee replacement were also higher in nonoperative treatment compare with meniscus root repair in other studies [7, 43].

6.2 Operative treatment

The treatment choices might depend on many factors. The goal of the operative treatment was to: 1. Relieve pain, 2. Increase quality of life, 3. Prevent progression of osteoarthritis and 4. Restore function of meniscus. Before proceeding to the operation, physicians needed to talk to their patients about the goal of treatment and consequence after surgery. For example, a patient suffering an acute tear of the medial meniscus root, but the patient could not follow the post-operative protocol due to economic problem. Then, meniscus repair might not be a good choice for this patient. The choices of operative treatment are list below.

6.2.1 Meniscectomy

Meniscectomy was the majority of procedures that were done for the meniscus in the past. The procedure included removing some part of the meniscal tissue which preserved most of the meniscal tissue called “partial meniscectomy”, or totally removed all the meniscal tissue called “total meniscectomy”. The goal of this operation was to relive symptomatic pain from the unstable meniscus. The mechanical irritation from the unstable meniscal tear could be removed. However, the meniscectomy in medial meniscal root tear was different from other meniscal tears. Because, in other meniscal tear such as radial tear or vertical tear, if most of the meniscal tissue could be preserved, the hoop stress function of the meniscus remained. On the other hand, no matter how much meniscal tissue was preserved in medial meniscus root tear, the function of the meniscus still impaired and articular cartilage would play a major role in weight bearing which could lead to articular damage later. Thus, meniscectomy should be done in low demand patients, patients with advanced osteoarthritis and mechanical symptom meniscal tear, patients with partial root tear and the remaining attachment were more than 50%, or patients with poor meniscal tissue quality. The procedure could relieve symptomatic pain and swelling in short term result but in long term results the knee joint could deteriorate. From a study by Krych et al., the conversion rate to total knee replacement at a mean follow up of 5 years was 54% [44]. The rate of total knee replacement was quite similar to other studies [7, 42, 45].

6.2.2 Meniscus root repair

Meniscus root repair is getting more attention at present due to better long term outcome compared with non-repair treatment [46]. Meniscus root repair can restore the biomechanics of the knee joint. Hence, the distribution of the load was restored. Although the normal distribution load could not completely be restored due to the elongation of the suture after repair, the contact pressure and contact area could almost resemble an intact meniscus root knee [47, 48]. On the other hand, if non-anatomic repair was done, the distribution of the load might be abnormal. From a biomechanical study by Laprade in 2015, the mean and peak contact pressure were significantly increased after non-anatomic repair compared with normal and anatomic repair [49]. There were many techniques of repairing meniscus posterior root. All of them showed a significant improvement of functional outcome and reduced conversion rate to total knee replacement.

6.2.2.1 Transtibial pull out technique

This technique was the most popular technique for repairing medial meniscus posterior root due to familiarity and ease of assessment to the instruments. Many companies provided specific instruments for the transtibial repair. The technical step involved the used drill from the tibia to the root attachment at the posterior tibia, stitched the tear meniscus, pulled the meniscus to the drill hole with a knot tied on the tibia (**Figure 10**). The disadvantages of this technique were: 1. Bungee effect on the repair site, 2. The risk of neurovascular injury due to the drill misplaced 3. Transtibial tunnel can interfere with concomitant procedures 4. possibility of suture elongation and abrasion through bone tunnel [50, 51].

Most of the clinical studies of transtibial pull out technique showed good functional outcome, prevent progression of osteoarthritis and reduced conversion rate of total knee replacement. The 10-year conversion rate was much lower compared with partial meniscectomy and nonoperative treatment (33.5% vs. 51.5% vs. 45.5%) [42]. In younger patients (<50 years) the risk of re-operation were higher than older patients. The activities and demands of younger patients might be more compared with older patients. As a result, the strength of fixation might not be enough in younger patients [52]. Although transtibial pull out repair prevented the progression of osteoarthritis, this could not completely prevent the

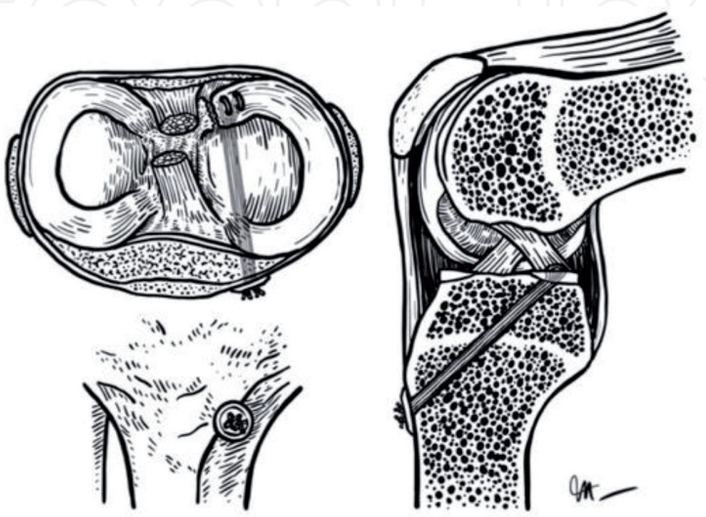

Figure 10.
Schematic drawing showed transtibial pull out repair of the medial meniscus root. The long tibial tunnel along with the "bungee effect" have the possibility of suture abrasion and elongation.

process. This helped only decelerate the process and most of the patients could not restore the meniscus extrusion [53, 54]. Healing of the repaired root and reduction of meniscal extrusion seem to be less predictable, being observed in two-third of the patients [55].

Stitches configuration might not play a major role for repairing the meniscal root. Modified Mason-Allen stitches had slightly better biomechanics in some studies but quite comparable to two simple stitches [56, 57]. There were no clinical different among repair configurations [58, 59].

6.2.2.2 Suture anchor technique

This technique was less popular when compared with transtibial technique due to the difficulty in placement of the anchor suture. This technical step involved the preparing the meniscal tissue and bed of the bone, placement of suture anchor, stitched the torn meniscal tissue, and tightened the knot (**Figure 11**).

The disadvantages of this technique were; 1. Difficult of suture anchor placement, 2. Potential cartilage irritation due to knots, 3. Fixation might loosen if anchor is not well placed, 4. Additional costs of suture anchor. To ease the placement of anchor suture, we proposed a technique to repair medial meniscus posterior root by using a curved sleeve soft anchor suture, made a far medial vertical portal, and flexed the knee while drilling the tibia for anchor suture placement (**Figure 12**) [60].

There were several methods to place anchor sutures proposed by several authors. Placing the anchor from the posteromedial portal was one option [61]. Also there was a technique which retrograde insertion of a soft anchor suture to the transtibial tunnel. So, additional portal for anchor placement was not required [62]. Functional outcome after repair showed a significant improvement. Complete healing rate form MRI was not different from transtibial repair. The meniscus extrusion was also not significantly reduced from pre-operative, similar to transtibial repair [27, 63].

Many comparison studies were made between transtibial technique and suture anchor technique because of their own advantages and disadvantages (**Table 1**).

In a biomechanics study by Feucht et al., Suture anchor provided lower displacement after cyclic loading and higher stiffness compared with the transtibial technique. However, both techniques did not reach the strength of the native tissue [57].

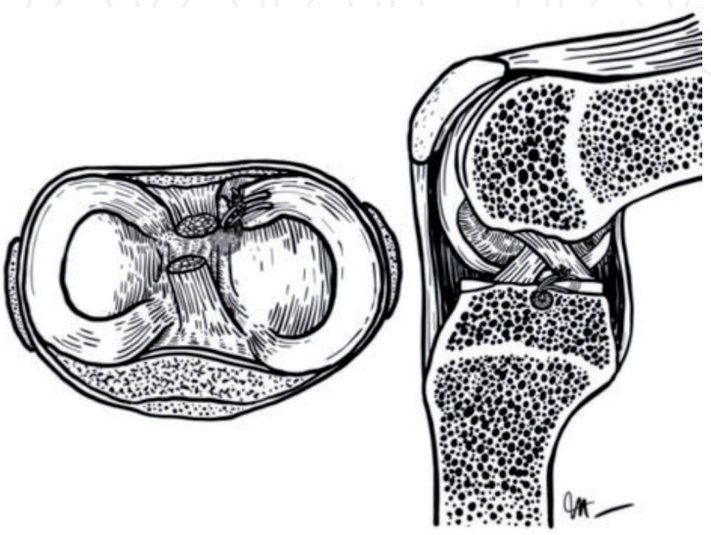

Figure 11.
Schematic drawing showed suture anchor repair of the medial meniscus root.

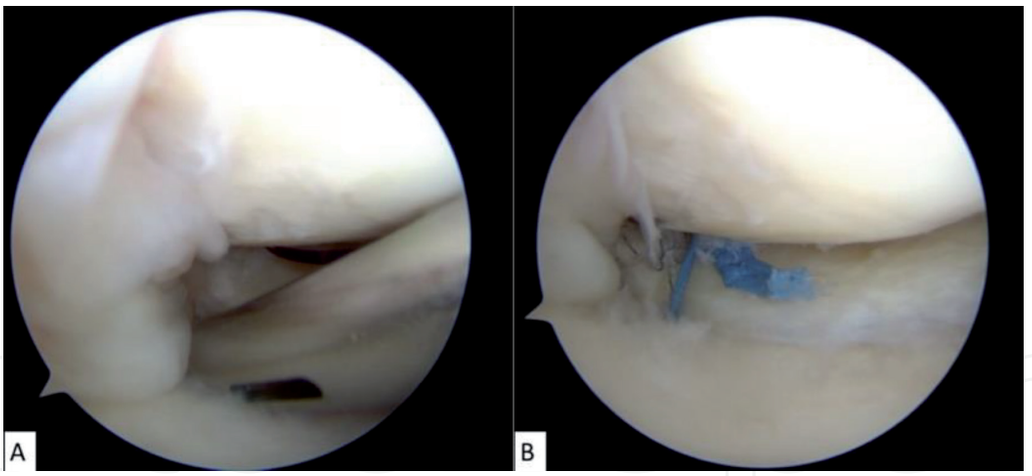

Figure 12.
Pictures of anchor suture repair for medial meniscus root tear. A: Placement of curved drill sleeve for soft anchor suture, B: After repair with 2 simple stitches.

	Transtibial technique	Suture anchor technique
Advantage	• Familiar to most surgeon • Technically easier than a suture anchor technique • Standard arthroscopic portals used • Fixation not rely on fixation device	• No Bungee effect • Not interfere with bone tunnel from other ligament reconstruction • Less elongation of suture • Low risk of neurovascular injury
Disadvantage	• Bungee effect on the repair site • The risk of neurovascular injury due to the drill misplaced • Transtibial tunnel can interfere with concomitant ligamentous procedures • Possibility of suture elongation and abrasion through bone tunnel.	• Difficult of suture anchor placement • Potential cartilage irritation due to knots • Fixation might loosen if anchor is not well placed • Additional costs of suture anchor

Table 1.
Advantages and disadvantages of transtibial technique compared with suture anchor technique.

In contrast, a study by Wu et al. showed that anchor suture had lower maximum load and stiffness compared with transtibial technique but the mean elongation was less. The reason might be because of the different techniques and the study was done with porcine knees which are different from human [64].

The mean meniscal extrusion, functional outcome, degree of cartilage loss and healing rate were comparable between these 2 techniques. The factor that significance effected the degree of cartilage loss was the healing status of the meniscal root. Complete healing showed significantly less cartilage loss compared with partial healing and no healing [27].

6.2.2.3 All inside technique (other than suture anchor)

This was another technique using for medial meniscus root repair. This technique was less popular when compared with other techniques because it depended on the condition of the meniscal tissue. This technical step was to suture the torn meniscus together with an all inside meniscus fixator device and may add a suture to the posterior capsule. This technique was suitable for tearing of the meniscus root which there was enough remnant for suturing and good tissue quality (**Figure 13**).

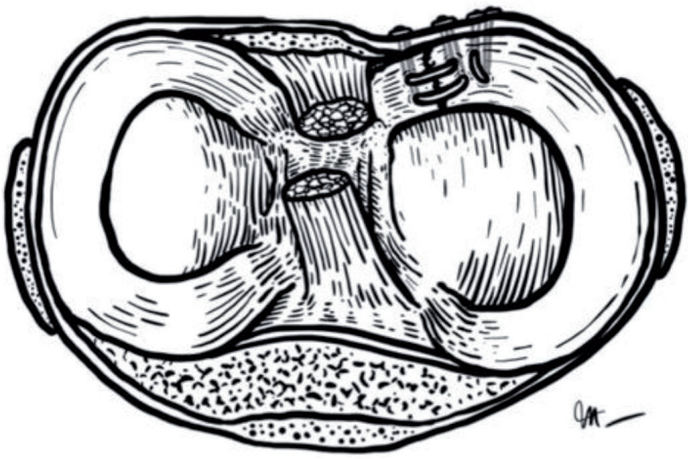

Figure 13.
Schematic drawing showed all-inside repair of the medial meniscus root with all-inside meniscal repair devices. Two horizontal stitches were used to repair the torn meniscal tissue together and one vertical stitch was used to repair the posterior capsule.

This technique provided a better functional outcome, lower progression rate of osteoarthritis, and lower conversion rate to total knee replacement compared with nonoperative treatment at a minimum of 2 years follow up [43].

Another all inside technique that was proposed by Zhu S., was using all the inside meniscus fixator device to non-anatomic repair the torn meniscus root to the posterior capsule. In contrast with previous biomechanics study, this non –anatomic repaired yielded an excellent outcome and a high rate of meniscus healing [65].

6.2.3 Reduction or centralization of medial meniscus extrusion

As mentioned above, the meniscal extrusion might not reduce after meniscal root repair regarding of technique. Thus, there were many techniques adding to the repair procedure to prevent meniscus displacement during flexion and extension of the knee [66–68]. There was a study of centralization the meniscus in rat knee by Ozeki et al. The study concluded that centralization improved the medial meniscus extrusion and delayed cartilage degeneration [69]. Centralization or reduction of extruded meniscus was still debatable. The mechanics and tension of the meniscus that changed might reflect pain and stiffness after doing the procedure.

From the available treatments mentioned above, the only treatment that could prevent the progression of the osteoarthritis and reduce the rate of knee replacement surgery was medial meniscus root repair [7, 42–46]. In addition, meniscal root repair had better long term functional outcome compare with nonoperative treatment and meniscectomy [42]. However, the result of the repair depended on multiple factors. To achieve the best result, all the necessary conditions must be presented. In systematic review from Jiang et al. in 2019, the bad prognostic factors for medial meniscus root repair were obesity, increasing age, advance osteoarthritis (KL III-IV), and varus malalignment >5° [70]. Therefore, the repair should preserve for patient who had medial meniscus posterior root tear without these conditions. For meniscectomy, the advantages of this procedure over the repair is the immediate pain relief, no need for special rehabilitation program, and could be done regardless of degree of osteoarthritis change. The present of a mechanical symptom such as "locking" was a good candidate for this procedure. The nonoperative treatment of medial meniscus posterior root tear was suitable for patients whose conditions were unfavorable for surgery and could not follow the post-operative protocol. The progression of osteoarthritis were high in both nonoperative and meniscectomy treatment [42].

The available treatments of medial meniscus posterior root tear with their advantages, disadvantages, and results concerning the development of osteoarthritis are summarized in **Table 2**.

6.3 Approach strategy for the treatment of medial meniscus posterior root tear

Due to many factors that alter the result of medial meniscus root repair. The significant factors were chronicity of tear, grading of osteoarthritis and mal-alignment (varus >5°). We developed a strategic approach for the treatment of medial meniscus posterior root tear (**Figure 14**).

Treatment	Advantages	Disadvantages	Results
Nonoperative	• symptomatic relief • less invasive • no surgical risks	• do not prevent OA progression • short term result	• 10 years - 95% progression of OA [42] • 10 years - 45% conversion to knee replacement surgery [7, 42–43]
Meniscectomy	• symptomatic relief • less complicated procedure • Immediate pain relief	• do not prevent OA progression • short term result	• 10 years - 99% progression of OA [42] • 5 years – 54% conversion to knee replacement surgery [44]
Meniscus root repair	• prevent OA progression • Good long term result	• reserve in none or mild OA change • technical demand • need rehabilitation	• 10 years - 53% progression of OA [42] • 10 years - 33% conversion to knee replacement surgery [42]

Table 2.
Advantages, disadvantages, and results of available treatment of medial meniscus posterior root tear.

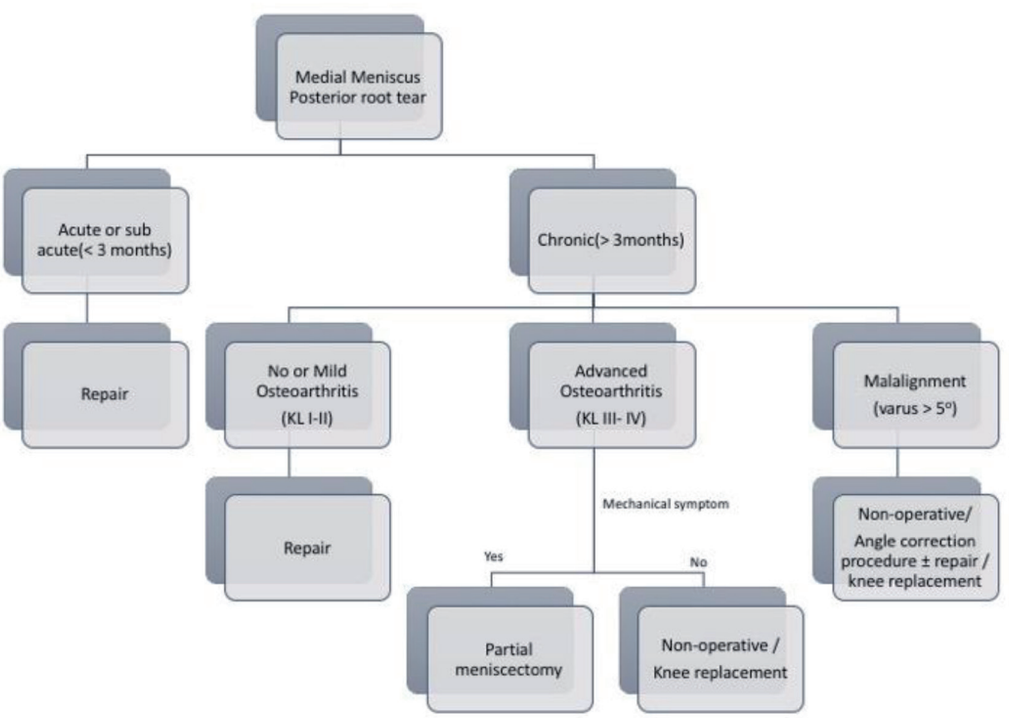

Figure 14.
Our strategic approach for symptomatic medial meniscus posterior root tear.

7. Post-operative protocol

In immediate post-operative period, the goal was to reduce pain and swelling. In one study, the continue passive motion machine was used immediately after surgery [71] but most of the studies would delay the motion after 4 weeks. Most of the repair protocol used cast or knee brace with locked flexion at first 4 weeks with the first 2 weeks in full extension and the other 2 weeks in 0-30° to prevent femoral roll back and injury to the repair meniscus [72]. Active range of motion exercise should be done after 4-6 weeks. Non-weight bearing or toe-touch weight bearing was used during the first 2 weeks after surgery. Then progressive weight bearing to full weight at 6-8 weeks after surgery. Isometric quadriceps exercise could start at the 1st post-operative day but active strengthening exercise should start at 8-12 weeks after surgery. In the majority of patients, full activity can be achieved by 4-6 months [23].

8. Conclusions

The number of medial meniscus root tear were found more often due to better understanding of the physicians and accessibility to the investigation tool such as MRI. The important aspect of meniscus root was the stability of the whole meniscus. With medial meniscus root tear, overall hoop stress function was impaired which will lead to early-onset osteoarthritis. Most of the tear occurred in adults through a minor trauma such as squatting or sitting. The pop sound is one of the significant happenings that is frequently found. Investigation of choice was the MRI because of its high sensitivity and specificity. Significance MRI finding included cleft sign, ghost sign, and medial meniscus extrusion. Diagnosis needed index of suspicious and confirmed by the investigation. Early detection would lead to better outcome of the treatment. The longer the duration, the worse the degree of meniscus extrusion and degree of cartilage damaged. Nonoperative treatment may relieve pain and swelling in the short term. We recommend meniscus root repair in case of acute tear, or mild degeneration of the knee. Early treatment may prevent the meniscal extrusion and reduce the rate of knee replacement conversion. Biologic treatments might have a role for enhancing repair and needing further study.

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Conflict of interest

The authors declare no conflict of interest.

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Author details

Thun Itthipanichpong* and Songthai Moonwong
Department of Orthopaedics, Faculty of Medicine, Chulalongkorn University, King Chulalongkorn Memorial Hospital, Bangkok, Thailand

*Address all correspondence to: thunthedoc@gmail.com

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