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A General Overview of The Meniscus and Rehabilitation Approaches After Menisectomy

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Abstract

Among the most frequent knee pathologies seen in orthopedic treatment are meniscal injuries, whose management, both surgical and rehabilitative, has changed dramatically. Emphasizing the reasons for surgical procedures, including partial, complete, and segmental meniscectomy as well as meniscal repair, this paper investigates the meniscus's structure and function. Particularly, the increased risk of osteoarthritis after meniscectomy, each operation is analyzed in terms of indications, results, and long-term consequences. The rehabilitation process after meniscal surgery, where present research shows no consistent strategy, is a main focus of this study. Rehabilitation, however, has to be customized to fit specific requirements. The paper reviews many rehabilitation techniques, including electrotherapy (EMG biofeedback, EMS, NMES), manual therapy, kinesio taping, and exercises

Keywords: meniscectomy, rehabilitation, exercise, post-operative

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Introduction

Particularly impacting the knee joint, meniscal injuries are among the most frequent orthopedic disorders seen in clinical practice. Maintaining knee stability, load transfer, lubrication, proprioception, and shock absorption all depend on the meniscus (Yılmaz & Gürger, 2018). Though it is essential, the meniscus is susceptible to both acute and degenerative tears, which untreated, may cause major functional impairment and long-term joint deterioration (Martin, 2022). Treatment choices differ according to the kind, location, and degree of the tear as well as patient-specific variables like age and amount of exercise. Although surgical treatments like partial or total meniscectomy, meniscal repair, and even transplantation may be required in more severe situations (Bozkurt & MA, 2018). Conservative methods, including physical therapy and pharmacological interventions, are often used first (Williams & Chen, 2020).

Although post-surgical problems, including joint instability and osteoarthritis, still cause concern, especially after meniscectomy, advances in arthroscopic methods have allowed less invasive treatments with improved recovery profiles (Jiang, Zhang, & Liu, 2021). Thus, structured rehabilitation is essential for restoring function and optimizing outcomes. This paper intends to provide a thorough survey of meniscal anatomy, injury processes, treatment methods, and evidence-based rehabilitation techniques to direct efficient clinical decision-making.

Anatomy of the Meniscus

The menisci are crescent-shaped, fibrocartilaginous structures located on the medial and lateral sides of the knee joint. Each knee contains two menisci, medial and lateral, which have a triangular cross-section and play a crucial role in joint stability and load distribution. They cover approximately two-thirds of the tibial plateau surface, facilitating articulation between the concave femoral condyles and the relatively flat tibial surface. The menisci are attached to the tibia through coronary (meniscotibial) ligaments, which secure them in place. The meniscal roots, which are ligamentous structures anchoring the menisci to the subchondral bone, help transfer shear and tensile forces from soft tissue to bone (Bozkurt & MA, 2018). The peripheral regions of the menisci are convex and attached to the joint capsule, except in the region where the lateral meniscus is adjacent to the popliteus tendon, which lacks this attachment. Anteriorly, the menisci are connected by the transverse ligament, which ensures coordinated movement during femoral sliding over the tibial plateau (DİZ & ANATOMİSİ, 2015). The cadaveric dissection image in Figure 1 illustrates the anatomical positioning of the medial and lateral menisci.

Figure 1. A cadaveric dissection image showing the medial and lateral menisci (Akkaya & Bozkurt, 2018)

Medial Meniscus

The medial meniscus is C-shaped and covers approximately 60% of the articular surface of the medial tibial plateau. Its posterior horn is wider than the anterior horn and gradually narrows from back to front. Additionally, the anteroposterior diameter of the medial meniscus is larger than its mediolateral diameter. As shown in Figure 3, the joint capsule attaches the peripheral edge of the medial meniscus; the coronary ligaments hold it to the tibia. Anatomically, the medial meniscus is split into five separate areas: the anterior root region (Region 1), the anteromedial region (Region 2, further divided into 2a and 2b), the medial region (Region 3), the posterior region (Region 4), and the posterior root region (Region 5) (Bozkurt & MA, 2018).

Unlike the lateral meniscus, which is more round as seen in Figure 2, the medial meniscus resembles a semicircle. The medial meniscus is more securely fixed in its tibial position than the lateral meniscus, which helps to explain its higher vulnerability. Figure 4 illustrates the five subregions of the medial meniscus, with each zone playing a specific role in structural support and force transmission. For instance, Region 2a spans from the anterior root to the transverse ligament; Region 2b extends from the transverse ligament to the medial collateral ligament.

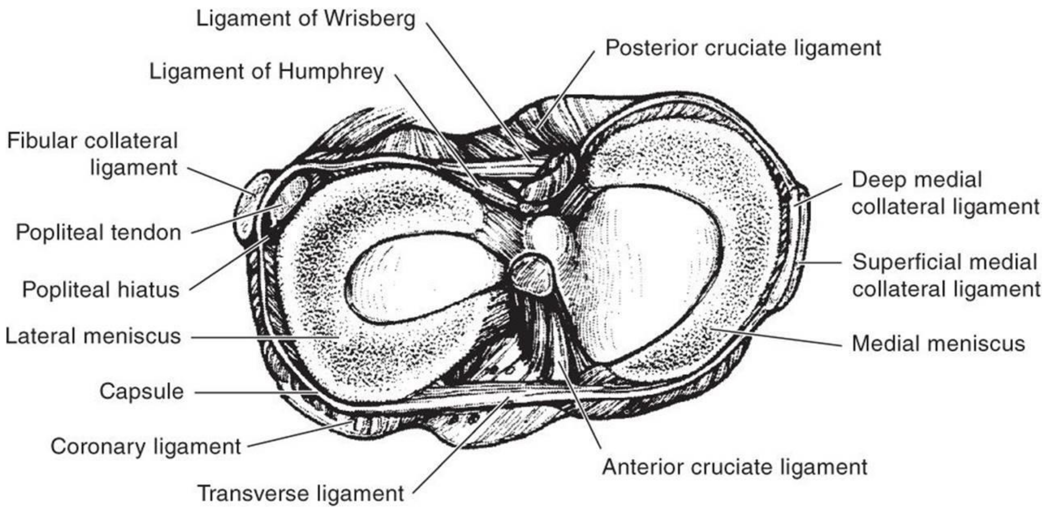

Figure 2. Lateral meniscus (Scott, 1991)

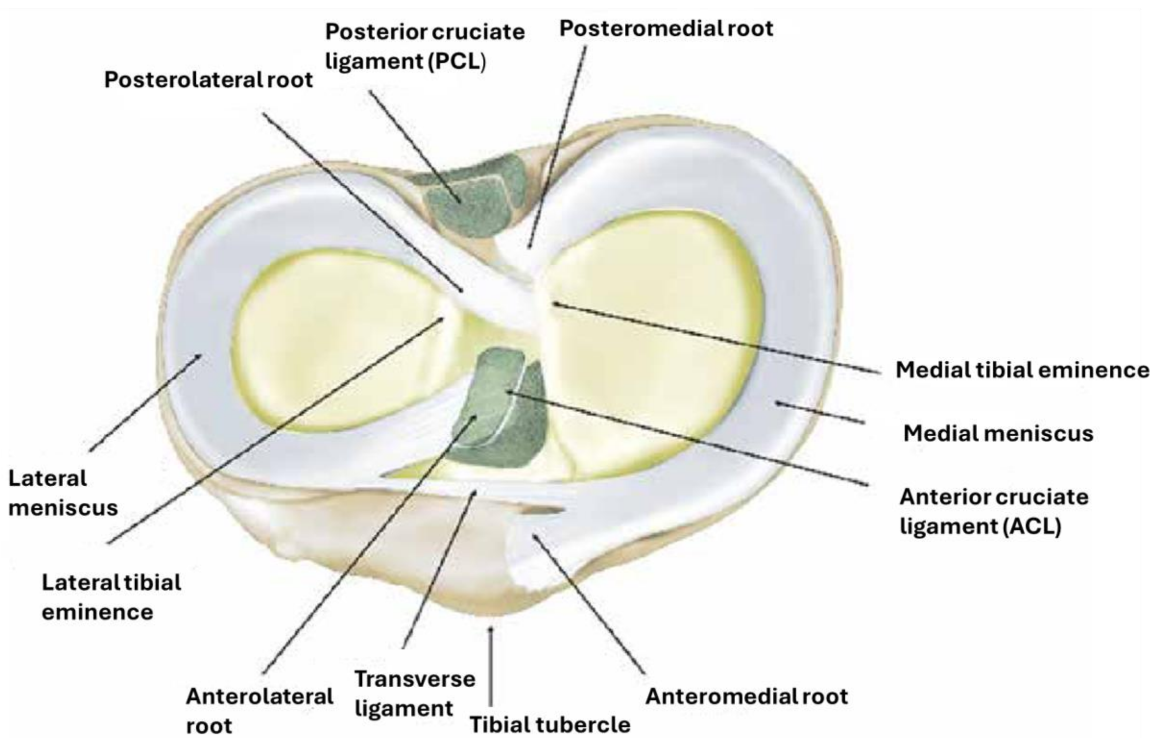

Figure 3. Placement of the medial and lateral menisci on the tibial plateau. The anterior root of the lateral meniscus intersects with the tibial attachment site of the anterior cruciate ligament (Bozkurt & MA, 2018)

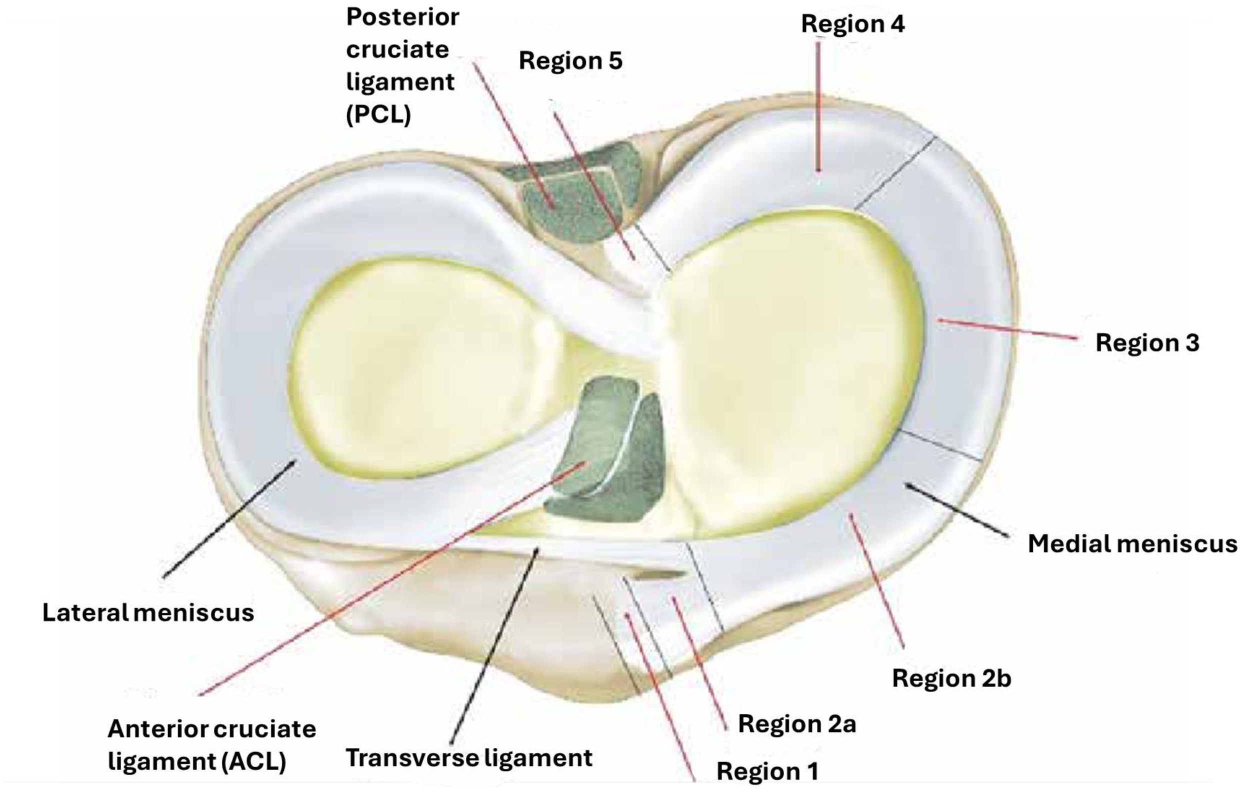

Figure 4. The medial meniscus can be examined in five distinct subregions. The first region is the anterior root zone. The second region extends from the anterior root zone to the vicinity of the medial collateral ligament. The second region is further divided into 2a (from the root portion to the transverse ligament) and 2b (from the transverse ligament to the medial collateral ligament). The third region is the area adjacent to the medial collateral ligament. The fourth region spans from the medial collateral ligament to the posterior root. The fifth region is the posterior root zone (Bozkurt & MA, 2018).

Lateral Meniscus

The lateral meniscus is more circular, smaller, and more mobile than the medial meniscus. It covers a larger portion, approximately 60–80%, of the lateral tibial plateau's articular surface. The anterior horn of the lateral meniscus attaches anterolateral to the anterior cruciate ligament (ACL) and anteromedial to the apex of the lateral tibial eminence. About 63% of its attachment area overlaps with the ACL, highlighting a close anatomical relationship.

The posterior horn of the lateral meniscus connects posteromedial to the peak of the lateral tibial eminence, anterior to the tibial attachment of the posterior cruciate ligament (PCL), and anterolateral to the attachment location of the medial meniscus's posterior horn. Apart from its primary fiber bundles, some lateral meniscus fibers link to the posterolateral area of the medial tibial eminence. Through the meniscofemoral ligaments, the anterior meniscofemoral ligament (ligament of Humphrey) and the posterior meniscofemoral ligament (ligament of

Wrisberg), it also links to the PCL and the femoral condyle. As shown in Figures 5 and 6 (Bozkurt & MA, 2018). The lateral meniscus is anatomically near the popliteus tendon posterolaterally, which also affects its movement.

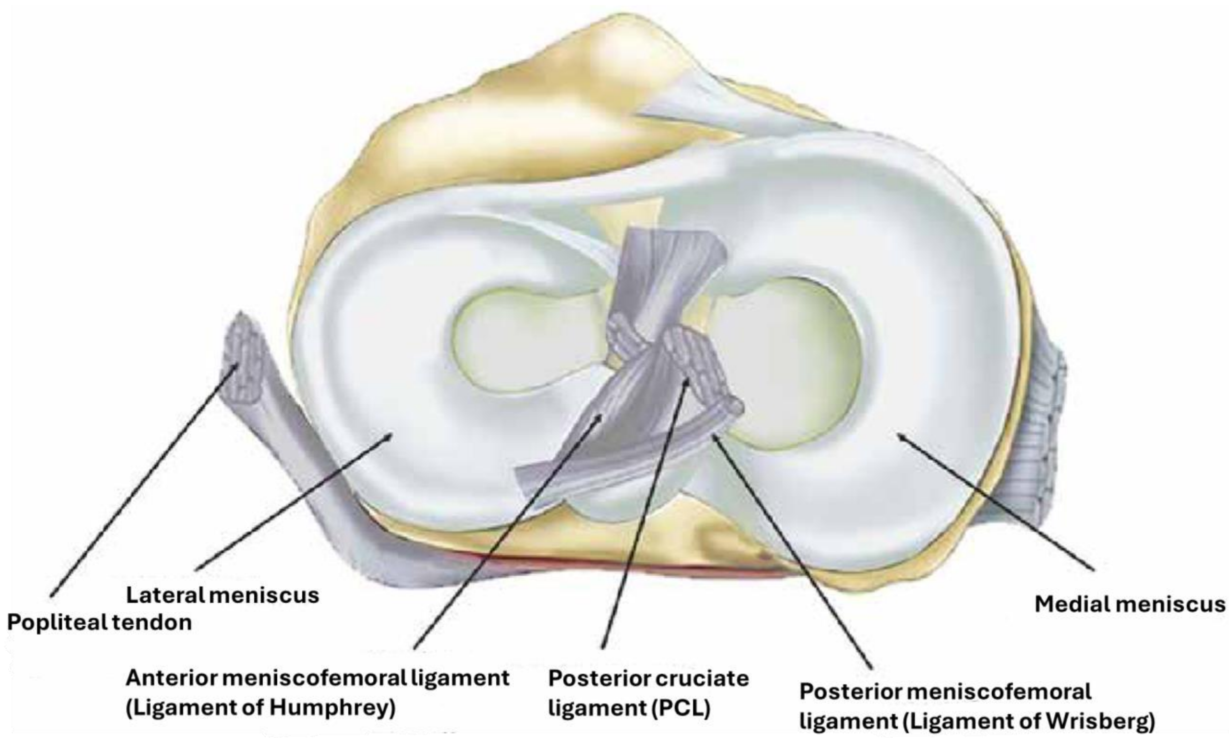

Figure 5. Anterior (Humphrey) and posterior (Wrisberg) meniscofemoral ligaments originate from the posterior horn of the lateral meniscus. The posterior ligaments attach to the medial femoral condyle. Posterolaterally, the popliteus tendon is located adjacent to the lateral meniscus (Bozkurt & MA, 2018).

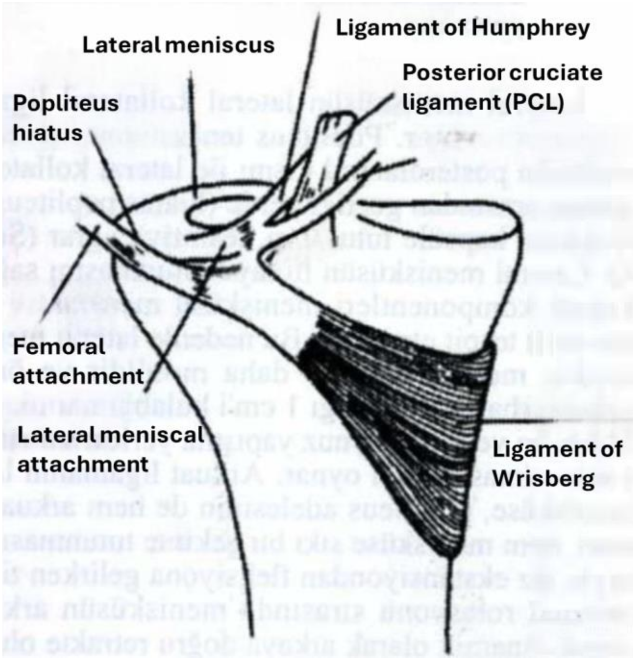

Figure 6. Partial insertion of the popliteus muscle into the posterior horn of the lateral meniscus (Pinar, 1997).

Meniscofemoral Ligaments

As shown in Figure 5, the meniscofemoral ligaments are additional ligaments running from the posterior horn of the lateral meniscus to the lateral side of the medial femoral condyle. The two main meniscofemoral ligaments are the anterior meniscofemoral ligament (Humphrey ligament), which runs in front of the PCL, and the posterior meniscofemoral ligament (Wrisberg ligament), which runs behind the PCL. By helping to transfer stresses between the meniscus and the femur, these ligaments support the biomechanics of the knee and aid to stabilize the lateral meniscus, particularly its posterior horn. Their thickness varies significantly; in some people, they may be almost as thick as half the PCL (Pinar, 1997).

Important Adjacent Structures Of The Medial And Lateral Meniscus

The posterior one-third regions of both the medial and lateral menisci are near several critical anatomical structures, which is especially important during arthroscopic meniscal repair. On the medial side, the saphenous nerve and saphenous vein are at risk due to their anatomical course near the posterior horn of the medial meniscus. On the lateral side, the common peroneal nerve (also known as the fibular nerve) is the primary structure at risk during surgical intervention involving the lateral meniscus.

In addition, the **popliteal artery**, which lies posterior to the knee joint, poses a risk during procedures involving the **posterior horn** of **either meniscus**. This is particularly critical when using instruments that penetrate through the posterior capsule, as even slight deviations can result in vascular injury. These anatomical relationships are illustrated in **Figure 7 and Figure 8**, which show axial cross-sections of the lateral and medial menisci, respectively, along with their surrounding neurovascular structures (Pinar, 1997).

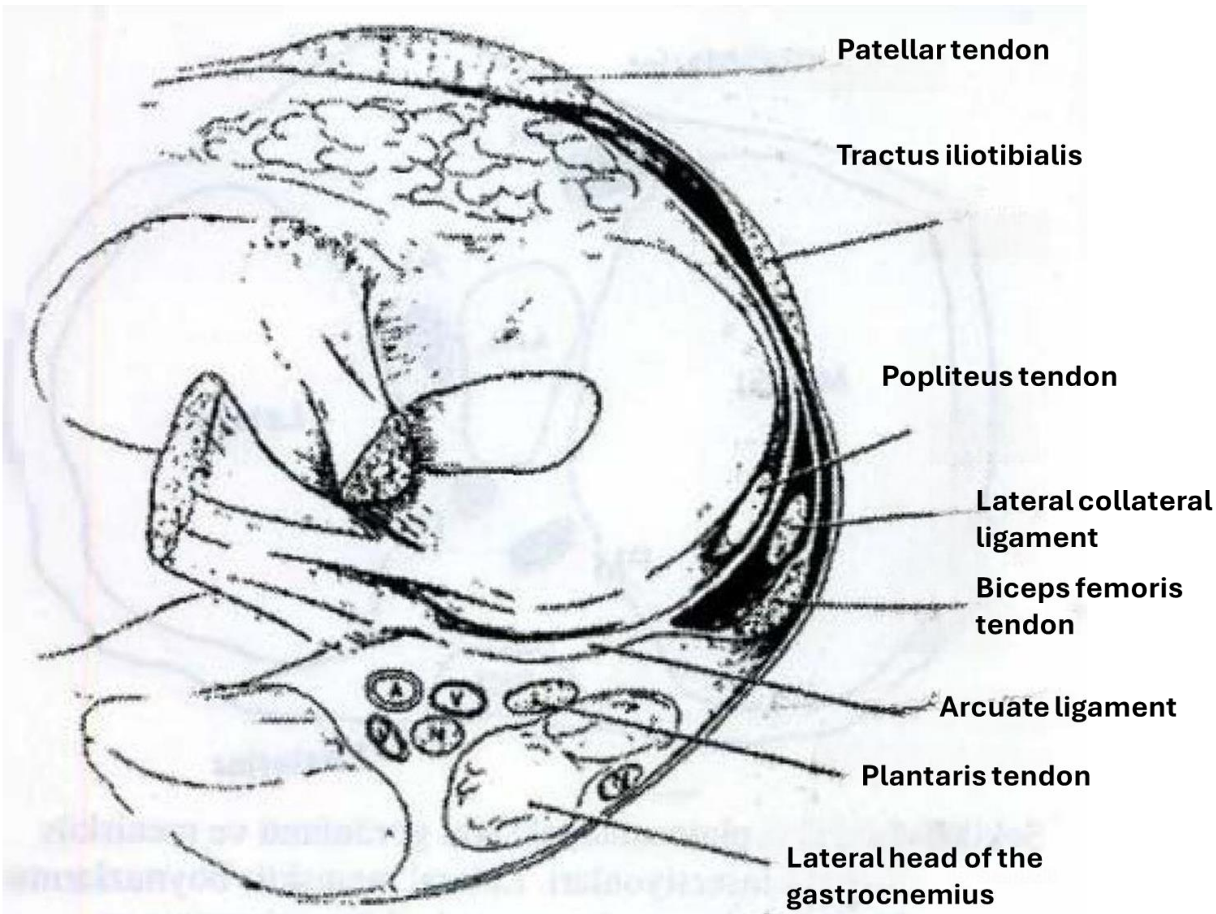

Figure 7. Axial section showing the relationship of the lateral meniscus with important surrounding structures (Pinar, 1997).

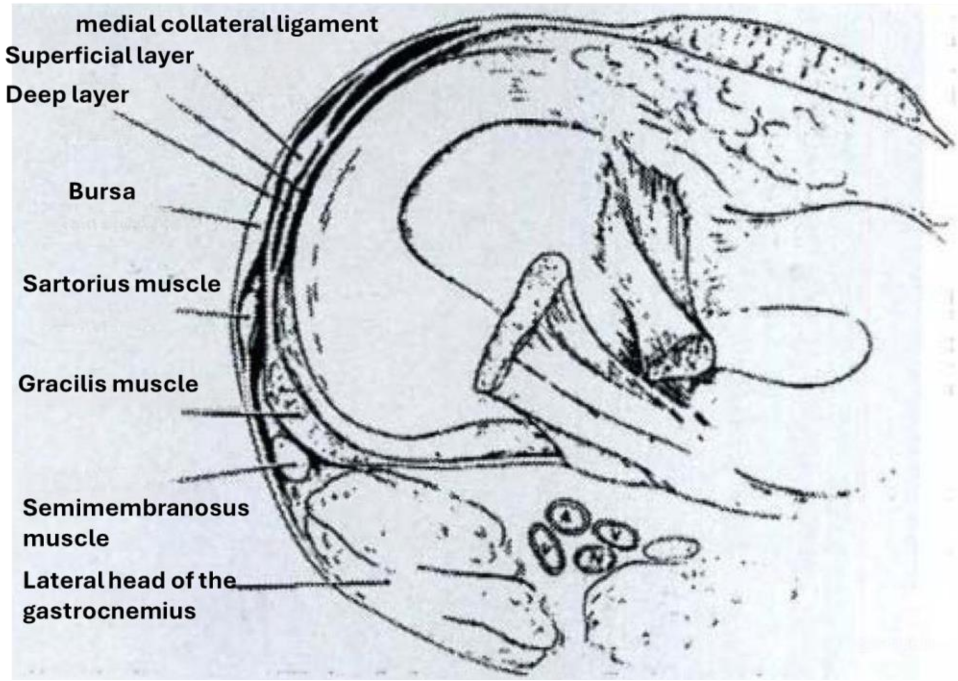

Figure 8. Axial section showing the relationship of the medial meniscus with important surrounding structures (Pinar, 1997).

Meniscal Vascularization

Relatively avascular structures in the knee joint, the menisci are Examining the triangular cross-section of the meniscus reveals three separate zones depending on vascular supply. At the edge, the red-red (RR) zone is completely vascularized. The red-white (RW) zone lies between the vascular and avascular areas and receives a partial blood supply. The white-white (WW) zone, which is the most central part of the meniscus, is completely avascular and lacks any direct blood flow)Arnoczky & Warren, 1982(. This zonal distribution of blood supply plays a critical role in the healing potential of meniscal injuries; tears located in the RR zone are more likely to heal due to the presence of blood vessels, while those in the WW zone often require surgical intervention. Illustrations provided in Figure 9a and 9b highlight the microvascular supply of adult meniscal tissue, demonstrating that only about 10–25% of the meniscal periphery is vascularized (Örs & Sarpel, 2018).

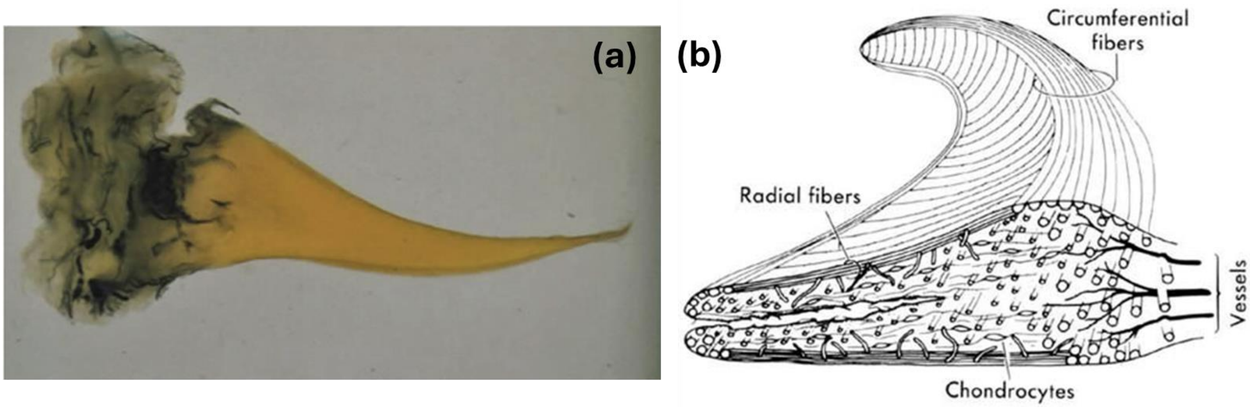

Figure 9. Microvascular supply of adult meniscus tissue (illustration showing vascularization of the peripheral 10–25% of the meniscus) (a). Peripheral vascularization and anatomical cross-section of the meniscus (b) (Örs & Sarpel, 2018).

Functional Properties of the Meniscus

Load Transmission

Its function depends much on the size and form of the meniscus. While the lateral meniscus spans about 59–71%, the medial meniscus covers around 50–54% of the tibial cartilage surface. Walking puts strain on the knee and causes peak contact stress on the cartilage-cartilage interface on the medial plateau. The contact area moves from the anterior to the posterior of the meniscus when the knee bends. Under stress, the lateral meniscus shows more movement than the medial one. In an extended knee under load, the medial meniscus bears about 40–50% of the load, while the lateral meniscus bears around 65–70% (Yılmaz & Gürger, 2018).

Lubrication and Nutrition

The meniscus contributes to the lubrication of the knee joint. Following meniscectomy, an increase in the coefficient of friction has been observed. The meniscus contains a porous network that connects its vascular structure to the synovial cavity. Under loading, fluid within the meniscus is able to move through these pores into the synovial space, delivering nutrients and reducing friction on the articular cartilage (Yılmaz & Gürger, 2018).

Proprioception

Different mechanoreceptors in the meniscal tissue help to promote its proprioceptive function. The meniscus has been shown to include structures like Golgi tendon organs (which sense joint position), Ruffini endings, and Pacinian corpuscles (which react to movement). These receptors let the body sense joint movement and location (Yılmaz & Gürger, 2018).

Shock Absorption

Many believe the meniscus to be a shock absorber for the knee joint. Some research, nevertheless, indicates that this role might rely more on the eccentric contractions of surrounding muscles. Recent studies reveal that articular cartilage is stiffer and absorbs more energy than the meniscus. This suggests that the meniscus has a limited role in shock absorption (Yılmaz & Gürger, 2018).

Joint Stability

Joint stability is improved by the size and form of the meniscus, which helps to match the femur and tibia. An undamaged meniscus is essential for maintaining general knee joint stability, as it limits excessive movement in all directions (Yılmaz & Gürger, 2018).

Etiology of Meniscal Tears

Meniscal tears are classified into two main categories, traumatic and degenerative. Traumatic tears are more commonly observed in young and physically active individuals. Usually, these injuries happen during unexpected twisting motions or when the knee is bent and the individual falls. Sports with strong loading pressures and quick directional shifts, such as basketball, football, and skiing, are particularly dangerous for this kind of rupture. A past of trauma or muscular imbalances around the knee also makes one more prone to damage.

In contrast, degenerative tears are more frequently seen in older adults. These tears result from the gradual wear and tear of the meniscal tissue over time. As the meniscus becomes more fragile with age, even minor stresses can lead to damage (Martin, 2022).

Types of Meniscal Tears

Meniscal tears are classified morphologically based on their orientation relative to the tibial plateau. They can be either vertical (perpendicular to the plateau) or horizontal (parallel to the plateau). Vertical tears are further divided into longitudinal and radial (transverse) types. There are also oblique or flap tears, which represent a combination of vertical and horizontal patterns. Certain tear patterns have been given descriptive names due to their appearance, such as "bucket handle" or "parrot beak" tears. Complex tears involve a combination of two or more of these tear types.

Oblique tears are the most common lesions. Longitudinal tears come next and often affect younger individuals due to trauma. Vertical longitudinal tears are typically linked to ACL injuries. Horizontal tears mostly occur in the lateral meniscus, making up about two-thirds of these cases. They usually result from degenerative changes worsened by everyday joint stress. Radial tears are usually caused by trauma. If they extend to the meniscocapsular junction, they can lead to complete loss of meniscal function.

The distribution of meniscal tear types is as follows, oblique tears (45%), vertical longitudinal tears (36%), degenerative tears (12%), radial (transverse) tears (3%), horizontal tears (3%), and miscellaneous types such as discoid meniscus or meniscal cysts (1%) (ALPARSLAN & ÇULLU, 2000). These different tear types are visually illustrated in Figure 10

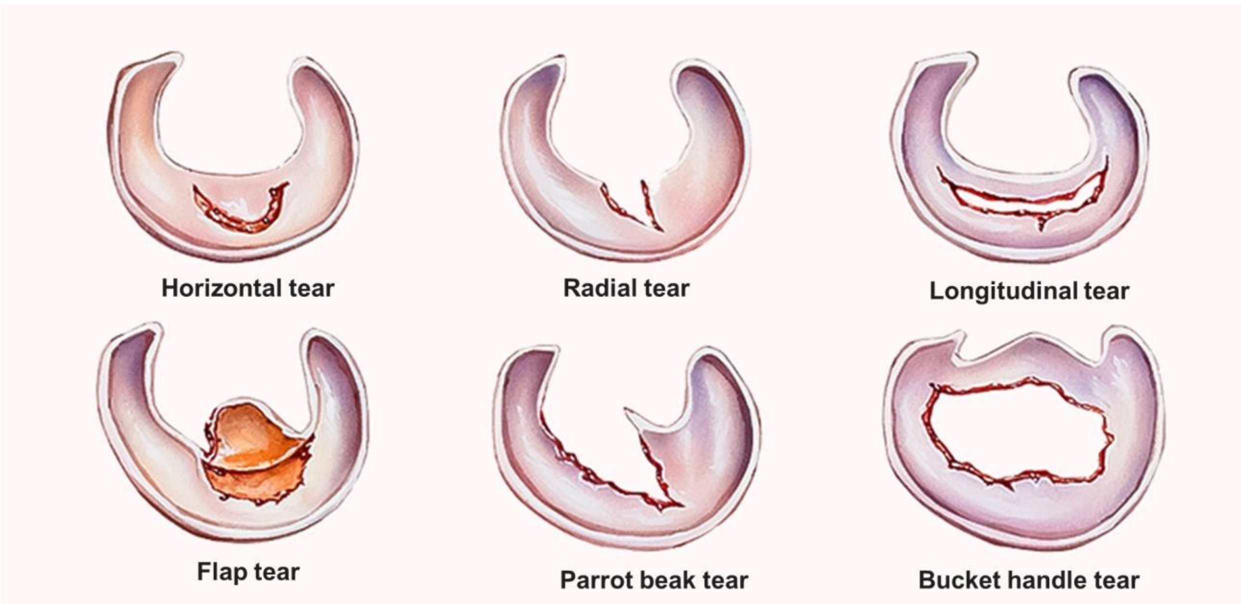

Figure 10. Types of meniscal tears (OLT, 2024).

Conservative Treatment of Meniscal Tears

The management of meniscal tears typically begins with a conservative treatment approach, especially in less severe cases. This involves the use of nonsteroidal anti-inflammatory drugs (NSAIDs) to reduce pain and inflammation, along with physical therapy programs designed to maintain joint range of motion and improve muscle strength around the knee (Williams & Chen, 2020). Conservative treatment is often effective for small, stable tears or in patients who are not ideal candidates for surgery due to age or activity level.

Surgical Treatment of Meniscal Tears

When conservative measures fail or the tear is more severe, surgical treatment may be required. The choice of surgical approach depends on factors such as the type, size, and location of the tear, as well as the patient's age and overall condition. The main goals of surgery are to preserve meniscal function, promote a return to normal daily activities, and reduce the long-term risk of osteoarthritis. Arthroscopic surgery is currently the most preferred method, as it is minimally invasive, allowing for quicker recovery and fewer complications compared to traditional open surgery (Duffy, Johnson, & Richards, 2020; Huang, Lee, & Wang, 2022). There are three primary surgical techniques used in the treatment of meniscal tears. The first is excisional surgery, which includes total meniscectomy, partial meniscectomy, and segmental meniscectomy, depending on how much of the meniscus needs to be removed. The second approach is meniscal repair, where the torn meniscus is sutured in place and allowed to heal, usually favored for younger patients with tears located in areas with good blood supply. The third and most advanced option is meniscal transplantation, used in cases where the meniscus has been extensively damaged or previously removed, requiring replacement with donor tissue (ALPARSLAN & ÇULLU, 2000). Each of these methods aims to restore knee function while minimizing further joint degeneration.

Meniscectomy

Meniscectomy, categorized under excisional procedures, involves the surgical removal of the damaged meniscal tissue. This method is typically selected when the meniscus has suffered extensive, irreparable damage, especially in older patients or when a significant portion of the meniscus is torn (Bennett, Hughes, & Smith, 2019). It aims to alleviate pain and restore joint mobility when conservative or reparative options are not viable.

Total meniscectomy is recommended for tears extending to the meniscocapsular region or in lateral tears where insufficient meniscal tissue remains anterior to the popliteal hiatus. However, this procedure has been associated with poor long-term outcomes due to the complete loss of the meniscus’s mechanical functions, highlighting the critical importance of preserving meniscal structures whenever possible (ALPARSLAN & ÇULLU, 2000).

Partial meniscectomy has become increasingly favored due to growing awareness of the meniscus’s functional role. This approach is preferred in avascular zones or when the damage is too extensive for repair. The objective is to remove the least amount of meniscal tissue necessary while retaining a stable and biomechanically functional remnant.

Segmental meniscectomy, on the other hand, disrupts the circumferential integrity of the meniscal ring. Regardless of how much tissue is preserved, this disruption compromises meniscal function. Moreover, during load transmission, the remaining tissue can catch or snag, leading to mechanical symptoms and patient discomfort (ALPARSLAN & ÇULLU, 2000).

Post-Meniscectomy

Following a meniscectomy, patients typically experience a relatively rapid recovery. Pain in the knee decreases shortly after the procedure, leading to an improvement in functional mobility. However, when evaluating the long-term outcomes of meniscectomy, there is a notable increase in the risk of developing osteoarthritis due to the loss of the meniscus's shock-absorbing and stabilizing functions (Jiang et al., 2021).

Meniscal Repair

Meniscal repair, on the other hand, is a preferred surgical approach for younger and more physically active patients, especially when the tear is located in the outer vascular region of the meniscus. This method is also commonly performed using arthroscopic techniques, which offer a minimally invasive route for effective tissue preservation and healing (Cohn, Fink, & Kim, 2021).

An important consideration in any surgical approach to meniscal injury is that surgery alone is rarely sufficient. While these interventions are critical, they often lead to complications or incomplete healing in the long run, necessitating a structured rehabilitation program. Unfortunately, there is currently no universally accepted or standardized rehabilitation protocol for the different types of meniscal repair procedures, which poses a challenge in post-operative management (Dağ, 2023).

Post-Meniscectomy Rehabilitation

One of the important aspects following meniscectomy is the implementation of effective rehabilitation strategies to optimize recovery and reduce long-term complications.

Electrotherapy

Among these strategies, electrotherapy has garnered considerable attention. In the domain of electromyography biofeedback (EMG-BF), a review by Karaborklu Argut, Celik, and Yasacı (2022) suggests that EMG-BF may be beneficial in improving quadriceps strength, knee function, and reducing pain following meniscectomy. Though orthopedic rehabilitation is a field rich in procedures and approaches, a huge gap still remains; there is no generally accepted rehabilitation program expressly intended for meniscectomy patients. This lack may mostly be attributed to the increasing knowledge that, especially following surgery, rehabilitation must be individualized to fit the needs and circumstances of the patient..

A randomized controlled experiment by Yu and Shin (2023) showed that, particularly when coupled with exercise, electrical muscle stimulation (EMS) favorably affects pain, muscular strength, and functional results. The authors, however, underline the need for further study to prove its general clinical acceptability.

A comprehensive study by Conley et al. (2021) offers encouraging proof of neuromuscular electrical stimulation (NMES) in strengthening postoperative quadriceps. These results support the possibility of NMES as a useful tool in post-meniscal surgery rehabilitation.

Manual Therapy

In a study conducted by Zahroh, Firdyansyah, and Khamdani (2022). The authors emphasize the necessity of an effective rehabilitation program following knee surgery to restore proper knee function, minimize the risk of osteoarthritis (OA), and prevent excessive strain on the knee. The study highlights that manual therapy plays a valuable role in this process, describing it as a passive movement applied directly or indirectly to specific structures aimed at reducing pain or creating functional change. The researchers concluded that manual therapy is effective in contributing to the functional restoration of the body and specifically enhances knee function, which they incorporated into their rehabilitation protocol. Similarly, in another study by Jahan, Dmitrievna, and Ismayilova (2018). Focused on improving postoperative rehabilitation following partial meniscectomy, manual therapy was also included among various interventions. Techniques such as Swedish massage, effleurage, myofascial release targeting the tensor fasciae latae, iliotibial band, and vastus lateralis, along with light stretches, were used. Although the protocol was described as clear, simple, and suitable for rehabilitation settings, the study acknowledged that the effectiveness of manual therapy alone could not be evaluated definitively. Therefore, more targeted research is needed in this area to better understand its individual contribution.

Kinesio Taping

Regarding kinesio taping, one notable observation in the literature is the limited number of studies available. However, a randomized controlled experiment by Ahmed et al. (2024), looked at the short-term effects of kinesio taping on quadriceps peak torque in people who had arthroscopic partial meniscectomy. While the control group got a placebo application, the experimental group in this research got taping on the rectus femoris, vastus medialis, and vastus lateralis using a suitable method. The findings indicated a notable rise in quadriceps torque in the experimental group, indicating that kinesio taping might be a helpful tool in improving muscular strength during the rehabilitation phase after meniscectomy.

Exercise in Post-Meniscectomy Rehabilitation

Exercise is a cornerstone of orthopedic rehabilitation, particularly following procedures like arthroscopic partial meniscectomy due to medial meniscus tears. Different studies emphasize the importance of therapeutic exercise regimens in recovering knee function and lowering pain. Compared to usual postoperative treatment, one study by Østerås (2014) emphasized the benefits of a 12-week medical exercise therapy program including aerobic training, quadriceps and hamstring strengthening, flexibility, stretching, and proprioceptive exercises. The outcomes revealed significant increases in knee function and pain decrease in the exercise group.

Ericsson, Dahlberg, and Roos (2009) explored the benefits of functional exercise training after meniscectomy, focusing on flexibility, coordination, strength, proprioception, and functional stability. Although further study is required to support these results, they discovered that functional workouts provided particular benefits above conventional ones, particularly in enhancing movement quality and balance. Timing is also rather important; St-Pierre et al. (1992). Research on early versus late isokinetic strength training revealed that early training had favorable outcomes just weeks after surgery, therefore stressing the need for prompt rehabilitation.

Another study by Nutarelli et al. (2021) compared home-based exercise and rest with outpatient rehabilitation. While patients did not initially report one method as superior, there were indications that home-based programs might be more beneficial over time, though more robust evidence is needed. Similarly, Reid, Rydwanski, Hing, and White (2012) conducted a systematic review on post-meniscectomy exercise rehabilitation and found the overall effectiveness of strengthening exercises to be moderate, with long-term benefits still uncertain due to inconsistent measurement standards.

Another article by Ergun (2004) provides a detailed explanation of the rehabilitation process following arthroscopic meniscectomy and meniscus repair. The rehabilitation process aims to reduce inflammation, restore range of motion, increase muscle strength, and facilitate return to sports. It is divided into six phases, preoperative, postoperative, early, late, developmental, and return to sport. Various techniques are highlighted, including isometric exercises, aquatic therapy, proprioceptive training, and closed kinetic chain exercises. The article emphasizes the importance of individualized rehabilitation programs. Based on the findings, a general exercise protocol can be outlined.

Preoperative exercises include isometric quadriceps and hamstring contractions, terminal knee extension, resisted straight leg rises, hip and ankle strengthening, isokinetic knee flexion, PNF patterns, and resistance training with therabands and sandbags. Passive motion using CPM devices, early start of isometric exercises, and aided walking with crutches using the three-point approach define the postoperative period. Closed kinetic chain strengthening, cross-over exercises, aquatic activities with protective bandaging, terminal extension exercises, straight leg lifts, and quadriceps, hamstrings, and gastrocnemius stretching make up the early phase. Isokinetic exercises, proprioceptive training employing balancing boards or trampolines, stationary bike, isotonic strengthening, toe and heel walking, static stretching, and mild running are included in the late phase. Along with different running drills, the growth stage advances to maximum resistance isotonic workouts and functional strengthening, including jump rope, squats, and leg press. Finally, the return to sport phase includes proprioceptive balance evaluations, coordination, agility exercises, plyometric workouts, strength, endurance tests, and sport-specific agility. This flexible yet systematic approach helps to ensure the best healing and a safe return to physical activity.

Conclusion

This paper emphasizes a basic idea by looking at the post-surgical rehabilitation process and the anatomical structure of the meniscus: efficient rehabilitation of damaged tissue is only feasible with a complete knowledge of its details. Although orthopedic rehabilitation is a sector rich in procedures and techniques, a major gap still exists; there is no widely acknowledged rehabilitation program especially designed for meniscectomy patients. This absence can largely be attributed to the growing awareness that rehabilitation must be tailored to the patient's demands and situation, especially after surgery.

Despite this, numerous studies offer valuable guidance in forming a general roadmap. Among all modalities, exercise stands out as the cornerstone of successful rehabilitation. Supporting therapies, such as electrotherapy, manual therapy, and kinesio taping, play important adjunctive roles. Though these techniques can enhance recovery, they are not substitutes for exercise but rather complementary elements that support its effectiveness. Importantly, incorporating exercise not only in the postoperative phase but also prior to surgery can significantly facilitate smoother and more effective recovery outcomes.

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