Compare Three Types of Surgery for Meniscal Tears

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Abstract. Meniscus injuries, often associated with sports, have become a growing concern because of their potential to affect patients' knee joints and, thus, People's Daily lives. A meniscal tear is a half-moon-shaped fibrous cartilage structure in the knee joint. This article explores the meniscus's complex anatomical structure and biochemistry, emphasizing its critical importance in maintaining optimal knee function. Our discussion extends to modern diagnostic procedures, particularly emphasizing the direct visualization capabilities of non-invasive magnetic resonance imaging (MRI) and arthroscopy. In addition, this paper lists three major surgical interventions for meniscus injuries: Meniscus repair, which aims to preserve the natural meniscus; Meniscectomy, the removal of the damaged meniscus; and Meniscus replacement using biological grafts or innovative synthetic materials. While meniscectomy can provide quick relief from symptoms, it carries the potential threat of diseases such as osteoarthritis in the long run. In contrast, meniscus repair and replacement strategies are longer-lasting treatment options, although postoperative recovery times and the complexity of the procedure vary.

Keywords: Meniscus tears; biochemistry; MRI, meniscus repair; meniscectomy; meniscus replacement.

1. Introduction

The prevalence of meniscus tears has increased in recent years, primarily due to the growing number of individuals engaging in athletic activities and the advancements in imaging technology, particularly MRI. Around 60 out of every 100,000 individuals are estimated to experience a meniscus injury [1]. The meniscus plays a crucial role in the knee joint. It is integral to joint biomechanics since it contributes to several functions, such as weight distribution, stability, shock absorption, and lubrication [2]. Given the function of the meniscus, untreated meniscus tears can lead to severe joint disease and accelerate osteoarthritis [2]. Hence, it is imperative to implement efficacious treatment options to preserve the muscular stability of the knee joint and avert any potential consequences.

Over the years, surgical interventions, especially those aimed at meniscus repair and preservation, have become the primary treatment option for managing meniscus tears [3]. These surgical approaches show results that reduce recovery time and improve functional outcomes compared to older excision-based approaches. However, surgery is not a one-size-fits-all solution. Other conservative treatment options, such as mobility adjustment, physical therapy, and knee braces, are effective for less complex degenerative and meniscal tears [3].

As the field of orthopedics continues to evolve, new approaches such as tissue engineering are making breakthroughs, offering the potential for meniscus tissue regeneration and thereby providing a more sustainable solution for long-term knee health. The increased availability of treatment options makes it critical for clinicians and researchers to critically examine and compare existing surgical techniques for treating traumatic meniscal tears [3].

This review article provides an in-depth comparison of three commonly used surgical approaches for treating traumatic meniscal tears. We will examine each approach's efficacy, recovery time, potential complications, and long-term outcomes to provide evidence-based guidelines for healthcare professionals when treating traumatic meniscal tears.

2. Anatomy and Biochemistry of Meniscus

The biomechanical efficiency and overall health of the knee joint strongly depend on the presence of two crescent-shaped fibrocartilage structures known as the menisci. The menisci are situated inside the intercondylar space of the femoral condyles and the tibial plateau, serving as crucial contributors to preserving knee stability, shock absorption, and load distribution [4].

2.1. Anatomy

The meniscus is characterized by its unique triangular cross-section profile and various shapes. According to the literature of Maffulli, it has been observed that the lateral meniscus demonstrates a structure resembling the letter C, whereas the medial meniscus possesses a larger morphology resembling the letter U [4]. The primary role of the joint capsule encompasses the secure fixation of the convex outer border of the meniscus. The anterior and posterior corners are firmly fixed to the bone by insertion of ligaments to ensure stability [4]. Each meniscus has a main body, anterior and posterior insertion ligaments, and a bone attachment site called the meniscus attachment site [4]. The meniscus is fully vascularized at birth but gradually decreases with age. Only the peripheral margin retains vascularization in adults, drawing nutrients from the perimembranous capillary cluster [4]. This limited vascularization affects the healing potential of meniscus injuries [5].

2.2. Biochemical Components

The meniscus contains a substantial amount of extracellular matrix, primarily composed of 72% water, 22% collagen, and 0.8% glycosaminoglycans [6]. A small fraction consists of proteins, glycoproteins, and scattered fibrochondrocytes that reflect the characteristics of fibroblasts and chondrocytes [6]. These cells synthesize ECM and contribute to the entire meniscal tissue.

At the same time, the meniscus is rich in collagen. The meniscus is structurally divided into shallow, layered, and deep layers, each with a different collagen orientation [6]. Type I collagen is mainly distributed in the meniscus, and type II collagen is more distributed in the interior [6]. Their interaction ensures the meniscus's resistance to compressive load, lubrication, and elasticity [6]. The orientation of the collagen fibers also plays a key role, adjusting according to biomechanical stressors and the movement of the knee joint [6].

2.3. Effects on Meniscus Health

The anatomical and biochemical characteristics of the meniscus directly determine its functional properties. A robust attachment system ensures payload distribution on the knee. In addition, the biochemical composition of the meniscus, especially its high-water content, is conducive to joint lubrication [4]. However, limited vascularization poses a challenge for meniscus injury repair, especially in the internal vascularized area. Therefore, understanding the anatomy and biochemistry of the meniscus is fundamental to effective therapeutic interventions.

3. Diagnosis of Meniscal Tears

Accurate diagnosis of meniscal tears is essential for effective management and treatment of the disease. Diagnosing such tears involves a variety of approaches, including clinical assessment, imaging techniques, and sometimes diagnostic procedures.

Clinical evaluation included history collection and physical examination. History collection provides valuable insight into the causes and manifestations of potential meniscal tears by collecting a comprehensive patient history [3]. Understanding symptoms' onset, nature, and duration can guide subsequent diagnostic steps. The physical examination includes assessing the patient's mobility and observing the gait of the patient, ability to squat, and other movements [3]. Specific procedures help identify the source of pain and narrow the location of potential tears. Imaging techniques include radiography and MRI. Radiography employs X-ray technology to detect bone pathology and indications of knee arthritis, including osteophytes, subchondral bone cysts, and joint space stenosis

[3]. Although X-rays cannot directly observe meniscal tears, radiographs can provide a way to eliminate other potential causes of the symptoms presented [4]. MRI can capture high-resolution images of soft tissue, showing meniscal tears in detail with a sensitivity and specificity of 93% and 88%, respectively [4]. Moreover, MRI provides insight into the location, depth, and shape of the tear and different planes, such as the sagittal, coronal, and axial planes, further improving diagnostic accuracy and providing a comprehensive view of the potential tear and its characteristics [4]. Arthroscopy is often used to directly observe the intraarticular structure after MRI determines a meniscus tear [3].

4. Surgical Protocol for Meniscus Tear

4.1. Meniscus Repair

4.1.1 Introduction

Meniscal prosthesis can be performed either open or arthroscopic and differs from meniscectomy in that the goal is to preserve the meniscus as much as possible [7]. There are three main meniscus repair techniques: from the inside out, from the outside in, and all inside [7]. The meniscus is divided into three regions from the outside to the inside: red-red, red-white, and white, white [1]. The red-red area has the most blood vessels in the meniscus, followed by the red-white area, and the white-white area has the least blood vessel distribution [1]. Among them, the most suitable for repair are acute traumatic tears in the red-red area of suitable peripheral blood vessels [7].

4.1.2 Short- and Long-term Results of Meniscus Repair

The findings of the two-year follow-up revealed a failure rate of meniscus repair that was below 10%, suggesting favorable outcomes in the short term. On the other hand, it is noteworthy that the long-term failure rate of meniscus repair remained consistently within the range of 23% to 30% [3]. The long-term outcomes of meniscus repair are quite favorable, exhibiting a minimal incidence of failure [1]. According to the findings of a study, the presence of a Grade IV femoral condylar cartilage injury during the surgical procedure is associated with poorer outcomes following repair [1]. The patient resumed total activity within roughly 7 to 9 months following the combined meniscus repair procedure and anterior cruciate ligament replacement (ACLR) [1].

4.1.3 Factors Affecting Rehabilitation

The type and location of meniscal tears can affect the rehabilitation after meniscal repair. Healing ability and recovery time may vary depending on the location of the tear within the meniscus, such as red-red, red-white, or white-white areas [1]. Similarly, the timing of surgery can also impact recovery from meniscal repair. Acute meniscus repair (done shortly after injury) may have better rehabilitation outcomes than chronic repair (done later) [1].

In addition, to promote healing after meniscus repair, a variety of enhancement techniques and biological products are used, such as platelet-rich plasma, Decellularized Scaffold and Growth Factors, fibrin clots, fibrin glue, mesenchymal stem cells and other substances [7]. Growth factors are crucial in meniscus repair by promoting healing and tissue regeneration. Platelet-rich plasma (PRP) therapy has shown positive results, including pain relief, improved functional outcomes, and growth factor response [6]. Studies have reported slight improvements in functional outcomes and healing recorded by MRI in treating meniscal tears with PRP [6]. Individual patient factors such as age, overall health, and adherence to the rehabilitation program also affect the rehabilitation process and outcome [1].

4.2. Meniscectomy

4.2.1 Introduction

Meniscectomy is a surgical procedure to remove the meniscus. There are two types of meniscectomies: total meniscectomy, in which the entire meniscus is removed, and Partial

meniscectomy, which involves removing only the torn part of the meniscus while preserving as much of the healthy meniscus as possible [8]. Meniscectomy is commonly used to treat symptomatic meniscal tears and knee osteoarthritis [9].

4.2.2 Short- and Long-term Effects of Meniscectomy

Short-term impact: Short-term results after partial meniscectomy are encouraging, with approximately 90% of patients showing satisfactory clinical outcomes [8]. Partial meniscectomy can relieve pain and improve functional products in symptomatic tears that cannot be repaired [8].

Long-term effects: Meniscectomy may lead to symptomatic knee osteoarthritis later in life, with a significantly increased rate of total knee replacement compared to peers [10]. The study found a more than four-fold increase in the relative risk of developing osteoarthritis 40 years after surgery, indicating the long-term effects of meniscectomy on the knee [10]. Meniscectomy, especially in the presence of chondromalacia, may produce fewer desirable results and may have an increased risk of osteoarthritis development [8].

4.2.3 Factors Affecting Postoperative Rehabilitation

The extent of surgery and the amount of meniscus tissue removed can affect the healing process [9]. Underlying osteoarthritis may affect the healing process and long-term outcomes [9].

4.3. Meniscus Replacement

4.3.1 Introduction

The surgical intervention known as meniscus replacement involves the replacement of a damaged or absent meniscus within the knee's joint. The most prevalent method of meniscus replacement is using a meniscus allograft (MAT), which involves the transplantation of a donor meniscus obtained from a deceased individual to replace a damaged or excised meniscus in the recipient's knee [11]. MAT is generally recommended for young, active patients who have lost meniscus function due to irreparable damage [12].

4.3.2 Short - and Long-Term Effects of Meniscus Replacement

Short-term impact: Meniscus compression (that is, the meniscus deviates from its normal position) is a common phenomenon after MAT surgery. However, this condition does not adversely affect surgical outcomes [11]. Interestingly, compared with medial MAT, lateral MAT showed better clinical outcomes and a relatively lower risk of failure [11]. In addition, although allograft meniscus can slow the progression of osteoarthritis, the effect may not be as significant as that of natural meniscus [11].

Long-term effects: The mean estimated survival time for meniscus transplantation is 12.6 ± 0.7 years [13]. However, the survival rate of meniscal allograft (MAT) decreased significantly in the medium to long term. The survival rate of MAT is about 85%-90% in the medium term, but it will drop to 50-70% in the long term [11].

4.3.3 Factors Affecting Rehabilitation

MAT is a complex treatment, and its success is affected by many factors. First, conditions such as degenerative diseases, osteoarthritis, obesity, skeletal immaturity, inflammatory arthritis, previous suppurative arthritis, and synovial diseases are considered contraindications for MAT [11]. Secondly, the success rate of MAT is closely related to factors such as the degree of cartilage injury, the type of meniscus (lateral versus medial), and whether accompanying surgery was performed [12]. Although meniscal compression, common after MAT, does not affect treatment outcomes negatively, it is essential to note that the long-term survival rate of MAT is affected by cartilage status and accompanying surgery [12]. Finally, a patient's recovery and recovery time will vary depending on individual differences, such as age, overall health, and the degree to which post-operative rehabilitation protocols are followed [12].

5. Discussion

Meniscectomy is the surgical removal of a torn meniscus. Meniscectomy treats meniscus injuries without clear indications of reconstruction [14]. It can rapidly relieve symptoms and allow the patient to resume normal activities, work, or sports as soon as possible [14]. The characteristics of postoperative care after partial meniscectomy are rapid and relatively unrestricted recovery. Patients can expect early weight-bearing, immediate full-range movement (ROM), and early active movement training [14]. Often, fluid accumulation and pain are the main limiting factors in the patient's recovery phase [14]. However, while meniscectomy can provide immediate relief of symptoms and speed recovery, doctors need to consider the potential long-term risk of associated degenerative changes.

Meniscus prosthesis is a method of stitching a torn meniscus to allow it to heal naturally. Meniscal prosthetics are usually used for meniscal lesions located in the peripheral area because the vascular nature of the meniscus contributes to the healing process [14]. Compared to meniscectomy, recovery after meniscus repair requires a longer recovery time. Generally, patients undergo a weight-restricted rehabilitation regimen in the early weeks after surgery and limit knee curvature for up to six weeks after surgery [14]. However, although meniscal prosthesis preserves the natural meniscus and may reduce the risk of degenerative changes, a more extended recovery period than meniscectomy may be a disadvantage for some patients.

Meniscus replacement involves replacing the damaged meniscus with a synthetic implant or graft. Patients undergoing this procedure must have a complete meniscal base and a stable margin of appropriate meniscal tissue [14]. However, the recovery protocol after meniscal replacement is more limited than the other two treatment options. Weight-bearing is significantly reduced and begins around four weeks after surgery. It is usually recommended to use a brace to stabilize the joint around eight weeks after surgery [14]. In addition, ROM is usually restricted for at least six weeks [14]. Although this procedure benefits patients with severe meniscus damage, it requires a more extended recovery period. In addition, due to the need for surgical skills, only a limited number of institutions offer this procedure.

For doctors, choosing the best treatment for a meniscus tear depends mainly on the nature and location of the injury, the patient's age and activity level, and the specific rehabilitation goals. While a meniscectomy can quickly relieve symptoms, it can carry a long-term degeneration risk. Although meniscus repair takes more time to recover, it can retain the natural meniscus. Meniscus replacement, while beneficial for severe meniscus injuries, requires specialized surgical skills and a more extended recovery period. Orthopedic surgeons must evaluate each case individually to determine the most appropriate treatment, considering their patients' unique circumstances and preferences.

6. Conclusion

As the field of orthopedics and sports medicine continues to evolve, the primary objectives of surgical interventions for meniscal tears encompass the restoration of knee functionality, alleviation of pain, and the postponement or mitigation of osteoarthritis. Knowing the pros and cons of each surgical method and being aware of the latest advances in the field will ensure the best outcome for patients with meniscal injuries.

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