Case report

Risk factors, presentation, and management of arthrofibrosis in post-arthroscopic knee surgery: a systematic review

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Abstract

Arthrofibrosis is a severe complication following arthroscopic knee surgery, particularly anterior cruciate ligament (ACL) reconstruction, leading to joint stiffness, pain, and functional limitations. Despite advancements in surgical and rehabilitation strategies, it remains a significant challenge in orthopedic practice. This systematic review examines the risk factors, clinical presentation, and management strategies for arthrofibrosis after arthroscopic knee surgery. A comprehensive literature search was conducted across PubMed, Embase, Scopus, Cochrane Library, and Web of Science following PRISMA guidelines. Studies addressing arthrofibrosis risk factors, diagnosis, and treatment outcomes were included. Relevant data were extracted and analyzed. Five studies met the inclusion criteria. Risk factors were categorized into surgical (graft malposition, prolonged tourniquet use, concomitant procedures), patient-related (prior surgery, systemic inflammation, genetic predisposition), and rehabilitation-associated (delayed mobilization, inadequate pain control). Clinically, arthrofibrosis presents as progressive stiffness, restricted range of motion, and quadriceps inhibition, often requiring imaging for confirmation. Management strategies range from early rehabilitation and pharmacological approaches to surgical interventions in refractory cases. Arthrofibrosis is a multifactorial condition requiring early recognition and targeted intervention. Preventive strategies focusing on optimized surgical techniques, patient selection, and rehabilitation protocols are essential. Further research is needed to develop novel antifibrotic therapies and improve functional outcomes.

Keywords

Arthrofibrosis; arthroscopic knee surgery; clinical presentation; management; risk factors

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Introduction

Arthrofibrosis is a well-recognized and debilitating complication following anterior cruciate ligament (ACL) reconstruction, characterized by excessive fibrotic tissue formation leading to restricted knee motion, persistent pain, and functional impairment. It represents one of the most challenging postoperative complications in orthopedic surgery, with a reported incidence ranging from 2% to 35%.[1] Despite advances in surgical techniques and rehabilitation protocols, arthrofibrosis remains a significant concern, often necessitating prolonged rehabilitation and, in severe cases, additional surgical interventions to restore joint mobility. The condition manifests in a spectrum of severity, from mild loss of terminal knee extension to severe joint contracture, profoundly affecting patients' quality of life and athletic performance.[2]

The reported global incidence of arthrofibrosis following arthroscopic knee surgery ranges between 2% and 35%. In high-volume orthopedic centers, the prevalence tends to be lower due to advancements in rehabilitation strategies and minimally invasive surgical techniques. However, arthrofibrosis remains a major concern among patients with delayed rehabilitation, improper graft placement, and those predisposed to excessive fibrotic responses.[3] In Indonesia, specific epidemiological data on arthrofibrosis following ACL reconstruction are limited. However, case reports and institutional studies indicate that the condition is present and clinically significant. A case report from Indonesia highlights the occurrence of arthrofibrosis as a debilitating complication post-ACL reconstruction, aligning with global incidence rates. Additionally, the rising number of ACL injuries in Indonesia, particularly among young athletes and physically active individuals, suggests a growing need to address postoperative complications, including arthrofibrosis.[4]

Numerous risk factors have been identified as contributing to the development of arthrofibrosis after ACL reconstruction, encompassing both surgical and patient-related variables. Intraoperative risk factors include aggressive synovial resection, improper tunnel placement leading to excessive graft tension, and prolonged tourniquet use, all of which can contribute to increased intra-articular inflammation and fibrosis.[5] The clinical presentation of arthrofibrosis is variable, with symptoms ranging from mild stiffness to profound motion loss. Early manifestations often include pain, swelling, and difficulty achieving full knee extension, which, if left untreated, may progress to more severe forms of fibrosis involving both the anterior and posterior compartments of the knee. In advanced cases, patients experience significant limitations in both extension and flexion, leading to impaired gait mechanics and functional disability.[6] The management of arthrofibrosis ranges from conservative approaches to surgical interventions. Early-stage arthrofibrosis is often managed through aggressive physiotherapy, pain control, and pharmacological interventions, including nonsteroidal anti-inflammatory drugs (NSAIDs) and corticosteroids, aimed at reducing inflammation and promoting joint mobility.[7] However, in cases where conservative measures fail, more invasive treatments such as manipulation under anesthesia (MUA), arthroscopic lysis of adhesions, and open surgical debridement may be necessary. Therefore, a systematic review of existing literature is essential to establish evidence-based guidelines for the prevention and treatment of arthrofibrosis after arthroscopic knee surgery.[8]

Despite the growing body of literature on arthrofibrosis after arthroscopic knee surgery, there remains a lack of high-quality evidence specifically addressing the risk factors, clinical presentation, and optimal management strategies for arthrofibrosis. Current studies provide conflicting results regarding the most effective surgical techniques, rehabilitation protocols, and pharmacologic treatments, making it difficult for clinicians to implement standardized best practices.[9] This systematic review aims to bridge this gap by synthesizing available evidence to provide a comprehensive analysis of arthrofibrosis after arthroscopic knee surgery

Method

This systematic review will be conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological rigor, transparency, and re-

producibility. The study protocol will be registered in PROSPERO, an international prospective register for systematic reviews, to enhance transparency and reduce the risk of duplication. The methodology will include clearly defined eligibility criteria, a comprehensive literature search, systematic study selection, rigorous data extraction, and a thorough quality assessment process. Additionally, quantitative synthesis will be conducted when possible to generate pooled estimates regarding risk factors, clinical presentation, and management strategies for arthrofibrosis after ACL reconstruction.

Eligibility Criteria

A set of inclusion and exclusion criteria will be established to guide the selection of relevant studies. The inclusion criteria will encompass studies that investigate arthrofibrosis as a complication following ACL reconstruction, particularly those that assess its risk factors, clinical presentation, or management. Eligible studies will include randomized controlled trials (RCTs), cohort studies, case-control studies, and case series studies. Only peer-reviewed journal articles published in English will be considered. Studies will be excluded if they focus on arthrofibrosis unrelated to ACL reconstruction, as well as case reports, conference abstracts, editorials, expert opinions, and narrative reviews. Pediatric studies will be excluded due to potential variations in outcomes related to open growth plates. Non-English publications will also be excluded due to feasibility constraints in translation and interpretation. Additionally, studies with insufficient data or poor methodological quality will not be considered for inclusion.

Information Sources and Search Strategy

A comprehensive literature search will be conducted across multiple electronic databases, including PubMed, Embase, Scopus, Cochrane Library, and Web of Science. The search strategy will incorporate Medical Subject Headings (MeSH) terms, keywords, and Boolean operators to maximize sensitivity and specificity. Keywords such as "arthrofibrosis," "arthroscopy," "ACL reconstruction," "knee stiffness," "risk factors," "surgical outcomes," and "management" will be used in various combinations to identify relevant studies. The search strategy will be tailored for each database, ensuring that appropriate indexing terms are utilized. A MeSH term includes such as: (("Arthrofibrosis"[MeSH] OR "Knee Stiffness") AND ("Anterior Cruciate Ligament Reconstruction"[MeSH] OR "ACL Reconstruction" OR "Arthroscopy" OR Arthroscop*)) AND ("Risk Factors" OR "Surgical Outcomes" OR "Management" OR "Rehabilitation"). The reference lists of included studies and relevant systematic reviews will be manually screened to identify additional articles that meet the inclusion criteria. Grey literature, including unpublished studies and conference proceedings, will not be considered due to concerns regarding quality control and reproducibility.

Study Selection Process

All retrieved studies will be imported into EndNote or Rayyan for duplicate removal and systematic screening. The study selection process will occur in three distinct phases. First, two independent reviewers will conduct a title and abstract screening to identify potentially relevant studies. Articles that clearly do not meet the eligibility criteria will be excluded at this stage. Second, the remaining articles will undergo a full-text review, where two independent reviewers will assess their relevance based on the inclusion and exclusion criteria. Any discrepancies in study selection will be resolved through discussion, and a third reviewer will be consulted if consensus cannot be reached. Finally, studies that meet all inclusion criteria will be included in the systematic review. The PRISMA flow diagram will be used to document the number of studies identified, screened, included, and excluded at each stage of the selection process. (Figure 1)

Data Extraction

A standardized data extraction form will be developed to ensure consistency in data collection. Two independent reviewers will extract key study information, including author, publication year, study design, sample size, and patient demographics such as age, sex, body mass index (BMI), and comorbidities. Surgical details will also be recorded, includ-

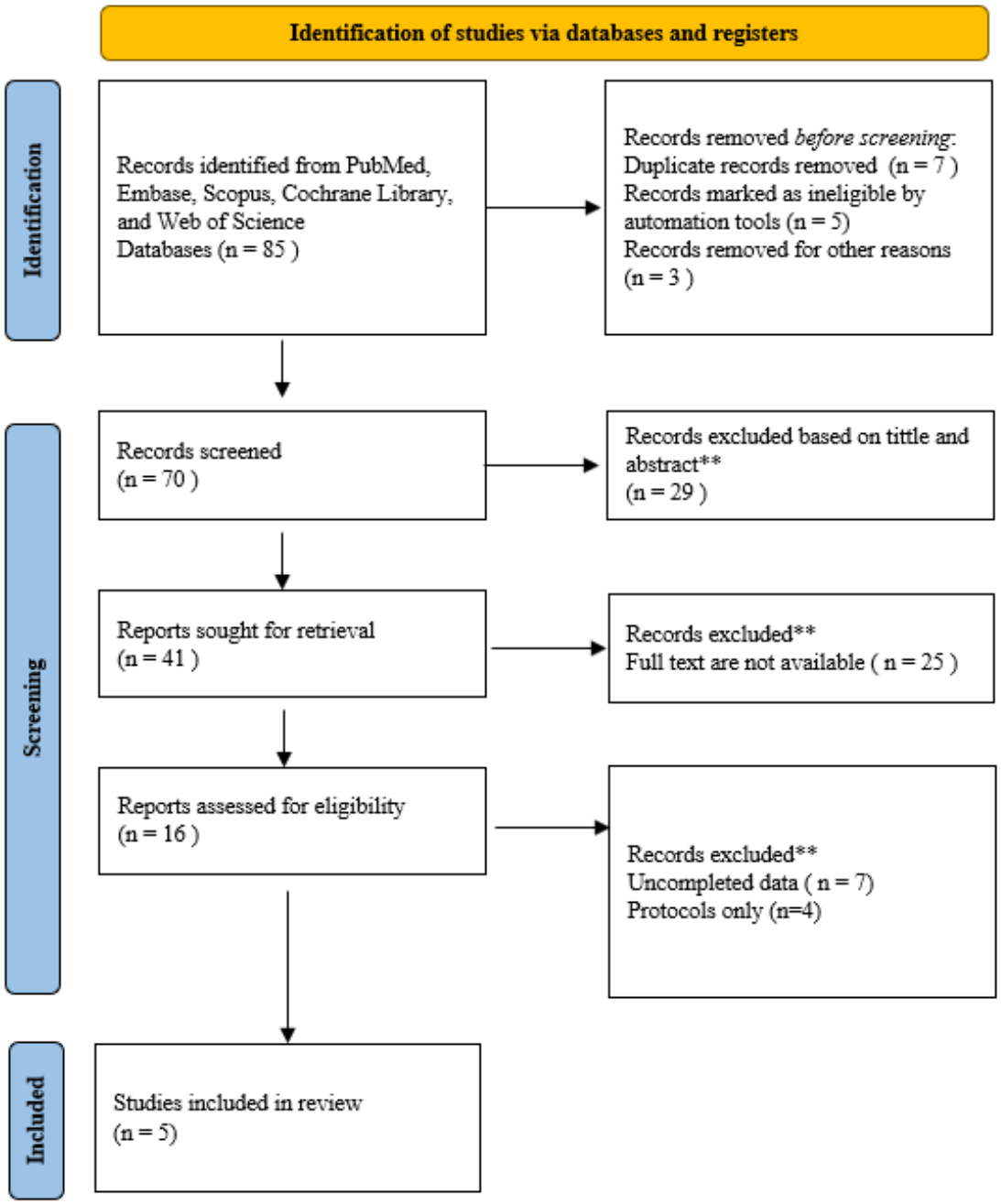

Figure 1. *PRISMA Flow Chart*

ing the type of ACL reconstruction performed, graft selection, tunnel placement, and surgical technique. Identified risk factors for arthrofibrosis will be categorized into patient-related, intraoperative, and postoperative variables. Data on clinical presentation will include symptom onset, severity of stiffness, and diagnostic methods used. The effectiveness of different management strategies, both conservative and surgical, will be assessed, along with reported clinical outcomes such as range of motion (ROM), functional scores (IKDC, Lysholm), patient satisfaction, and recurrence rates.

Quality Assessment

Each study will be independently assessed by two reviewers to determine the risk of bias in domains such as selection bias, performance bias, detection bias, attrition bias, and reporting bias. Any disagreements will be resolved through discussion, and a third reviewer will be consulted if necessary. Studies with a high risk of bias will be discussed in the limitations section and may be excluded from meta-analysis if their inclusion is deemed to significantly affect the validity of pooled estimates.

Result

The PRISMA flowchart provides a structured overview of the study selection process in this systematic review on arthrofibrosis following post-arthroscopic knee surgery. It ensures transparency and rigor by detailing how studies were identified, screened, and included. A total of 85 records were initially retrieved from databases. Before screening, 15 records were removed, where seven were duplicates, five were excluded by automation tools, and three were removed for other reasons. This step helps eliminate redundancy and irrelevant studies. Sixteen studies were assessed in detail for relevance and completeness. However, 11 studies were excluded, seven due to incomplete data and four because they were protocols without actual results. Ultimately, five studies met all eligibility criteria and were included in the final review. These studies form the basis of the systematic analysis of arthrofibrosis risk factors, presentation, and management.

All included studies utilize either a retrospective cohort design or case series, focusing on analyzing past clinical cases rather than conducting prospective trials. (Table 1) This approach provides insights into long-term treatment outcomes but may introduce limitations related to data completeness and potential bias. The sample sizes vary significantly across studies, ranging from small cohorts of 32 participants to larger groups exceeding 200 patients. Gender distribution is inconsistent, with some studies reporting a predominance of male participants, such as Rushdi et al. (93% male), while others do not provide gender details. The mean age of participants also varies, reflecting the diverse populations analyzed in different studies.

Regarding clinical characteristics, all studies focus on arthrofibrosis as a complication of knee surgery, with some specifying patellofemoral arthrofibrosis as a distinct condition. The primary interventions examined include arthroscopic lysis of adhesions, capsular release, and surgical management, all aimed at improving the range of motion (ROM) and reducing symptoms. Follow-up durations differ across studies, spanning from 6 months to over 10 years, which influences the assessment of long-term treatment effectiveness. Outcomes across studies consistently demonstrate that arthroscopic interventions lead to significant improvements in ROM, reduced pain levels, and better functional scores, such as the International Knee Documentation Committee (IKDC) score and Lysholm score. Additionally, some studies identify potential risk factors for arthrofibrosis, including early ACL reconstruction (within one month of injury) and female gender. Despite variations in study populations and methodologies, the overall findings suggest that timely intervention and proper rehabilitation can lead to positive outcomes in patients with arthrofibrosis following knee surgery.

Discussions

Arthrofibrosis is a pathological condition characterized by excessive fibroproliferative response and intra-articular scarring following knee surgery, particularly after anterior cruciate ligament (ACL) reconstruction. It is one of the most significant complications associated with arthroscopic knee procedures, leading to restricted joint mobility, persistent pain, and functional limitations. The condition results from an aberrant wound healing process, where excessive collagen deposition and fibrosis lead to adhesions within the intra-articular and periarticular structures, ultimately restricting the normal biomechanics of the knee joint.[15] Despite advances in surgical techniques and postoperative rehabilitation strategies, arthrofibrosis remains a major challenge in orthopedic surgery, often necessitating prolonged physical therapy and, in severe

Table 1. Characteristics of Study

No	Author (Year)	Year	Country	Design Study	Sample Size (n)	Gender	Age (mean)	Lysholm score (Points / 100)	Diagnosis	Etiology	Type of Intervention	Follow-up (mean)	Conclusions
1	Calloway et al.[10]	2018	USA	Case Series	32	7 females	32.8 years (range, 19-58 years)	NR	Refractory patellofemoral arthrofibrosis	NR	arthroscopic release for refractory PFA after ACL reconstruction	43.6 months (range, 16-98 months).	The IKDC score significantly improved from 49.6 to 69.4 (P < .00001), with 50% of patients reaching a meaningful clinical improvement. WOMAC scores also increased from 74 to 85.3 (P < .00001), with 47% achieving clinical improvement. Most patients (97%) felt the procedure was beneficial, and 78% said they would undergo it again.
2	Dauty et al.[11]	2023	Australia	Cohort retrospective	Arthrofibrosis group (n=92), control group (n=842)	NR	28.0 ± 8.0	83 ± 9	Arthrofibrosis	Pre-existing joint condition	NR	NR	Female gender, early ACL reconstruction (<1 month), BPTB procedure, meniscal repair, and BMI ≥ 25 were not confirmed as risk factors. The only identified risk factor was a history of competitive sports (OR: 3.56, 95% CI: 2.20–5.75, p = 0.0001). Meanwhile, age under 18 (OR: 0.40, p = 0.015) and inpatient rehabilitation (OR: 0.28, p = 0.0001) were protective factors.
3	Fabricant et al.[12]	2018	USA	Cohort retrospective	90	31% male	14.4 ± 3.5 years	NR	Arthrofibrosis	NR	lysis of adhesions and manipulation	42± 56 months.	Patients who had preoperative dynamic splinting (51%) initially had better flexion (99° vs. 77°, P=0.001), but there was no significant difference at the final follow-up (121° vs. 128°, P=0.08).

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No	Author (Year)	Year	Country	Design Study	Sample Size (n)	Gender	Age (mean)	Lysholm score (Points / 100)	Diagnosis	Etiology	Type of Intervention	Follow-up (mean)	Conclusions
													Treatment failure was not affected by the time between the initial procedure and LOA/MUA. The percentage of patients who regained full ROM was similar between those who had dynamic splinting and those who did not (65% vs. 59%, P=0.70).
4	Lamba, et al.[13]	2023	USA	Cohort retrospective	40	46.2% male	27.2 years (range, 11.0-63.8 years)	NR	Arthrofibrosis	Delayed rehabilitation	lysis of adhesions, capsular release with or without manipulation under anesthesia, and excision of cyclops lesions.	10.0 years (range, 2.9-20.7 years)	Before surgery, the average knee flexion was 102° (range: 40°–150°) and extension was 8° (range: 0°–25°). After arthroscopic treatment, flexion improved to 131° (range: 110°–150°), and extension averaged 0° (range: –10° to 5°). The overall range of motion (ROM) significantly increased from 94° (range: 40°–140°) preoperatively to 131° (range: 107°–152°) at the final follow-up (P < .001). Pain levels also improved, with the visual analog scale (VAS) score decreasing from 3.0 before surgery to 1.2 afterward (P = .001).

Table 1. Characteristics of Study

No	Author (Year)	Year	Country	Design Study	Sample Size (n)	Gender	Age (mean)	Lysholm score (Points / 100)	Diagnosis	Etiology	Type of Intervention	Follow-up (mean)	Conclusions
5	Rushdi, et al.[14]	2019	Malaysia	Case Series	200	93% male	26 years old	NR	Arthrofibrosis	NR	Surgical intervention	6 months	The incidence of arthrofibrosis following ACL reconstruction in our centers is approximately 5%. However, this rate can be minimized through appropriate preventive strategies, including comprehensive preoperative assessment, careful patient selection, ensuring full restoration of range of motion (ROM) before surgery, and optimizing the timing of the procedure.

cases, surgical intervention to restore joint motion. This systematic review provides a comprehensive synthesis of current evidence on the risk factors, clinical presentation, and management strategies for arthrofibrosis following ACL reconstruction, a significant complication that adversely affects postoperative recovery and functional outcomes. The findings highlight the multifactorial etiology of arthrofibrosis, involving an interplay between biological, biomechanical, and rehabilitation-related factors. This condition remains a major concern in orthopedic surgery, as it can prolong rehabilitation, increase the likelihood of revision procedures, and impair long-term knee function. Understanding the underlying mechanisms, risk factors, and available management strategies is critical for optimizing treatment outcomes and preventing excessive joint fibrosis.

Arthrofibrosis is a multifactorial condition that arises from an excessive fibrotic response following arthroscopic knee surgery, particularly anterior cruciate ligament (ACL) reconstruction. (Table 2) The pathogenesis involves a complex interplay between surgical, patient-related, and postoperative rehabilitation factors that contribute to aberrant tissue healing and scar formation. Identifying these risk factors is critical for early prevention, timely intervention, and improved patient outcomes. Several intraoperative factors have been implicated in the development of arthrofibrosis, primarily due to their role in triggering an exaggerated inflammatory response and excessive scar tissue formation.

One of the most significant contributors is improper graft placement, particularly anteriorization or excessive tensioning of the ACL graft, which can lead to biomechanical alterations and increased strain on the joint capsule. Studies have demonstrated that malpositioned grafts may cause impingement within the intercondylar notch, promoting inflammation and fibrosis.[16] Furthermore, excessive synovial resection and aggressive intraoperative soft tissue manipulation can disrupt normal joint homeostasis, increasing the likelihood of inflammatory-mediated fibrotic changes.[17]

Prolonged tourniquet use during arthroscopic procedures is another surgical factor associated with a heightened risk of arthrofibrosis. Prolonged ischemia-reperfusion injury leads to increased cytokine release, oxidative stress, and endothelial damage, all of which contribute to an amplified inflammatory cascade that predisposes patients to fibrotic adhesion formation.[18] Additionally, the use of allografts versus autografts has been debated in the context of arthrofibrosis risk. While allografts reduce donor site morbidity, some studies suggest that autografts, particularly bone-patellar tendon-bone (BPTB) grafts, may be associated with a higher incidence of postoperative stiffness due to increased local inflammation at the harvest site.[19] The type of concomitant procedures performed during ACL reconstruction also influences the likelihood of arthrofibrosis. For example, patients undergoing additional meniscal repairs, microfracture surgery, or cartilage restoration procedures have an elevated risk of stiffness due to the combined inflammatory burden and the necessity for postoperative motion restrictions.[20] Similarly, lateral extra-articular tenodesis (LET) or anterolateral ligament reconstruction (ALLR), often performed adjunctively in cases of high-grade rotational instability, may increase joint fibrosis if not carefully managed during rehabilitation.

Certain patient-specific variables predispose individuals to a heightened fibrotic response following knee surgery. One of the most well-established risk factors is a history of prior knee surgery. Patients with previous surgical interventions, particularly open procedures or multiple revisions, exhibit an increased risk of developing intra-articular adhesions due to pre-existing scar tissue and altered synovial fluid composition.[21] Additionally, a history of joint infections, such as septic arthritis, further exacerbates the risk of arthrofibrosis by inducing chronic synovial inflammation and fibrosis. Systemic inflammatory conditions, including diabetes mellitus, rheumatoid arthritis, and other autoimmune disorders, have also been linked to an increased predisposition to excessive scar formation. Hyperglycemia, for instance, is known to impair collagen remodeling and promote fibroblast proliferation, contributing to the pathogenesis of arthrofibrosis.[22] Similarly, patients with hypercoagulable states, such as those with a genetic predisposition to deep vein thrombosis (DVT), may experience heightened fibrin deposition within the joint, further exacerbating the risk of adhesions.

Genetic predisposition plays a crucial role in determining an individual's likelihood of developing arthrofibrosis. Variations in genes associated with inflammatory cytokine regulation, such as tumor necrosis factor-alpha (TNF-α), transforming growth factor-beta (TGF-β), and matrix metalloproteinases (MMPs), have been implicated in abnormal wound healing responses.[23] These genetic factors may explain why certain patients exhibit an exaggerated fibrotic response despite optimal surgical and rehabilitation protocols. Age and sex are additional demographic variables that may influence arthrofibrosis risk. Younger patients, particularly those under 20 years of age, may have a more robust healing response, predisposing them to excessive scar tissue formation. Conversely, older individuals with pre-existing osteoarthritis may develop joint stiffness due to underlying degenerative changes. Sex-based differences have also been reported, with some studies suggesting that female patients may be at a slightly higher risk due to hormonal influences on collagen synthesis and soft tissue remodeling.[4]

The postoperative rehabilitation phase plays a pivotal role in determining the risk of arthrofibrosis. One of the most critical factors is delayed mobilization and prolonged immobilization following surgery. Early joint motion is essential for preventing intra-articular adhesions, maintaining synovial flu-

Table 2. Risk Factors and Management Strategies for Arthrofibrosis After Arthroscopic Knee Surgery

	Category	Key Factors / Strategies	Clinical Interpretation
Risk Factors	Surgical-related	Graft malposition, excessive graft tension, aggressive synovectomy, prolonged tourniquet use, concomitant procedures	Technical errors and excessive intraoperative tissue trauma amplify inflammatory response, increasing the risk of fibrotic adhesion formation
	Graft-related	BPTB autograft, larger graft diameter, harvest-site morbidity	Certain graft characteristics may provoke greater local inflammation, potentially predisposing to postoperative stiffness
	Patient-related	Prior knee surgery, systemic inflammatory disease, genetic predisposition, female sex, young age	Host biological response plays a critical role in fibrotic tendency, independent of surgical technique
	Rehabilitation-related	Delayed mobilization, prolonged immobilization, inadequate pain control, poor protocol adherence	Failure to restore early knee extension and controlled ROM is a major modifiable risk factor for arthrofibrosis
Management	Conservative	Early physiotherapy, controlled ROM exercises, CPM, NSAIDs, corticosteroids	Early-stage arthrofibrosis may be reversed by suppressing inflammation and promoting collagen remodeling through guided motion
	Minimally invasive	Manipulation under anesthesia, arthroscopic lysis of adhesions	Early arthroscopic intervention is associated with superior restoration of ROM compared with delayed procedures
	Surgical (advanced)	Open capsular release, revision procedures	Reserved for refractory cases with established fibrosis and severe functional limitation
	Emerging therapies	Antifibrotic agents, PRP, MSCs, gene-targeted therapies	Novel biologic approaches aim to modulate fibrotic pathways but currently lack robust clinical evidence

id circulation, and promoting collagen remodeling. Patients who fail to achieve full extension within the first six weeks postoperatively are at an increased risk of developing long-term stiffness.[24] Inadequate pain control is another major contributor to arthrofibrosis. Persistent pain leads to reflexive quadriceps inhibition, reduced joint mobility, and subsequent scar tissue formation. Multimodal analgesia, including regional nerve blocks, nonsteroidal anti-inflammatory drugs (NSAIDs), and cryotherapy, is essential for mitigating this risk.[25] However, over-reliance on opioid medications without an emphasis on early mobilization may paradoxically contribute to stiffness due to prolonged inactivity.

Rehabilitation intensity and protocol adherence significantly impact arthrofibrosis development. Overly aggressive rehabilitation, including excessive forced stretching or premature high-impact loading, may exacerbate inflammation and contribute to fibrotic tissue deposition. Conversely, an overly conservative approach that does not prioritize early weight-bearing and range-of-motion exercises can lead to avoidable stiffness.[26] Striking the right balance between protecting the healing graft and promoting functional recovery is paramount in preventing arthrofibrosis. Additionally, postoperative complications such as hemarthrosis and persistent joint effusion can further increase the risk of fibrosis. Uncontrolled intra-articular bleeding leads to fibrin deposition, which serves as a scaffold for fibrotic adhesions. Therefore, proper surgical hemostasis, the judicious use of anticoagulation therapy, and close monitoring for postoperative swelling are crucial in reducing the incidence of arthrofibrosis.[27]

Arthrofibrosis is a significant and potentially debilitating complication following arthroscopic knee surgery, particularly anterior cruciate ligament (ACL) reconstruction. It is characterized by excessive fibrotic tissue formation within the joint, leading to restricted motion, persistent pain, and functional impairment. The condition varies in severity, ranging from mild stiffness and discomfort to profound joint contracture, severely affecting mobility and quality of life. The clinical presentation of arthrofibrosis is influenced by multiple factors, including the extent of intra-articular fibrosis, the involvement of periarticular structures, and the presence of underlying patient-specific risk factors such as a history of previous surgery, systemic inflammatory conditions, and genetic predisposition.[28]

In the early postoperative phase, patients with arthrofibrosis may present with disproportionate and persistent knee pain, localized swelling, and an inability to achieve full range of motion despite adherence to rehabilitation protocols. While some degree of transient stiffness is common following knee surgery, arthrofibrosis is characterized by a progressive and sustained limitation in movement that does not resolve with conservative management.[13] One of the earliest signs is difficulty in achieving full extension, often accompanied by increased resistance during passive stretching and pain upon forced extension. Patients may also report an unusual sensation of tightness within the joint, which is exacerbated during weight-bearing activities. Quadriceps inhibition and muscle atrophy may develop due to reduced knee mobility and pain-associated disuse, further compounding the functional impairment.[29]

As the condition progresses, the fibrotic process extends to the joint capsule, synovial tissues, and periarticular structures, leading to worsening motion deficits. A hallmark clinical feature of arthrofibrosis is the loss of terminal knee extension, commonly referred to as an "extension deficit," which alters normal gait mechanics and predisposes the patient to patellofemoral maltracking, increased joint stress, and secondary cartilage degeneration. In more advanced cases, flexion deficits also develop, resulting in global joint stiffness and profound disability. Patients may experience increasing pain with activities of daily living, particularly during stair climbing, prolonged sitting, or attempts at deep squatting. The loss of both extension and flexion significantly impairs functional mobility and is often associated with a sensation of joint instability, further limiting physical activity.[12]

The clinical classification of arthrofibrosis is based on the severity and anatomical distribution of fibrotic adhesions within the knee. Localized arthrofibrosis, such as the well-documented Cyclops lesion, involves the formation of a fibroproliferative nodule anterior to the ACL graft, mechanically obstructing

terminal extension and causing painful impingement. This condition, often detected during follow-up evaluations, typically requires surgical debridement to restore full extension. Diffuse intra-articular arthrofibrosis, on the other hand, involves extensive fibrosis within the joint capsule, leading to progressive loss of both extension and flexion. In more severe cases, extracapsular arthrofibrosis extends beyond the intra-articular structures, affecting the quadriceps muscle, patellar tendon, and posterior knee structures, further exacerbating functional deficits. The most severe form, global arthrofibrosis, is characterized by widespread fibrosis throughout the knee joint, resulting in severe motion loss, chronic pain, and significant long-term disability, often requiring aggressive surgical intervention.[24]

Diagnosis of arthrofibrosis is primarily clinical, with a thorough history and physical examination being the cornerstone of assessment. Key diagnostic criteria include a persistent limitation in passive and active knee motion, particularly in extension, despite appropriate rehabilitation efforts. The passive and active range of motion (ROM) assessment is crucial in determining the severity of restriction, with extension loss of more than 5° often considered significant. The patellar mobility test is useful in evaluating patellar tracking abnormalities and the presence of fibrotic adhesions restricting patellar movement. Additionally, the quadriceps activation test may reveal persistent quadriceps inhibition and muscle atrophy, further indicating the presence of arthrofibrosis-related dysfunction.[30]

While clinical evaluation remains the gold standard for diagnosing arthrofibrosis, imaging modalities play a complementary role in assessing the extent of fibrotic changes and ruling out other postoperative complications. Magnetic resonance imaging (MRI) is the most utilized imaging technique, capable of detecting intra-articular adhesions, capsular thickening, and synovial fibrosis. MRI is particularly valuable in identifying Cyclops lesions and evaluating the presence of associated joint effusion, which may suggest ongoing inflammation.[31] Dynamic fluoroscopy can be used to assess impingement during knee motion, providing additional insight into the mechanical restrictions caused by fibrotic tissue. In cases where diagnostic uncertainty remains, arthroscopic evaluation serves as the definitive diagnostic tool, allowing direct visualization of intra-articular fibrosis and adhesions while offering the opportunity for therapeutic intervention if necessary.

The management of arthrofibrosis following arthroscopic knee surgery remains a significant challenge in orthopedic practice, requiring a multifaceted approach tailored to the severity of the condition and the individual patient's response to treatment. Arthrofibrosis is a progressive condition characterized by excessive fibroproliferation, intra-articular adhesions, and capsular contracture, leading to pain, stiffness, and functional impairment.[32] The primary goal of management is to restore knee range of motion (ROM), alleviate symptoms, and prevent further fibrosis while minimizing the risk of recurrence. Given the heterogeneous nature of arthrofibrosis, treatment strategies range from conservative rehabilitation-based approaches to invasive surgical interventions, with emerging therapies focusing on the modulation of inflammatory and fibrotic pathways to improve long-term outcomes.[10]

The cornerstone of arthrofibrosis management is early detection and aggressive rehabilitation to prevent the progression of fibrosis. Conservative treatment remains the first-line approach, particularly in cases of mild to moderate arthrofibrosis, where early intervention can yield significant improvements in ROM and functional recovery. A structured physiotherapy regimen emphasizing controlled ROM exercises, stretching, and strengthening is essential to counteract the effects of fibrosis and restore joint mechanics. Evidence suggests that early postoperative mobilization, initiated within the first few days following arthroscopic surgery, significantly reduces the risk of developing arthrofibrosis by preventing intra-articular adhesions and promoting synovial fluid circulation. Physical therapy modalities such as passive stretching, continuous passive motion (CPM) devices, and aquatic therapy have been utilized to enhance ROM and minimize joint stiffness. CPM therapy has been shown to reduce postoperative stiffness by promoting mechanical elongation of collagen fibers and inhibiting fibroblast prolifer-

ation. Studies indicate that patients who undergo early CPM therapy demonstrate improved knee extension and decreased rates of arthrofibrosis compared to those who undergo delayed mobilization.[33] Additionally, eccentric quadriceps strengthening and neuromuscular re-education programs play a crucial role in restoring knee function and preventing muscle atrophy, which is commonly observed in patients with prolonged immobilization due to arthrofibrosis.

Pharmacologic interventions, including nonsteroidal anti-inflammatory drugs (NSAIDs) and corticosteroids, have been employed as adjunct therapies to mitigate inflammation and reduce fibrotic tissue formation. NSAIDs, such as celecoxib, have demonstrated efficacy in controlling postoperative inflammation and minimizing fibroblast activation, thus reducing the progression of arthrofibrosis. Intra-articular corticosteroid injections, particularly triamcinolone, have been used to modulate the inflammatory response in early-stage arthrofibrosis, with some studies reporting transient improvements in ROM and pain relief. However, long-term use of corticosteroids poses the risk of chondrotoxicity and should be used judiciously in select patients.[11]

When conservative measures fail to yield satisfactory improvements in ROM, more invasive interventions may be warranted. One of the earliest procedural interventions for arthrofibrosis is manipulation under anesthesia (MUA), in which the knee is forcibly flexed and extended to break intra-articular adhesions and restore mobility.[33] MUA is most effective when performed within the first 12 weeks postoperatively, as early-stage adhesions are more pliable and responsive to mechanical stretching.[34] However, aggressive manipulation carries the risk of iatrogenic injury, including ligamentous strain, chondral damage, and even femoral fractures in osteoporotic patients.

For patients who fail to respond to MUA or present with established fibrotic changes, arthroscopic lysis of adhesions is a preferred minimally invasive alternative. Arthroscopic debridement allows direct visualization and excision of fibrotic tissue, cyclops lesions, and infrapatellar contractures contributing to motion restriction.[22] Studies have shown that early arthroscopic intervention, particularly within six months post-surgery, leads to superior outcomes compared to delayed procedures, as long-standing fibrosis is more resistant to mechanical release.[10] Postoperative rehabilitation following arthroscopic debridement is critical to sustaining gains in ROM, with intensive physiotherapy and bracing protocols recommended to prevent recurrent fibrosis.

In severe and refractory cases of arthrofibrosis, open surgical intervention may be necessary to restore functional mobility. Open capsular release involves extensive excision of fibrotic tissue, including anterior and posterior capsular contractures, to re-establish knee extension and flexion.[22] This procedure is often reserved for patients with chronic arthrofibrosis unresponsive to previous interventions, where severe joint contracture significantly impairs daily activities and quality of life. Clinical outcomes following open capsular release are variable, with reports indicating that while many patients achieve functional improvements, a subset remains at risk for recurrent fibrosis, particularly in the presence of ongoing inflammation or genetic predisposition to excessive scar formation.[13]

Total knee arthroplasty (TKA) is considered a last resort for patients with end-stage arthrofibrosis, particularly in cases where joint degeneration and chondral damage are extensive. While TKA can alleviate pain and restore some degree of function, postoperative stiffness remains a concern, necessitating strict adherence to rehabilitation protocols to optimize outcomes.[33] Recent advancements in surgical techniques, including patient-specific implants and robotic-assisted TKA, have shown promise in improving precision and reducing the risk of postoperative fibrosis, although long-term studies are needed to validate these approaches.[21]

With growing insights into the molecular mechanisms underlying arthrofibrosis, emerging therapies are being explored to target the fibrotic cascade at a cellular level. Antifibrotic agents, such as losartan and pirfenidone, have demonstrated potential in modulating TGF-β signaling and reducing fibroblast proliferation in preclinical studies.[35] Additionally, biologic therapies, including platelet-rich plasma (PRP) and mesenchymal stem cell (MSC) in-

jections, have been investigated for their regenerative properties in mitigating fibrosis and promoting tissue remodeling. While early findings are promising, large-scale clinical trials are needed to establish the efficacy and safety of these novel interventions. Gene therapy is another exciting avenue, with research focusing on gene silencing techniques to suppress key fibrotic mediators and prevent excessive scar formation. CRISPR-based approaches targeting fibrotic genes such as connective tissue growth factor (CTGF) and periostin are being explored as potential therapeutic strategies to prevent arthrofibrosis at the molecular level.[36] Although still in experimental stages, these advancements offer hope for more effective and personalized management of arthrofibrosis in the future.

This systematic review provides a comprehensive analysis of arthrofibrosis following arthroscopic knee surgery, focusing on its risk factors, clinical presentation, and management strategies. By synthesizing current evidence, it offers valuable insights into the pathophysiology and treatment approaches, aiding clinicians in optimizing patient outcomes. The review follows PRISMA guidelines, ensuring methodological rigor, transparency, and reproducibility. Additionally, by including recent epidemiological data and emerging therapeutic approaches, this study highlights key advancements and areas for future research. Despite its strengths, this review has several limitations. The variability in definitions, diagnostic criteria, and outcome measures across studies introduces heterogeneity, making direct comparisons challenging. Some included studies may have selection biases, and the quality of evidence may be limited due to small sample sizes or retrospective designs. Additionally, the lack of high-quality randomized controlled trials on novel antifibrotic treatments limits definitive conclusions on emerging therapies. Future research should focus on standardized methodologies and long-term outcomes to strengthen the evidence base for arthrofibrosis management.

Conclusion

Arthrofibrosis after arthroscopic knee surgery remains a significant challenge, leading to pain, stiffness, and functional limitations. Despite advancements in surgical techniques and rehabilitation, it continues to affect patient outcomes, emphasizing the need for early diagnosis and effective management. A multimodal treatment approach is essential, beginning with conservative strategies such as early mobilization and physiotherapy. When non-surgical methods fail, interventions like manipulation under anesthesia or arthroscopic adhesiolysis may be required. In severe cases, open surgical release or total knee arthroplasty may be necessary, though the risk of recurrence remains a concern. Future research should focus on refining risk assessment, optimizing rehabilitation protocols, and exploring novel antifibrotic therapies. Standardizing diagnostic criteria and treatment guidelines will be crucial in improving outcomes. By integrating early intervention and personalized treatment strategies, clinicians can better prevent and manage arthrofibrosis, ultimately enhancing patient recovery and long-term knee function.

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Conflict of Interest

The authors declared no conflicts of interest.

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