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REVIEW

REHABILITATION APPROACHES AFTER MENISCAL ALLOGRAFT TRANSPLANTATION: A SYSTEMATIC REVIEW

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LEVEL OF EVIDENCE: 2a

ABSTRACT

Purpose: This study aimed to (i) evaluate long-term outcomes after meniscal allograft transplantation (MAT), and (ii) review current rehabilitation protocols, including immobilization, weight-bearing, range of motion (ROM) progression, and return-to-sport timing.

Methods: A systematic search of databases was conducted for articles published between January 2019 and April 2025 using the terms "meniscus transplantation OR meniscus allograft transplant" AND "rehabilitation OR physiotherapy OR physical therapy."

Results: Post-operative rehabilitation following MAT varies significantly. ROM is typically restricted to 0-90° during the first 4-6 weeks, with full range achieved by 8-12 weeks. Partial weight-bearing begins within the first month, progressing to full weight-bearing by weeks 6-8. Strengthening and proprioceptive training usually start between weeks 6 and 12. Daily activities typically resume in 3-4 months, while return to sport occurs around 9-12 months. However, only about half of the patients regain their previous performance levels. Outcomes are influenced by symptoms, psychological readiness, and clinical guidance. Although improvements are seen in IKDC (International Knee Documentation Committee), Lysholm, KOOS (Knee Injury and Osteoarthritis Outcome Score), Tegner, and VAS (Visual Analogue Score) scores, the absence of standardized rehabilitation protocols underscores the need for personalized approaches based on surgical technique and patient-specific factors.

Conclusions: MAT is a promising joint-preserving option for active individuals with meniscal deficiency. A phased rehabilitation strategy—focusing on protection, gradual loading, and functional recovery—is essential. Future research should prioritize standardized, adaptable, and evidence-based rehabilitation protocols.

KEYWORDS

Meniscus transplant, meniscus transplantation, meniscal allograft transplantation, physical therapy, physiotherapy, rehabilitation

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INTRODUCTION

The menisci are essential knee structures with wedge-shaped cross sections that play a crucial role in deepening the tibial plateau. They contribute to shock absorption, joint stabilization, load transmission, as well as facilitating lubrication and proprioception[1]. The meniscus, with its wedge-shaped structure, enhances the distribution of axial loads across the joint while reducing peak contact pressures on the articular cartilage[2]. This shape improves joint congruency by increasing the contact area between the flat tibial plateau and the curved femoral condyle. The menisci of the knee are fibrocartilaginous tissue which appear to be a mixture of fibroblasts and chondrocytes[3]. Meniscal tears have varying healing potential depending on the vascular zone involved. Tears in the red-red and,to some extent, the red-white zones are considered to have a favorable healing capacity, making repair a common treatment option[4]. Conversely, tears in the white-white zone were traditionally believed to have limited healing potential, leading to partial meniscectomy being the preferred approach for such cases[2,5,6].

Meniscal tears and the resulting partial meniscectomy have been found to considerably elevate articular cartilage contact pressures in the tibiofemoral joint, contributing to degenerative changes[7,8]. Multiple studies have highlighted the unfavorable clinical outcomes associated with both partial and total meniscectomy. To reduce the risk of knee arthritis following meniscal removal, attention has shifted toward meniscal transplantation as a means of restoring normal knee biomechanics and kinematics[9,10].

Given the significant changes caused by meniscectomy and the increased risk of osteoarthritis, the crucial role of the meniscus became evident, prompting the exploration of alternative surgical techniques[8,11,12]. Meniscal allograft transplantation, now recognized as a viable option for eligible young patients, was first performed in 1984 by Milachowski and colleagues in Munich, Germany. Although research on the procedure expanded globally, it only gained widespread adoption in the 1990s with the increased availability of tissue banks[13].

Management of degenerative, non-obstructive meniscal tears remains debated. Recent level I evidence shows arthroscopic partial meniscectomy provides no added benefit over structured physical therapy in middle-aged adults for PROMs, pain, or osteoarthritis progression[14]. These findings emphasize the critical role of conservative, rehabilitation-driven protocols in optimizing clinical outcomes, underlining the importance of synthesizing evidence-based rehabilitation strategies for meniscal injuries.

Biomechanically, meniscal allograft transplantation (MAT) is recognized for improving knee load distribution. Although it does not completely restore native biomechanics, MAT significantly increases tibiofemoral contact area and lowers contact pressures compared to a post-meniscectomy knee. Bone bridge techniques offer the closest match to native knee mechanics,emphasizing the importance of graft fixation choices in surgical planning and rehabilitation[15].

Several factors must be taken into account when assessing a candidate for meniscal allograft transplantation as a joint preservation strategy. MAT is a technically complex procedure, making surgeon expertise essential for success. Additionally, not all patients with meniscal deficiency are suitable candidates, and properly identifying those who are is crucial for achieving favorable outcomes. The general criteria for candidacy include[5,16-19]:

- Patients under 50 years old whose primary complaint is activity-limiting pain;
- BMI (Body Mass Index) below 35 kg/m^2;
- History of meniscectomy or non-viable meniscus with pain localized to the affected compartment;
- Normal or correctable coronal and sagittal alignment;
- Normal or correctable ligamentous stability;
- Normal or correctable articular cartilage condition;
- Commitment to following the rehabilitation protocol;
- Realistic expectations regarding post-surgical activity levels;

There are no standardized protocols for initiating range of motion exercises or advancing WB (weight-bearing) during the rehabilitation process following MAT[17]. Furthermore, no universally accepted guidelines or criteria exist for determining a safe return to sports after the procedure.

While previous meta-analyses on MAT have primarily focused on surgical outcomes and graft survival, limited attention has been given to standardized rehabilitation strategies and their quantitative timelines. To address this gap, the present study systematically reviews the literature on post-surgical rehabilitation protocols for MAT, examining key aspects such as knee joint immobilization, range-of-motion progression, strengthening exercise initiation, weight-bearing restrictions, and return-to-sport timelines to provide practical insights for clinicians and researchers.

MATERIALS AND METHODS

Protocol and registration

The present study is a systematic review and meets the standards of the essential items of PRISMA[20].

The protocol details were registered on PROSPERO (Registration number: CRD420251046623)

The Coleman scores of the articles obtained from the research were calculated, and considering the minimum threshold of 70 points, a total of 15 articles were identified.

Eligibility criteria

To develop the targeted question for this study, the PICOS acronym was utilised. The structured PICOS format was detailed as follows:

- *P (Population):* Patients with meniscal allograft transplantation;
- *I (Intervention):* Physiotherapy/exercise therapy;
- *C (Comparison):* Controlled, usual care;
- *O (Outcomes):*Range of motion (ROM), weight bearing,

return to daily activities, return to sports;

- *S (Study design):* Randomized controlled trials.

Information and search strategy

The study covering literature research on clinical outcomes and rehabilitation protocols of meniscus transplantation published in the last 5 years was conducted through English in PubMed, Scopus, Cochrane, Web of Science (WOS) , and Elsevier. Additionally, a search of the gray literature (Google Scholar) and a manual search from the reference list of eligible articles was performed.

The keywords used for this search included “meniscus transplant”, “meniscus transplantation”, “meniscus allograft transplant”, “physical therapy”, “physiotherapy” and “rehabilitation” alone and with their various combinations *(Fig. 1)*.

Data extraction

Two reviewers conducted independent screening of titles and abstracts based on predefined inclusion and exclusion criteria, followed by a comprehensive examination of relevant literature in full text.

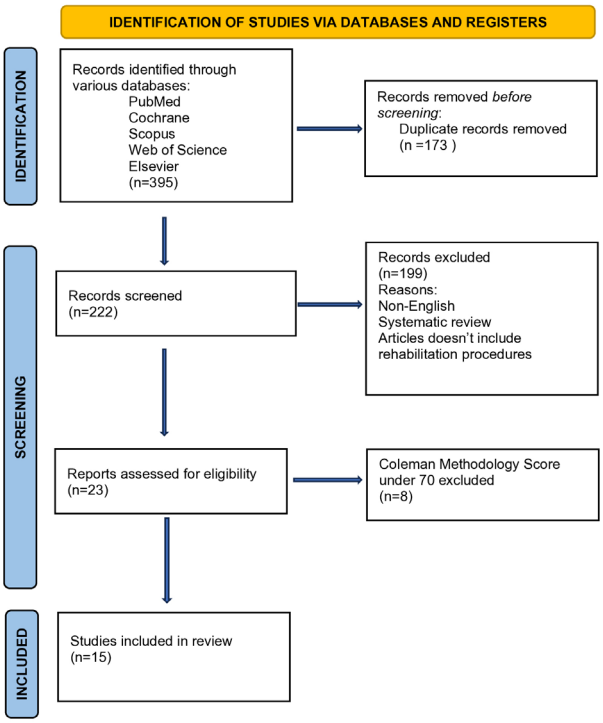


Figure 1. *Flow diagram of the study selection process.*

Methodological quality assessment

Qualified studies were evaluated using the Coleman Methodology Score (CMS), and data collection was independently implemented by two reviewers. The CMS is a validated tool designed to evaluate the methodological rigor of clinical studies, particularly in the field of orthopedic and sports medicine research. It consists of 10 criteria that assess various aspects of study design, including sample size, follow-up duration, study type, outcome criteria, and statistical analysis. The total score ranges from 0 to 100, with higher scores indicating superior methodological quality. This scoring system allows for a standardized and objective evaluation of study reliability and helps in interpreting the overall strength of the evidence presented in the systematic review.

RESULTS

Study selection

A total of 395 articles were identified from the search engines in database. The title and abstract of each study were reviewed prior to selection. Based on the inclusion criteria and after removing duplicates, finally 15 studies were ultimately included in the systematic review. The articles that were excluded either due to duplication or because they did not meet the inclusion criteria. A summary of the search strategy and the reasons for excluding studies are illustrated in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) flow diagram *(Fig. 1)*.

Study characteristics

The 15 RCT studies examined the effect of rehabilitation on participation with one or more outcome measures in the patient with MAT, published between 2019 and 2025, 8 of which in 2022 and 2025. A total of 1406 participants were included. The methodologic qualities of the included studies are given in *Table 2*. According to CMS, studies with a methodological quality above 70 points were included.

Outcome Measures

Range of motion (ROM)

Most studies recommend limiting knee ROM for the first 4 to 6 weeks after meniscus allograft transplantation, following by gradual increases[21]. In some studies patients are limited to 0-90° knee motion for the first 6 weeks and full range of motion is allowed after 6 weeks[22]. While some studies suggests during week 1 and 2 to wear the brace with locked in extension and only removing for hygiene and exercises. After this phase, weeks 3 through 8, it is suggested to lock the brace at 0° to 90° during the day and may be removed at night for sleeping[23,24]. CPM (Continuous passive motion) machines are not widely recommended but may be used in selected cases although not considered mandatory[25]. After 6 weeks, patients can begin active ROM exercises, and full knee flexion is allowed[26]. The time to achieve full ROM typically varies between 8-12 weeks[26]. Most protocols[21-23,25-29] restrict knee motion to 0–90° during the first 4 to 6 weeks post-surgery to safeguard the graft during the initial healing period. Full ROM is typically achieved by 8 to 12 weeks. Some studies include CPM devices in early rehabilitation, although their effectiveness remains subject to debate[30].

Weight bearing

Standard protocols recommend partial weight-bearing

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Study	Sample (n patients)	Type of study	Use of scoring system	Range of motion	Weight bearing	Return to daily activities	Return to sport	Rehabilitation key points/conclusion
Rucinski et al.[21]	102	Retrospective cohort	Lysholm IKDC	0-90 first 4-6 weeks, full ROM by 12 weeks	Partial WB 4-6 weeks, full by 6-8	3-4 months	9-12 months	Accelerated rehab with early weight bearing and activity improved adherence and PROMs without raising failure risk.
Rucinski et al.[25]	83	Prospective cohort	IKDC Tegner	Gradual increase over 6 weeks	Partial WB 4 weeks	3 months	12 months	Strict protocol adherence improves outcomes; early safe mobilization reduces stiffness without compromising grafts.
Rucinski et al.[30]	118	Prospective study	KOOS	Early CPM usage, full ROM by 10-12 weeks	Progressive WB	3-4 months	9-12 months	Early CPM and progressive WB aid recovery; patient education and timeline adherence are key.
van der Wal et al.[32]	312	Multicentre retrospective	IKDC Lysholm	Standard ROM timeline	WB gradual progression	3-4 months	Varies by case	Rehab should account for individual differences; delayed RTS and ROM can still yield good results.
Cvetanovich et al.[23]	64	Prospective cohort	Tegner VAS	0-90 early, full ROM by 10-12 weeks	WB 25%-100% by week 6	3 months	9-12 months	Gradual ROM and WB are essential; variability highlights the need for personalized protocols.
Liu et al.[33]	97	Retrospective cohort	Tegner Lysholm	Standard protocol	WB gradual progression by standard protocol	3-4 months	Varies by case	Standard protocol gave consistent results; ROM and WB progressed with graft protection in mind.
Vivekanantha et al.[27]	68	Retrospective cohort	IKDC KOOS	0-90 initially	Partial WB first 4 weeks	3 months	9-12 months	Limiting early ROM and gradual WB protect the graft; PROMs improved notably post-op.
Aavikko et al.[26]	77	Prospective study	KOOS	Early ROM allowed	Gradual WB	3 months	Not before 9 months	Early ROM with controlled WB can be effective; focus is on milestones, not strict timelines.
Agarwalla et al.[28]	89	Prospective study	Not detailed	Gradual over 6 weeks	Gradual WB	3-5 months	12 months	Gradual ROM and WB advised; no set exercises, but flexible timelines emphasized.
Huddleston et al.[22]	61	Retrospective cohort study	IKDC KOOS Tegner VAS	0-90 for first 6 weeks;full ROM after 6 weeks	Partial WB with heel contact for 6 weeks; full WB after	Significant improvement in 6-8 months	Allowed after 9 months	Activity resumed at 6–8 months if symptoms improved; protocol began with heel-touch WB.
Liu et al.[31]	98	Retrospective cohort study	IKDC KOOS Tegner VAS	Standard protocol	Heel contact for 6 weeks then full WB	Most patients achieved clinically significant outcomes by 1 year	9-12 months	Significant gains often seen by 1 year with standard protocol and progressive rehab.
Wagner et al.[24]	22	Retrospective comparative cohort	Lysholm IKDC KOOS	0-90 for first week 2-8.	Heel touch WB first 2 week. Full WB progressed at week 6.	3 months	6 months	Early WB (by week 6) and activity by 6 months aid recovery; close monitoring is crucial.
Searle et al.[29]	60	Retrospective cohort study	IKDC KOOS Tegner Lysholm	0-90 for first 6 weeks	Gradual WB	Not detailed	12 months	Rehab protocol was gradual but not detailed; standard ROM and WB practices seem sufficient in most cases.
Arnold et al.[35]	144	Randomised controlled trial	KOOS4 EQ- 5D- 5L SWEMWBS Tegner IKDC	Gradual increase over 6 weeks	Standard protocol	3 months	6-12 months	Rehabilitation pathways (PKT vs MAT) under comparison; optimized rehab is under investigation for effectiveness.
Stone et al.[34]	108	Therapeutic case series, retrospective.	IKDC isolated pain scale question scoring	Limited ROM (0-90) first 4-6 weeks	Full WB starts at week 4, with moderate protection maintained through week 12.	3 months	12 months	Gradual loading from week 4 supports long-term pain and function gains, favouring MAT in older adults.

Table 1. *Detailed analysis of the included studies based on the following criteria: sample, type of study, use of scoring system, range of motion, weight bearing, return to daily activities, return to sport and rehabilitation key points/ conclusion.*

Abbreviations: IKDC, International knee documentation committee; ROM, range of motion; WB, weight bearing; PROMs, patient-reported outcomes; KOOS, Knee Injury and Osteoarthritis Outcome Score; CPM, continuous passive motion; RTS, return to sport; VAS, Visual Analogue Scale; EQ-5D-5L, EuroQol-5 Dimensions-5 Levels; SWEMWBS, Warwick-Edinburgh Mental Wellbeing Scale; PKT, personalised knee therapy; MAT: meniscal allograft transplant.

for the first 4 to 6 weeks, with progression to full weight-bearing by 6 to 12 weeks. Some studies suggest accelerated weight-bearing, which has shown improved adherence and better patient-reported outcomes compared to standard protocols[21,23]. Partial weight-bearing with heel contact is allowed in first 6 weeks and after 6 weeks full weight-bearing is permitted according to some protocols[22,31]. Full weight-bearing is usually permitted from week 6 onwards. In some accelerated rehabilitation protocols, patients may progress to partial weight-bearing as early as weeks 3-4[26]. In cases of bone-fixed allografts, the weight-bearing process is generally more gradual[33]. Some studies recommend full weight-bearing introduced at 4 weeks and continued progressively in a moderate protective phase until the 12th week[9]. While some restricted patients to nonweight bearing or heel-touch weight-bearing status for the first 6 weeks postoperatively and are allowed to progress to full weight bearing after that time point[34].

Return to daily activities

The return to daily activities is generally completed within 3-4 months. Patients with desk job or light physical work can typically return within 1-2 months, while those with moderate-to-heavy physical jobs may need 3-5 months. 97.8% of patients were able to return to work, but 6.4% couldn't resume their previous work intensity. Those with physically demanding jobs face more challenges in returning to full capacity[28]. Early adherence to rehabilitation protocols is linked to better long-term functional outcomes as well as psychological counseling and patient education programs have been shown to improve adherence and decrease failure rates[30]. Significant improvements in IKDC and KOOS scores are observed within 6 months-1 year which indicated most patients regain functional levels necessary for daily activities[22,31]. Patients generally resume daily activities within 3 to 4 months[21,30,32,33]. Individuals with sedentary or light-duty jobs may return to work in 1 to 2 months, while those in physically demanding roles might require up to 5 months.

Return to sports

Return to athletic activities is generally not recommended before 9 months postoperatively[21]. Return-to-play criteria are often time based, with 6 months being the most common recommendation, though some studies caution against high-impact sports indefinitely.Reported on guidelines return to sport is generally allowed at 9 months postoperatively. Studies indicates that most patients can return within this period,but those with higher BMI and

Study	1	2	3	4	5	6	7	8	9	10
Rucinski et al.[21]	5	5	10	10	5	5	10	10	10	5
Rucinski et al.[25]	10	5	10	10	10	10	10	10	10	5
Rucinski et al.[30]	10	5	10	10	10	10	10	15	10	5
van der Wal et al.[32]	10	5	10	10	5	5	10	10	10	5
Cvetanovich et al.[23]	10	5	10	10	5	5	10	10	10	5
Liu et al.[33]	5	5	10	10	5	5	10	10	10	5
Vivekanantha et al.[27]	10	5	0	10	5	10	10	10	10	5
Aavikko et al.[26]	5	5	10	10	5	5	10	10	10	5
Agarwalla et al.[28]	5	5	10	10	5	5	10	5	10	5
Huddleston et al.[22]	5	5	10	10	10	5	10	15	10	5
Liu et al.[31]	5	5	10	10	10	10	10	15	5	5
Wagner et al.[24]	5	5	10	10	10	10	10	10	10	5
Searle et al.[29]	5	5	10	10	10	5	10	10	5	5
Arnold et al.[35]	5	5	10	10	10	5	10	15	10	5
Stone et al.[34]	10	5	10	10	5	5	10	10	10	5

Table 2. *Coleman methodology score distribution across included studies.*

Coleman Methodology Score: 1, Study size (10); 2, Mean follow-up duration(5); 3, Surgical approach description(10); 4, Rehabilitation details(10); 5, Number of procedures(10); 6, Type of study (RCT,cohort,etc.)(15); 7, Outcome criteria clearly defined(10); 8, Use of scoring system(15); 9, Timing of assessment(10); 10, Description of complications(5).

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workers' compensation claims may take longer[22,31]. The return-to-sport period generally ranges between 9-12 months[23]. Studies indicate 75-87.5% of patients can return to at least one sport, but only 48.4% regain their pre-injury performance level[23,33]. Returning to sports is usually permitted between 9 and 12 months post-operatively[21,23,27,30,31]. Although 75-87% of patients resume some level of sport, only about 48% return to their pre-injury performance. Common reasons for discontinuing high-impact sports include persistent pain or swelling, fear of reinjury, and clinical advice. High-impact contact sports should generally be avoided and the most common reasons for discontinuing sports after MAT are listed as:

- Pain and swelling in the joint (51.4%)
- Preventing further damage (73.6%)
- Fear of re-injury (48.6%)
- Surgeon's recommendation (33.3%)

According to some studies patients were specifically advised against returning to any impact type exercise/sport[29].

Rehabilitation protocols and exercises after meniscal allograft transplantation

Table 1 provides a detailed analysis of the included studies based on the following criteria: Sample, type of study, use of scoring system, range of motion, weight bearing, return to daily activities, return to sport and rehabilitation key points/conclusion

Postoperative rehabilitation after MAT is commonly structured into four progressive phases, designed to protect the graft, restore mobility, enhance neuromuscular control, and enable safe return to activity. While protocols vary among studies, milestone-based progression is consistently emphasized across the literature[21].

Early phase (0-6 weeks) typically restricts ROM to 0-90°, with partial or toe-touch weight bearing and brace immobilization to minimize graft stress[21]. Deep flexion, rotational loads, and impact activities are contraindicated during this period. Mid-phase rehabilitation (6-12 weeks) involves gradual lifting of ROM restrictions and initiation of closed-chain exercises such as squats, step-ups, lunges, and leg presses. Stationary cycling is widely used for safe early mobilization and cardiovascular conditioning[21]. Progressive weight bearing is allowed under supervision, focusing on restoring quadriceps and hamstring strength without overloading the graft[30].

Strength and neuromuscular training (12-24 weeks) prioritizes neuromuscular retraining through proprioceptive exercises (e.g., balance boards, trampolines) and introduction of open-chain strengthening and light jogging where appropriate. Many studies recommend return to jogging after 20 weeks, provided pain and functional thresholds are met.

Return to sport and function (6-12 months) prepares patients for return to sport (RTS), incorporating plyometric drills, agility tasks, and cutting manoeuvres. RTS is generally allowed around 9-12 months postoperatively, contingent upon strength symmetry and functional testing[21,30].

Phase 1: early phase (weeks 0-6)

Goals:

- Protect the graft
- Minimize swelling and pain
- Maintain quadriceps activation

Exercises:

- Passive knee range of motion exercises (0-90°)
- Heel slides and seated knee flexion-extension to gradually restore range of motion
- Assisted stretching for the hamstring, quadriceps and gastrocnemius
- Straight leg raises in all four directions (flexion, extension, abduction, adduction)
- Quadriceps isometric contractions to prevent muscle atrophy
- Ankle pumps to promote circulation and prevent deep vein thrombosis
- Electrical muscle stimulation for muscle activation
- Patellar mobilization
- Partial weight-bearing with heel touch only

Phase 2: mid-phase rehabilitation (weeks 6-12)

Goals:

- Achieve full range of motion
- Improve neuromuscular control
- Gradually progress weight-bearing

Exercises:

- Active-assisted and active range of motion exercises progressing beyond 90°
- Light wall slides
- Resistance band exercises for hamstring and quadriceps
- Balance and stability exercises such as single-leg stands on stable and unstable surfaces, eyes open and closed
- Closed-chain quadriceps strengthening (wall sits, mini squats)
- Step-ups and step-downs (starting with small height)
- Stationary cycling with low resistance
- Progress to full weight-bearing

Phase 3: strength and neuromuscular training (months 3-6)

Goals:

- Regain full strength
- Improve dynamic stability and balance
- Increase endurance

Exercises:

- Leg press with low weight
- Core stabilization exercises like planks and side planks
- Hamstring curls and quadriceps strengthening with resistance bands
- Single-leg balance exercises (starting with stable surfaces and progressing to unstable ones)

- Lateral lunges and controlled squats
- Proprioception exercises (Bosu ball balance exercises)
- Plyometric progression (if the patient is indicated, box jumps,squat jumps and agility drills for neuromuscular control)
- Dynamic balance exercises such as reaching movements while balancing on one leg

Phase 4 : return to sport and function (months 6-9+)

Goals:

- Regain agility and sports-specific movements
- Full functional recovery

Exercises:

- Lateral steps with resistance bands
- Sport-specific drills such as ladder drills and directional changes
- Controlled running progression, starting on a treadmill before transitioning to outdoor running
- Plyometrics (box jumps)
- Resistance training for lower limb explosiveness
- Low-impact sports participation before attempting high-impact activities.

Multiple studies emphasize that patient adherence and structured progression are key to successful recovery. Strength-focused rehabilitation has been linked to improvements in KOOS, IKDC, and VAS scores, though muscle recovery varies with patient and surgical factors. Importantly, early ROM combined with controlled loading and regular monitoring can accelerate recovery without compromising graft integrity. Ultimately, a phased and flexible rehabilitation approach—balancing protection with functional progression—is vital for maximizing patient outcomes and long-term success after MAT.

As summarized in *Table 3*, the variability of rehabilitation protocols across the included studies is visually illustrated, highlighting differences in range-of-motion restrictions, weight-bearing progression, strengthening initiation, and return-to-sport timelines.

Long-term outcomes after meniscal allograft transplantation

Graft survival

Multiple studies report strong long-term graft survival rates. One of the most comprehensive studies found median graft survival of 13.5 years, with survival rates at 2, 5, 10, 15, and 20 years as 94%, 66%, 34%, 15%, and

Study	ROM	Weight bearing	Strengthening start	Return to sport timing
Rucinski et al.[21]	🟡	🟡	🟡	🟡
Rucinski et al.[25]	🟡	🟡	🟡	🔴
Rucinski et al.[30]	🟡	🟡	🟡	🟡
van der Wal et al.[32]	🟡	🟡	🟡	🟡
Cvetanovich et al.[23]	🟡	🟢	🟡	🟡
Liu et al.[33]	🟡	🟡	🟡	🟡
Vivekanantha et al.[27]	🟡	🟡	🟡	🟡
Aavikko et al.[26]	🟢	🟡	🟡	🟡
Agarwalla et al.[28]	🟡	🟡	🟡	🔴
Huddleston et al.[22]	🟡	🟡	🟡	🟡
Liu et al.[31]	🟡	🟡	🟡	🟡
Wagner et al.[24]	🟢	🟢	🟢	🟢
Searle et al.[29]	🟡	🟡	🟡	🔴
Arnold et al.[35]	🟡	🟡	🟡	🟡
Stone et al.[34]	🟡	🟢	🟡	🔴

Table 3. *🟢 Early; 🟡 Moderate; 🔴 Late.*

ROM: *0–90° within the first 2-4 weeks 🟢; 0–90° within the first 6 weeks 🟡; Restricted ROM beyond 6 weeks 🔴*

Weight bearing: *Full WB ≤ 6 weeks 🟢; Full WB between 6-8 weeks 🟡; Full WB > 8 weeks 🔴*

Strengthening start: *≤ 6 weeks 🟢; 6–8 weeks 🟡; 8 weeks 🔴*

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6%, respectively[34]. Another large cohort study from the Netherlands reported a mean survival of 16.1 years, with older age being a risk factor for failure[32].

Conversion to arthroplasty

Across multiple cohorts, mean time to arthroplasty ranged from 8 to 10.6 years, with some patients delaying joint replacement up to 20.5 years post-MAT[34]. This delay is clinically meaningful in patients aged 50-70, as avoiding early arthroplasty reduces revision risk later.

Patient-reported outcomes (PROMs)

PROMs like IKDC, KOOS, and VAS showed sustained improvement across 5-15 years. In Stone et al.'s study, IKDC scores increased from 48.2 to 78.5, with pain scores dropping from 5.3 to 2.2, and over 50% of patients achieving MCID (Minimal clinically important differences) for pain relief up to 10 years postoperatively[34].

Factors influencing outcomes

- *Age:* Older patients (>50 years) tend to have higher failure rates, while those under 35 may report lower PROMs despite higher graft survival[32].
- *Adherence:* Patients compliant with rehab protocols were 7.5 times more likely to experience success at 1-3 years and 6.3 times less likely to need revision or arthroplasty[25].
- *Concomitant procedures:* The impact of additional procedures (e.g., paste graft, osteotomy, anterior cruciate ligament reconstruction ACLR) on long-term survival was inconsistent. Some associations suggest lower survival with osteotomy, but findings were not statistically significant across all studies[34].

Satisfaction and quality of life

High levels of satisfaction (91%) and willingness to repeat the procedure were reported even in older populations or those with moderate osteoarthritis (OA). Improvements in KOOS and Lysholm scores remained clinically significant up to 2 years and beyond[26].

Scoring systems and outcomes

Most studies employed validated scoring systems such as IKDC, Lysholm, KOOS, Tegner, and VAS to evaluate patient outcomes[32]. Consistent improvements in these scores were observed across the literature, suggesting positive clinical results when MAT is combined with well-structured rehabilitation protocols.

DISCUSSION

In this systematic review, I found that rehabilitation protocols following meniscal allograft transplantation (MAT) vary significantly across the literature. While most studies recommend restricting knee range of motion to 0-90° for the first 4-6 weeks and achieving full ROM by weeks 8-12, weight-bearing progression was found to be dependent on the graft fixation technique. Strengthening and proprioceptive exercises are typically initiated after week 6, and return to daily activities generally occurs within 3-4 months. Return to sport is usually allowed around 9-12 months postoperatively; however, only about half of the patients regain their pre-injury performance levels. Factors such as symptom severity, psychological readiness, and adherence to the protocol were found to influence outcomes. Overall, my findings indicate that a phased, individualized, and functionally driven rehabilitation strategy plays a critical role in optimizing recovery and long-term success after MAT.

Our findings are consistent with recent high-level evidence showing no significant differences between APM and structured physical therapy in terms of functional outcomes, pain relief, and osteoarthritis progression[14]. This highlights the importance of rehabilitation-driven care, particularly in non-obstructive, degenerative meniscal tears, and further supports the development of standardized rehabilitation protocols focusing on neuromuscular control, load management, and gradual return to function.

Meniscal allograft transplantation has become a widely accepted surgical intervention for alleviating pain and improving knee function in patients with symptomatic meniscal deficiency, particularly those with a prior history of meniscectomy[29]. Although there have been notable advancements in surgical techniques and graft preservation, the post-operative rehabilitation process remains a crucial factor in determining the success of MAT[22,23]. A review of the current literature reveals substantial variability in rehabilitation strategies, especially concerning range of motion, weight-bearing progression, muscle strengthening protocols, and the timing for returning to activity[32,34,35].

In the early stages of recovery, post-operative care is primarily aimed at protecting the graft and minimizing mechanical stress on the healing tissue. Most studies restrict passive ROM to 0-90 degrees during the first 4 to 6 weeks to support initial graft integration[22,23,33]. The use of continuous passive motion devices is occasionally recommended to aid in joint mobility, though their routine application remains debated[29]. By 8 to 12 weeks post-operation, full ROM is typically permitted, with active motion exercises introduced around the sixth week to encourage flexibility while avoiding excessive load on the graft[22,32]. Considering all these factors, the early weeks following meniscal transplantation represent a critical period in which the biological integration of the graft into the recipient tissue begins; during this phase, joint loading and motion should be restricted to help prevent complications.

Weight-bearing guidelines vary considerably, often influenced by the method of graft fixation. Generally, partial weight bearing with crutches is maintained for the first 4 to 6 weeks, followed by a gradual progression to full weight-bearing after the sixth week[22,23,28,33]. In certain cases—particularly in younger, more active patients

or those receiving soft-tissue fixation—accelerated protocols are employed. Conversely, patients with bone plug fixation usually follow a more conservative weight-bearing schedule to reduce the risk of graft failure or displacement[34]. These findings highlight the importance of tailoring weight-bearing protocols based on individual patient characteristics and surgical techniques. The variability observed—especially between soft-tissue and bone plug fixation methods—suggests that a "one-size-fits-all" approach may not be appropriate in post-MAT rehabilitation. While accelerated protocols can be beneficial in selected cases, particularly for younger and more active individuals, a more conservative strategy may be essential for those at higher risk of graft failure, such as patients with bone plug fixation. This reinforces the need for surgeon- and patient-specific rehabilitation planning that carefully balances graft protection with functional recovery.

In line with these clinical observations, from a biomechanical perspective, our review supports the notion that MAT enhances load distribution across the tibiofemoral joint. Consistent with the findings of Kelly et al., although MAT does not fully restore native biomechanics, bone bridge fixation techniques offer superior stability and more favorable pressure distribution compared to suture-only or bone plug techniques. These biomechanical insights further justify a gradual and load-protected rehabilitation progression to optimize graft healing and functional outcomes[15].

Strengthening exercises are typically introduced after the initial healing phase. Closed kinetic chain movements —such as mini-squats, wall slides, and resistance band exercises— are frequently started between weeks 6 and 12[27]. Proprioceptive and neuromuscular training become more prominent by the third month of rehabilitation, and advanced activities like plyometrics and sport-specific drills are introduced between 6 and 9 months, especially for patients intending to return to high-impact sports. Core strengthening and balance training are particularly emphasized due to their critical role in restoring neuromuscular control and preventing re-injury[22,23,34]. When considering patients undergoing combined ACL reconstruction and meniscal repair, rehabilitation timelines often raise concerns regarding delayed functional recovery. However, recent prospective analyses in elite athletes demonstrated no significant delay in strength recovery compared to isolated ACL reconstruction, despite more cautious early-phase protocols[36]. These findings suggest that while early-phase modifications are warranted to protect the repaired meniscus, long-term outcomes in terms of strength and performance recovery are not compromised The phased introduction of strengthening and neuromuscular training after MAT is crucial for safe functional recovery. Emphasizing closed-chain exercises early on, followed by proprioceptive and core stability work, supports joint protection while preparing patients—especially athletes—for a safe return to high-impact activity.

RTS timelines varied among the studies, with most patients being cleared for sports participation between 9 and 12 months after surgery. However, a full return to pre-injury performance levels was achieved by only 48–50% of individuals[23,29,33]. Commonly reported barriers included lingering symptoms such as pain or swelling, psychological concerns like fear of reinjury, and clinical recommendations to avoid high-impact activities. Patients involved in contact sports were less likely to resume play at their previous intensity[23,29]. These findings highlight that while most patients are medically cleared to return to sport within 9–12 months post-MAT, achieving pre-injury performance remains a challenge for many. Persistent symptoms, psychological barriers, and clinical caution—particularly regarding high-impact or contact sports—limit full return. This underscores the importance of integrating psychological support and realistic goal setting into rehabilitation programs.

Despite overall positive clinical outcomes, the lack of standardized rehabilitation protocols poses challenges for comparing results across studies. Rehabilitation outcomes are influenced by numerous variables, including graft type, surgical technique, additional procedures (e.g., osteotomies), and patient-specific characteristics[24,34]. As a result, many researchers advocate for rehabilitation strategies based on functional and clinical milestones rather than rigid timelines[32,35]. The variability in rehabilitation protocols makes it difficult to draw consistent comparisons between studies, emphasizing the need for flexible, milestone-driven strategies. Considering the impact of surgical methods, graft types, and individual patient factors, recovery plans should be guided by functional progress rather than predetermined schedules to achieve the best outcomes.

Outcome measures across the studies were diverse, though commonly used tools included the IKDC score, Lysholm score, Tegner activity scale, KOOS, and the VAS[22,24,29,32]. Most studies demonstrated statistically significant improvements in patient-reported outcomes following MAT, affirming the procedure's clinical effectiveness when supported by a structured and individualized rehabilitation plan[22,24,29]. The consistent improvements observed across various outcome measures reinforce the clinical value of MAT when paired with a well-structured and personalized rehabilitation program. Despite the heterogeneity in assessment tools, the positive trends in patient-reported outcomes highlight the procedure's effectiveness in restoring function and reducing symptoms.

CONCLUSION

Meniscal allograft transplantation serves as an effective joint-preserving intervention for young, active individuals experiencing post-meniscectomy syndrome or loss of meniscal function. Post-operative rehabilitation is a crucial component of MAT, significantly influencing graft preservation, functional restoration, and long-term clinical

success. Although there is no standardized rehabilitation protocol, most approaches follow a phased structure—initially limiting range of motion and allowing only partial weight bearing, then gradually incorporating muscle strengthening, proprioceptive exercises, and eventually sport-specific training in the later stages. Typically, patients regain the ability to perform daily activities within 3 to 4 months, while a return to athletic participation is often possible between 9 and 12 months, though not all reach their pre-injury performance levels.

These observations emphasize the need for tailored rehabilitation strategies that consider the patient's specific condition, surgical method, and type of graft fixation. Continued research is essential to establish consistent, evidence-based rehabilitation guidelines that can enhance recovery outcomes and reduce the risk of complications following MAT.

REFERENCES

1. Vasta S, Zampogna B, Hartog TD, El Bitar Y, Uribe-Echevarria B, Amendola A. Outcomes, Complications, and Reoperations After Meniscal Allograft Transplantation. Orthop J Sports Med. 2022;10(3):23259671221075310. doi: 10.1177/23259671221075310.
2. Chen S, Fu P, Wu H, Pei M. Meniscus, articular cartilage and nucleus pulposus: a comparative review of cartilage-like tissues in anatomy, development and function. Cell Tissue Res. 2017;370(1):53-70. doi: 10.1007/s00441-017-2613-0.
3. Simonetta R, Russo A, Palco M, Costa GG, Mariani PP. Meniscus tears treatment: The good, the bad and the ugly-patterns classification and practical guide. World J Orthop. 2023;14(4):171-185. doi: 10.5312/wjo.v14.i4.171.
4. Makris EA, Hadidi P, Athanasiou KA. The knee meniscus: structure-function, pathophysiology, current repair techniques, and prospects for regeneration. Biomaterials. 2011;32(30):7411-31. doi: 10.1016/j.biomaterials.2011.06.037.
5. Jeong HW, Kim JS, Nam HS, Noh GS, Lee YS. Assessment of Anatomic Restoration and Clinical Outcomes Between Medial and Lateral Meniscal Allograft Transplantation. Orthop J Sports Med. 2022;10(9):23259671221113280. doi: 10.1177/23259671221113280.
6. Mameri ES, Dasari SP, Fortier LM, Verdejo FG, Gursoy S, Yanke AB, Chahla J. Review of Meniscus Anatomy and Biomechanics. Curr Rev Musculoskelet Med. 2022;15(5):323-335. doi: 10.1007/s12178-022-09768-1.
7. Fan BS, Ye J, Xu BB, Sun ZW, Zhang JY, Song ST, et al. Study on feasibility of the partial meniscal allograft transplantation. Clin Transl Med. 2022;12(1):e701. doi: 10.1002/ctm2.701.
8. Ganokroj P, Fossum BW, Hollenbeck J, Whalen RJ, Garcia AR, Foster MJ, et al. Biomechanical Analysis Evaluating Meniscal Extrusion After Knotless Suture Anchor Fixation for Segmental Medial Meniscal Allograft Transplantation. Orthop J Sports Med. 2023;11(8):23259671231182978. doi: 10.1177/23259671231182978.
9. Seiter MN, Haber DB, Ruzbarsky JJ, Arner JW, Peebles AM, Provencher MT. Segmental Meniscus Allograft Transplantation. Arthrosc Tech. 2021;10(3):e697-e703. doi: 10.1016/j.eats.2020.10.059.
10. Baker BM, Gee AO, Sheth NP, Huffman GR, Sennett BJ, Schaer TP, et al. Meniscus tissue engineering on the nanoscale: from basic principles to clinical application. J Knee Surg. 2009;22(1):45-59. doi: 10.1055/s-0030-1247727.
11. Young J, Tudor F, Mahmoud A, Myers P. Meniscal transplantation: procedures, outcomes, and rehabilitation. Orthop Res Rev. 2017;9:35-43. doi: 10.2147/ORR.S94378.
12. Atik I, Gul E, Atik S. Evaluation of the relationship between Knee Osteoarthritis and Meniscus Pathologies. Malawi Med J. 2024;36(1):48-52. doi: 10.4314/mmj.v36i1.8.
13. Milachowski KA, Weismeier K, Wirth CJ. Homologous meniscus transplantation. Experimental and clinical results. Int Orthop. 1989;13(1):1-11. doi: 10.1007/BF00266715.
14. Migliorini F, Oliva F, Eschweiler J, Cuozzo F, Hildebrand F, Maffulli N. No evidence in support of arthroscopic partial meniscectomy in adults with degenerative and nonobstructive meniscal symptoms: a level I evidence-based systematic review. Knee Surg Sports Traumatol Arthrosc. 2023;31(5):1733-1743. doi: 10.1007/s00167-022-07040-0.
15. Kelly S, Panwar K, Cutter B, Reyes N, Huish EG. Biomechanics of Meniscal Allograft Transplantation: A Meta-Analysis. Vol. 14, Muscles, Ligaments and Tendons Journal. 2024;14 (1):46-53 doi: 10.32098/mltj.01.2024.05.
16. Frank RM, Cole BJ. Meniscus transplantation. Curr Rev Musculoskelet Med. 2015;8(4):443-50. doi: 10.1007/s12178-015-9309-4.
17. Worhacz KM, Carter TR. Meniscal Allograft Transplantation: Does Surgical Technique Influence Clinical Outcomes? Curr Rev Musculoskelet Med. 2023;16(5):163-172. doi: 10.1007/s12178-023-09825-3.
18. Cotter EJ, Frank RM, Waterman BR, Wang KC, Redondo ML, Cole BJ. Meniscal Allograft Transplantation With Concomitant Osteochondral Allograft Transplantation. Arthrosc Tech. 2017;6(5):e1573-e1580. doi: 10.1016/j.eats.2017.06.051.
19. Figueroa F, Figueroa D, Calvo R, Vaisman A, Espregueira-Mendes J. Meniscus allograft transplantation: indications, techniques and outcomes. EFORT Open Rev. 2019;4(4):115-120. doi: 10.1302/2058-5241.4.180052.
20. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. J Clin Epidemiol. 2009;62(10):e1-34. doi: 10.1016/j.jclinepi.2009.06.006.
21. Rucinski K, Stannard JP, Crecelius C, Nuelle C, Cook JL. Accelerated versus Standard Rehabilitation after Meniscus Allograft Transplantation in the Knee. J Knee Surg. 2024;37(10):710-717. doi: 10.1055/a-2274-6914.
22. Huddleston HP, Polce EM, Gilat R, Mehta N, Alzein M, Dandu N, et al. Time to Achieving Clinically Significant Outcomes After Meniscal Allograft Transplantation. Cartilage. 2022;13(3):19476035221102568. doi: 10.1177/19476035221102568.
23. Cvetanovich GL, Christian DR, Garcia GH, Liu JN, Redondo ML, Yanke AB, et al. Return to Sport and Patient Satisfaction After Meniscal Allograft Transplantation. Arthroscopy. 2020;36(9):2456-2463. doi: 10.1016/j.arthro.2020.04.034.
24. Wagner KR, Horner NS, Gilat R, Kaiser JT, Meeker ZD, Swindell HW, et al. Revision and Primary Meniscal Allograft Transplantations Provide Clinical Benefit at Mid-Term Follow-Up: A Matched-Cohort Analysis of Patient-Reported Outcomes, Reoperations, and Failures. Arthroscopy. 2024;40(2):412-421.e1. doi: 10.1016/j.arthro.2023.06.047.
25. Rucinski K, Cook JL, Crecelius CR, Stucky R, Stannard JP. Effects of Compliance With Procedure-Specific Postoperative Rehabilitation Protocols on Initial Outcomes After Osteochondral and Meniscal Allograft Transplantation in the Knee. Orthop J Sports Med. 2019;7(11):2325967119884291. doi: 10.1177/2325967119884291.
26. Aavikko A, Bister V, Reito A, Lindahl J. Meniscal allograft transplantation improves patient-reported outcomes in both minimal and moderate knee osteoarthritis at 1 and 2 years postoperatively. Knee Surg Sports Traumatol Arthrosc. 2023;31(12):5765-5772. doi: 10.1007/s00167-023-07625-3.
27. Vivekanantha P, Diao D, Cohen D, Murphy B, de Sa D. Strength-Based Rehabilitation on Clinical Outcomes in Patients Postpartial Meniscectomy: A Systematic Review and Meta-analysis. Am J Phys Med Rehabil. 2023 Sep 1;102(9):764-772. doi: 10.1097/PHM.0000000000002198.
28. Agarwalla A, Liu JN, Christian DR, Garcia GH, Cvetanovich GL, Gowd AK, et al. Return to Work Following Arthroscopic Meniscal Allograft Transplantation. Cartilage. 2021;13(1_suppl):249S-255S. doi: 10.1177/1947603520938440.
29. Searle H, Asopa V, Coleman S, McDermott I. The results of meniscal allograft transplantation surgery: what is success? BMC Musculoskelet Disord. 2020;21(1):159. doi: 10.1186/s12891-020-3165-0.
30. Rucinski K, Stucky R, Crecelius CR, Stannard JP, Cook JL. Effects of Patient Assessment and Education by an Integrated Care Team on Postoperative Adherence and Failure Rates After Osteochondral Allograft and Meniscal Allograft Transplantation in the Knee. Orthop J Sports Med. 2023;11(5):23259671231160780. doi: 10.1177/23259671231160780.
31. Liu JN, Gowd AK, Redondo ML, Christian DR, Cabarcas BC, Yanke AB, Cole BJ. Establishing Clinically Significant Outcomes After Meniscal Allograft Transplantation. Orthop J Sports Med. 2019;7(1):2325967118818462. doi: 10.1177/2325967118818462.
32. van der Wal RJP, Nieuwenhuijse MJ, Spek RWA, Thomassen BJW, van Arkel ERA, Nelissen RGHH. Meniscal allograft transplantation in The Netherlands: long-term survival, patient-reported outcomes, and their association with preoperative complaints and interventions. Knee Surg Sports Traumatol Arthrosc. 2020;28(11):3551-3560. doi: 10.1007/s00167-020-06276-y.
33. Liu JN, Agarwalla A, Garcia GH, Christian DR, Gowd AK, Yanke AB,

et al. Return to Sport and Work After High Tibial Osteotomy With Concomitant Medial Meniscal Allograft Transplant. Arthroscopy. 2019;35(11):3090-3096. doi: 10.1016/j.arthro.2019.05.053.
34. Stone KR, Walgenbach AW, Slatter S, Turek TJ, Ferguson-Dryden C, Dicker M, et al. Meniscus Allograft Transplantation in Conjunction With Arthroscopic Biologic Knee Restoration Delays Arthroplasty in Patients Older Than 50 Years. Arthroscopy. 2025;41(4):1019-1026. doi: 10.1016/j.arthro.2024.06.008.
35. Arnold S, Spalding T, Parsons H, Beard D, Bradley H, Crisford P, et al. Meniscal Transplant surgery or Optimised Rehabilitation full randomised trial (MeTeOR2): a study protocol. BMJ Open. 2024;14(6):e085125. doi: 10.1136/bmjopen-2024-085125.
36. Albarello JCDS, Laett CT, de Palma AMS, Mandarino M, Silva SC da, Goes RA, et al. Associated ACL Reconstruction and Meniscal Repair do not Affect the Evolution of Isokinetic Parameters in Professional Athletes: A Prospective Study with a One-Year Follow-Up. Muscles Ligaments Tendons J. 2024;14(3):450–7. doi: 10.32098/mltj.03.2024.08.

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