Accelerated versus Standard Rehabilitation after Meniscus Allograft Transplantation in the Knee

Kylee Rucinski, MHA, PhD[1,2] James P. Stannard, MD[1,2] Cory Crecelius, MPT[1]
Clayton Nuelle, MD[1,2] James L. Cook, DVM, PhD, OTSC[1,2]

[1] Department of Orthopaedic Surgery, University of Missouri, Columbia, Missouri
[2] Thompson Laboratory for Regenerative Orthopaedics, University of Missouri, Columbia, Missouri

Address for correspondence James L. Cook, DVM, PhD, OTSC, Department of Orthopaedic Surgery, Missouri Orthopaedic Institute, University of Missouri, 1100 Virginia Ave, Columbia, MO 65212 (e-mail: cookjl@health.missouri.edu).

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Abstract

Meniscus allograft transplantation (MAT) is a proven treatment option for patients with symptomatic irreparable meniscus deficiency. When patients are adherent to prescribed postoperative restriction and rehabilitation protocols, outcomes after MAT are considered good to excellent. However, nonadherence to standard protocols is common and can be associated with undesirable outcomes and patient dissatisfaction. Based on demonstrated safety for early weight-bearing following MAT in conjunction with significant advances in graft preservation and surgical techniques, our joint preservation center implemented a shift in practice toward accelerated weight-bearing following MAT and designed this study to test the hypothesis that accelerated rehabilitation would be associated with superior adherence, patient-reported outcomes, and patient satisfaction, without diminishing patient safety, when compared with standard rehabilitation. Patients were included for analyses when they had undergone fresh or fresh-frozen MAT using a double bone plug technique for treatment of medial or lateral meniscus deficiency and had at least 1-year treatment outcomes recorded. The results of this study revealed that patients who were prescribed accelerated rehabilitation after MAT were significantly more adherent than patients who were prescribed standard rehabilitation and reported statistically significant and clinically meaningful improvements in knee pain and function for at least 1-year following MAT, whereas those in the standard cohort did not. While not statistically different, treatment failure rate was lower in the accelerated rehabilitation cohort when compared with the standard rehabilitation cohort (11 vs. 29%). Importantly, initial outcomes for revision MAT were associated with short-term success in all the patients who opted for this option in the study population. These data suggest that accelerated weight-bearing after MAT is safe, promotes patient adherence, and is associated with statistically significant and clinically meaningful improvements in patient-reported knee pain and function at early and mid-term follow-up.

Keywords
- meniscus allograft transplantation
- weight-bearing
- patient-reported outcomes

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Meniscus allograft transplantation (MAT) is a proven treatment option for patients with symptomatic irreparable meniscus deficiency.[1,2] MAT has been associated with midterm success rates between 75 and 90%, with longer term functional survival rates reported to be between 50 and 70%.[1–4] Treatment failures are most often attributable to allograft tears, shrinkage, extrusion, fixation failure, and progression of degenerative joint disease with 10 to 40% of cases requiring reoperation.[5–8] MAT is typically reserved for patients $\leq$ 55 years of age with limited or correctable articular cartilage pathology, normal or correctable lower extremity alignment, and normal or correctable knee ligament stability.[4,9–11] In addition, patients must be willing and able to commit to prolonged and restrictive postoperative management protocols.[9,12] When patients are adherent to prescribed protocols, return-to-work, return-to-sport, and patient satisfaction levels after MAT are considered good to excellent.[5,13–18] However, nonadherence is common and can be associated with undesirable outcomes and patient dissatisfaction.[12,19–21]

While no evidence for an optimal management protocol following MAT has been established, the majority of those outlined in the peer-reviewed literature advocate for limited weight-bearing and restricted knee range of motion (ROM) for 4 to 6 weeks, followed by a progressive return to full weight-bearing and full ROM by 6 to 12 weeks postoperatively.[9,11,13,22] Recommended timing for return to athletic activities varies widely, but is typically not prior to 9 months after MAT.[5,13,22] In light of demonstrated safety for early weight-bearing following MAT in conjunction with significant advances in graft preservation and surgical techniques, consideration for an accelerated rehabilitation protocol following MAT is appropriate.[7,23–25] As such, our joint preservation center implemented a shift in practice toward accelerated weight-bearing following MAT. The objective of this study was to compare outcomes for patients prescribed accelerated versus standard rehabilitation after MAT. The study was designed to test the hypothesis that accelerated rehabilitation would be associated with superior adherence, patient-reported outcomes, and patient satisfaction, without diminishing patient safety, when compared with standard rehabilitation.

Methods

Study Patients

With Institutional Review Board approval (IRB 2003053, IRB 2008288), electronic medical record (EMR) data were searched to identify all patients who had undergone fresh or fresh-frozen MAT using a double bone plug technique for treatment of medial or lateral meniscus deficiency at the authors' institution between January 1, 2015, and December 1, 2022. MAT surgeries were performed on patients with symptomatic meniscus deficiency who chose this treatment option over other nonsurgical or surgical options as indicated and were approved for coverage by their insurance provider. Patient demographics, prior surgeries, MAT surgery data, and rehabilitation protocol assignment were documented.

Patients were included for analyses when they had a primary meniscus transplant with or without concurrent procedures in the affected knee, and at least 1-year treatment outcomes recorded in the EMR. Exclusion criteria included revision MAT, or insufficient outcomes data available (►**Fig. 1**).

MAT Surgeries

Radiographically size-matched meniscus allografts were obtained from American Association of Tissue Banks (AATB)-accredited tissue banks and used in conformance of the tissue to the Food and Drug Administration classification of a Human Cell and Tissue Product under Section 361 of the Public Health Services Act. Fresh-frozen meniscus allografts were obtained from one of three AATB-accredited tissue banks and used prior to labeled expiration date. Fresh meniscus allografts preserved using the Missouri Osteochondral Preservation System (MOPS) were obtained from one AATB-accredited tissue bank and used within 56 days after recovery. All MAT procedures were performed by one of five fellowship-trained orthopaedic surgeons using a double bone plug technique with suspensory fixation of donor bone plugs in recipient sockets for root fixation as previously described.[7,26] If indicated, concomitant procedures including ligament reconstruction or chondroplasty were performed concurrently according to standard of care.

Rehabilitation Cohorts

Based on an evidence-based shift in practice toward use of fresh (viable) meniscus allografts with meniscotibial ligament reconstruction and documented safety for early weight-bearing following MAT, our joint preservation center instituted an accelerated rehabilitation protocol for patients undergoing primary MAT (►**Fig. 2**).[7,26–29] This shift in practice allowed for comparison of two patient cohorts, as follows:

- *Standard*: Patients were instructed to remain toe-touch weight-bearing through 4 weeks after surgery, moving to partial weight-bearing between 4 and 6 weeks after surgery, and released to weight-bearing as tolerated (WBAT) between 6 and 8 weeks. Treated knee ROM was limited to 90 degrees for the first 2 weeks and then 120 degrees until 4 weeks post-MAT. Limited stationary bike and closed chain strengthening exercises were initiated by the physical therapist between 8 and 12 weeks postoperatively. Straight line jogging was initiated followed by release to full plyometric, cutting, and jumping activities at 9 months or more post-MAT based on assessments of strength, balance, and knee joint health and the surgeon's discretion.
- *Accelerated*: Patients were instructed to remain toe-touch weight-bearing through 2 weeks after surgery and released to WBAT after the 2-week follow-up appointment. Treated knee ROM was limited to 90 degrees for 6 weeks. Limited stationary bike, leg press, and closed chain strengthening exercises were initiated between 10 and 12 weeks postoperatively. At 5 months after MAT, straight

CONSORT
TRANSPARENT REPORTING of TRIALS

CONSORT 2010 Flow Diagram

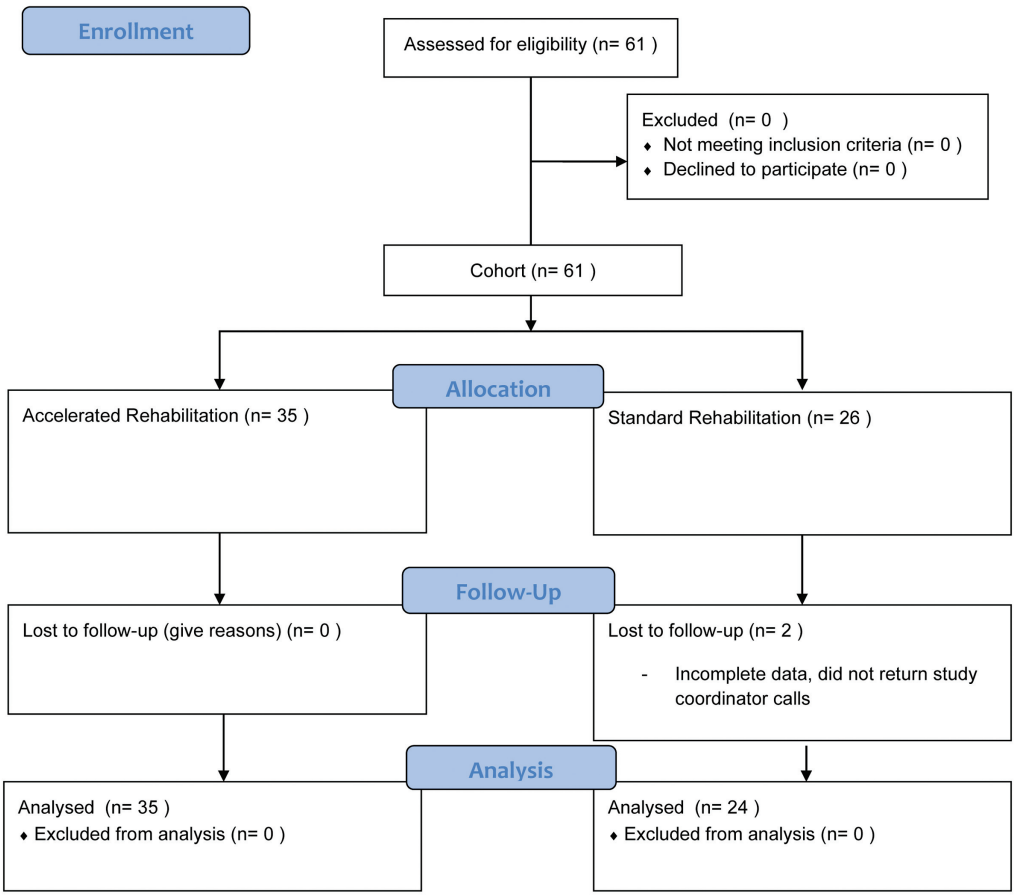

Fig. 1 CONSORT flow diagram for study subjects.

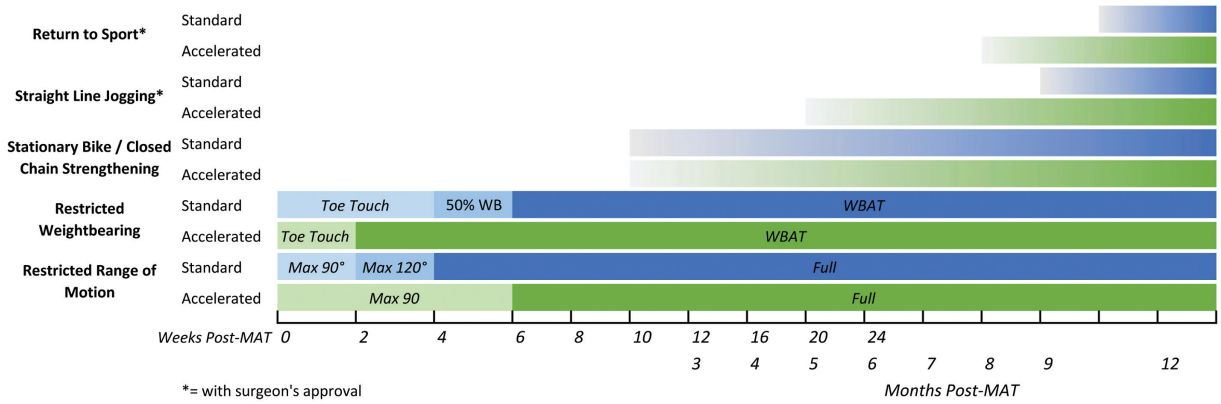

Fig. 2 Comparison of standard versus accelerated post-MAT rehabilitation protocols. MAT, meniscus allograft transplantation.

line jogging was initiated followed by release to full plyometric, cutting, and jumping activities at 8 months or more post-MAT based on assessments of strength, balance, and knee joint health and the surgeon's discretion.

If necessary, each protocol was adjusted based on concomitant surgeries and assessment of patient progress by the physician and physical therapist.

Patient adherence with the rehabilitation protocol was monitored and documented based on patient communication and outpatient physical therapy reports. Patients were categorized as nonadherent when definitive deviations from the prescribed protocol were documented to occur during the first year after surgery.[12,30] Follow-up appointments were scheduled for 2 weeks, 6 weeks, 3 months, 6 months, 1 year, and then annually with standardized radiographic imaging ordered for each appointment except for the 2-week follow-up appointment.

Outcome Measures

Patients were evaluated preoperatively and then at 6 months and yearly after MAT. Demographic and operative data including age, sex, body mass index (BMI), and tobacco use were collected from the EMR. Patient-reported outcome measures (PROMs), including Patient-Reported Outcomes Measurement Information System Physical Function,[31] International Knee Documentation Committee (IKDC) form,[32] Single Assessment Numeric Evaluation (SANE),[33] and visual analog scale for pain[34] were collected at each time point. All reported complications and reoperations were recorded in the EMR. For the purposes of the present study, treatment failure was defined as need for revision surgery or conversion to knee arthroplasty (total [TKA] or unicompartmental [UKA]) for any reason. Revision was defined as a second operation to revise the meniscal allograft specifically. The decision to pursue revision surgery or arthroplasty was based on the attending surgeon's discussion of joint pathology, treatment options, and related prognosis in conjunction with patient preference and informed consent. Patient satisfaction was measured using a single question from the Surgical Satisfaction Questionnaire-8, "How satisfied are you with the results for your surgery?" at final follow-up.[19,35] Final follow-up was defined as the longest time point post-MAT for which treatment success/failure as defined *a priori* was available for each included patient. Treatment was categorized as successful when patients returned to functional activities without need for revision or arthroplasty surgery. Initial success rate was calculated using the formula: 100% − (revision% + failure%).

Statistical Analysis

Cases were included for statistical analyses when treatment success/failure data were available for patients undergoing MAT for the first time (primary transplant) with at least 1-year follow-up. Descriptive statistics were calculated to report means, ranges, standard deviations, and percentages. Outcomes were compared based on patient sex, BMI, age, concomitant procedures, history of ligament reconstruction, and reported adherence to the treatment protocol. Chi-square or Fisher's exact tests were used to assess for significant differences in proportions. Odds ratios were calculated when significant differences were identified. Normality tests were performed, and unpaired *t*-tests were used to assess differences between cohorts. Paired *t*-tests were performed to calculate differences between pre- and postoperative PROMs. Statistical significance was set *a priori* at $p < 0.05$. Differences in PROMs were also assessed for minimum clinically important differences.[36–41]

Results

From a total of 61 potentially eligible patients, 59 patients (accelerated: $n = 35$; standard: $n = 24$) with mean final follow-up times of 43 (range, 12–89) and 52 (range, 12–102) months, respectively, were included. There were no statistically significant differences between rehabilitation cohorts with respect to patient demographics, history of prior ligament reconstruction, MAT surgical variables assessed, or follow-up duration. However, nonadherence to the prescribed rehabilitation protocol was significantly different between cohorts, with patients in the standard rehabilitation cohort 2.3*x* more likely to be nonadherent ($p = 0.02$) (►**Table 1**).

Treatment success rate for all patients combined was 81.4% with four treatment failures (11.4%) in the accelerated cohort and seven treatment failures (29.2%) in the standard cohort. Treatment failure occurred at a mean of 23 months (range, 1–60 months) for patients in this study. For the 11 patients who experienced treatment failure, 6 patients (55%) reported an acute injury during activity that was associated with a meniscus allograft tear. Four patients (36%) reported an insidious onset of knee pain and/or dysfunction without a clear mechanism for MAT failure. One patient (9%) did not provide information related to treatment failure. Seven patients (64%) underwent revision MAT, with none reporting need for further surgical intervention during the study period (3–97 months after revision). One patient (9%) underwent repair of the meniscus allograft with no need for further surgical intervention at 26months after repair. Three patients (27%) who experienced treatment failure declined further surgical intervention of any type and opted for nonsurgical management of their meniscus deficiency. No patients opted for conversion to TKA or UKA during the study period. History of prior ligament reconstruction was significantly associated with treatment failure ($p = 0.04$, OR=4.73). Patient age ($p = 0.18$), sex ($p = 1$), BMI ($p = 0.87$), tobacco use ($p = 0.23$), concurrent ligament reconstruction ($p = 0.74$), graft type (fresh vs. frozen, $p = 0.31$), laterality (medial vs. lateral, $p = 0.48$), and nonadherence ($p = 0.71$) were not significantly associated with treatment failure.

There were statistically significant and clinically meaningful improvements for all measured PROMs for patients in the accelerated rehabilitation cohort. Patients in the standard rehabilitation cohort did not report significant or clinically meaningful improvements for any of the measured PROMs (►**Table 2**).

Table 1 Variables assessed for patients undergoing meniscal allograft transplantation in accelerated versus standard rehabilitation cohorts

Variables	Accelerated, $n = 35$	Standard, $n = 24$	*p*-Value
Age (y), Avg (SD)	30.7 (13.2)	26.0 (9.0)	0.07
Sex: female, *n* (%)	13 (37.1)	8 (33.3)	1
BMI, Avg (SD)	29.8 (7.1)	27.6 (4.5)	0.09
Tobacco use status, *n* (%)	3 (8.6)	2 (8.3)	1
Concurrent ligament reconstruction, *n* (%)	18 (51.4)	16 (66.7)	0.29
Previous ligament reconstruction, *n* (%)	11 (31.4)	14 (58.3)	0.06
Medial:lateral, *n*	25:12[a]	16:8	1
Nonadherence, *n* (%)	6 (17.1)	11 (45.8)	***0.02***
Follow-up (mo), Avg (SD)	43 (22.8)	52 (25.4)	0.15

Abbreviations: Avg, average; BMI, body mass index; SD, standard deviation.
Note: The *p*-value in bold italics indicates statistically significant differences.
[a]Two patients underwent concurrent medial and lateral meniscus allograft transplantations.

Table 2 Patient-reported outcome measures prior to and after meniscus allograft transplantation in accelerated versus standard rehabilitation cohorts

	Group (*n*)	Preoperative	Final follow-up	*p*-Value
VAS pain	Accelerated (24)	5.0 (1.8)	2.4 (2.3)	***<0.001***
	Standard (19)	4.3 (2.2)	3.3 (2.3)	0.19
PROMIS physical function	Accelerated (23)	39.5 (7.4)	46.0 (8.6)	***0.003***
	Standard (15)	42.2 (8.6)	43.4 (7.4)	0.59
IKDC	Accelerated (15)	43.4 (8.7)	60.5 (20.5)	***0.01***
	Standard (8)	52.2 (15.8)	50.4 (20.2)	0.78
SANE	Accelerated (11)	49.5 (15.9)	74 (22.8)	***0.003***
	Standard (11)	52.1 (27.5)	57.3 (23.9)	0.66

Abbreviations: IKDC, International Knee Documentation Committee; PROMIS, Patient-Reported Outcomes Measurement Information System; SANE, Single Assessment Numeric Evaluation; VAS, visual analog scale.
Note: The *p*-values in bold italics indicate statistically significant improvements from preoperative to final follow-up.

Patient satisfaction data were provided by 69% of patients in the accelerated cohort ($n = 24$) and 21% of patients in the standard cohort ($n = 5$). In the accelerated cohort, 88% of respondents ($n = 21$) reported they were satisfied or very satisfied with the results of their surgery, and 40% of respondents ($n = 2$) in the standard cohort reported they were satisfied or very satisfied with the results of their surgery.

Discussion

The results of this study allow for acceptance of the hypothesis in that accelerated rehabilitation after MAT was associated with superior adherence, patient-reported outcomes, and patient satisfaction, without diminishing patient safety, when compared with standard rehabilitation. Patients who were prescribed accelerated rehabilitation after MAT were significantly more adherent than patients who were prescribed standard rehabilitation and reported statistically significant and clinically meaningful improvements in knee pain and function for at least 1-year following MAT, whereas those in the standard cohort did not. While not statistically different, treatment failure rate was lower in the accelerated rehabilitation cohort when compared with the standard rehabilitation cohort (11 vs. 29%). Importantly, initial outcomes for revision MAT were associated with short-term success in all the patients who opted for this option in the study population.

The overall treatment failure rate documented in the present study falls within the range reported in previous studies.[1,3,4,9] Similarly, mechanisms for treatment failure and time to failure in our patient population were similar to prior reports.[42–44] In previous studies, obesity, laterality, and articular cartilage pathology have been associated with increased risk for treatment failure following MAT.[42,43,45] In our patient population, we did not note any statistically significant associations for obesity or laterality with treatment failure. In our study population, only history of prior ligament reconstruction was significantly associated with treatment failure, suggesting that more complex indications for MAT may have higher risk for

treatment failure. In conjunction with previous studies, the data from the present study highlight the importance of discussing potential risk factors for treatment failure during a patient–health care team shared decision-making process when considering MAT for treatment of symptomatic meniscus deficiency.

In previous studies, prescribed rehabilitation after MAT has typically included limited weight-bearing and restricted knee ROM for a minimum of 4 to 6 weeks, progressive return to full weight-bearing and ROM by 6 to 12 weeks postoperatively, and return to athletic activities no sooner than 9 months after MAT.[5,13–16,22] The key differences for the accelerated rehabilitation protocol used in the present study included:

- Earlier initiation and faster progression of weight-bearing.
- Knee flexion limitation ($\leq$90 degrees) extended by 1 month.
- Earlier return to straight line jogging and release to full plyometric, cutting, and jumping activities.

These protocol differences were implemented based on previously reported results associated with early weight-bearing after MAT[7] in conjunction with evidence-based advances in allograft preservation methods,[7,21,28] MAT fixation techniques,[7,24–26,28] and patient management strategies[7,12,21,30] that directly or indirectly mitigate known mechanisms of MAT failure. In the present study, these differences were associated with patient safety based on a lower treatment failure rate, better patient adherence to the prescribed postoperative rehabilitation protocol, and greater improvement in PROMs after MAT when compared with the standard rehabilitation cohort. Patient satisfaction was also high in the accelerated cohort. These benefits associated with the accelerated weight-bearing rehabilitation protocol may be related to better patient adherence, focus on return to normal activities of daily living before progression to strengthening, and/or improved healing and joint health. However, the benefits may also be associated with differences in graft types, transplantation techniques, and/or other unaccounted for variables such that further study is required before conclusive recommendations can be made.

Limitations for this study include that it was a single-center, nonrandomized design, which did not control for patient variables, graft types, or transplantation techniques. While this design is subject to confounding variables, it represents a "real-world" scenario in terms of the spectrum of patients indicated for MAT, as well as the influences of surgeon preferences. Further, we were only able to provide mid-term outcomes. However, mean follow-up period exceeded 42 months for both cohorts, mean time to failure was 23 months, and only 3% of patients were lost to follow-up, such that treatment outcome results are considered valid. Similarly, while outcome measures did not include diagnostic imaging assessments, the criteria used to define treatment failure were conservative and strict such that it is unlikely that success was overstated. This is further supported by the robust PROMs data provided by all patients included in the study. Unfortunately, patient satisfaction data were not provided at the same levels such that comparisons between groups for this outcome measure could not be considered valid. Ongoing studies at our center are expanding the patient population to provide sufficient data for multivariate analyses and long-term outcome measures including patient satisfaction data and diagnostic imaging assessments for more conclusive and generalizable results.

Conclusion

The results of this study demonstrate that accelerated weight-bearing after MAT is safe, promotes patient adherence, and is associated with statistically significant and clinically meaningful improvements in patient-reported knee pain and function at early and mid-term follow-up.

Conflict of Interest
- J.P.S. is a board or committee member for the American Orthopaedic Association; is a board or committee member for AO Foundation; is a board or committee member for AO North America; is a paid consultant and receives research support from Arthrex, Inc; is a paid consultant for DePuy, Johnson & Johnson Company; is on the editorial or governing board for the *Journal of Knee Surgery*; is a board or committee member for Mid-America Orthopaedic Association; receives research support from National Institutes of Health (NIAMS & NICHD); is a paid consultant for Orthopedic Designs North America; is a paid consultant for Smith & Nephew; receives publishing royalties, financial or material support from Thieme; and receives research support from U.S. Department of Defense.
- C.W.N. is a board or committee member for AAOS; is a board or committee member for American Orthopaedic Society for Sports Medicine; receives other financial or material support from AO Foundation; is a paid presenter or speaker for Arthrex, Inc; is on the editorial or governing board, receives publishing royalties, financial or material support from Arthroscopy; is a board or committee member for Arthroscopy Association of North America; is a paid consultant for Guidepoint Consulting; and is a paid presenter or speaker for Vericel, Inc.
- J.L.C. receives research support from AANA; receives research support from AO Trauma; receives IP royalties, is a paid consultant and receives research support from Arthrex, Inc; is a paid consultant from Bioventus; is a paid consultant for Boehringer Ingelheim; is a paid consultant and receives research support from Collagen Matrix Inc; receives research support from GE Healthcare; is on the editorial or governing board of the *Journal of Knee Surgery*; is a board or committee member for Midwest Transplant Network; is a board or committee member, receives IP royalties and research support from Musculoskeletal Transplant Foundation; receives research support from National Institutes of Health (NIAMS & NICHD); receives research support from OREF; receives research support from Orthopaedic Trauma Association; receives research support from PCORI; receives research support from Regenosine;

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- K.R. and C.C. have no conflict of interest to disclose.

References

1 van der Wal RJP, Thomassen BJW, van Arkel ERA. Long-term clinical outcome of open meniscal allograft transplantation. Am J Sports Med 2009;37(11):2134–2139

2 Fanelli D, Mercurio M, Gasparini G, Galasso O. Predictors of meniscal allograft transplantation outcome: a systematic review. J Knee Surg 2021;34(03):303–321

3 Ha JK, Jang HW, Jung JE, Cho SI, Kim JG. Clinical and radiologic outcomes after meniscus allograft transplantation at 1-year and 4-year follow-up. Arthroscopy 2014;30(11):1424–1429

4 Stone KR, Adelson WS, Pelsis JR, Walgenbach AW, Turek TJ. Long-term survival of concurrent meniscus allograft transplantation and repair of the articular cartilage: a prospective two- to 12-year follow-up report. J Bone Joint Surg Br 2010;92(07):941–948

5 Grassi A, Bailey JR, Filardo G, Samuelsson K, Zaffagnini S, Amendola A. Return to sport activity after meniscal allograft transplantation: at what level and at what cost? A systematic review and meta-analysis. Sports Health 2019;11(02):123–133

6 A Cavendish P, DiBartola AC, Everhart JS, Kuzma S, Kim WJ, Flanigan DC. Meniscal allograft transplantation: a review of indications, techniques, and outcomes. Knee Surg Sports Traumatol Arthrosc 2020;28(11):3539–3550

7 Schreiner AJ, Stannard JP, Cook CR, et al. Initial clinical outcomes comparing frozen versus fresh meniscus allograft transplants. Knee 2020;27(06):1811–1820

8 Gilat R, Cole BJ. Meniscal allograft transplantation: indications, techniques, outcomes. Arthroscopy 2020;36(04):938–939

9 Figueroa F, Figueroa D, Calvo R, Vaisman A, Espregueira-Mendes J. Meniscus allograft transplantation: indications, techniques and outcomes. EFORT Open Rev 2019;4(04):115–120

10 Frank RM, Cole BJ. Meniscus transplantation. Curr Rev Musculoskelet Med 2015;8(04):443–450

11 Lubowitz JH, Verdonk PCM, Reid JB III, Verdonk R. Meniscus allograft transplantation: a current concepts review. Knee Surg Sports Traumatol Arthrosc 2007;15(05):476–492

12 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

13 Hurley ET, Davey MS, Jamal MS, et al. High rate of return-to-play following meniscal allograft transplantation. Knee Surg Sports Traumatol Arthrosc 2020;28(11):3561–3568

14 Chalmers PN, Karas V, Sherman SL, Cole BJ. Return to high-level sport after meniscal allograft transplantation. Arthroscopy 2013;29(03):539–544

15 Ahmed AF, Rinaldi J, Noorzad AS, Zikria BA. Return to sports following meniscal allograft transplantation is possible but remains questionable: a systematic review. Arthroscopy 2022;38(04):1351–1361

16 Cvetanovich GL, Christian DR, Garcia GH, et al. Return to sport and patient satisfaction after meniscal allograft transplantation. Arthroscopy 2020;36(09):2456–2463

17 Hergan D, Thut D, Sherman O, Day MS. Meniscal allograft transplantation. Arthroscopy 2011;27(01):101–112

18 Elattar M, Dhollander A, Verdonk R, Almqvist KF, Verdonk P. Twenty-six years of meniscal allograft transplantation: is it still experimental? A meta-analysis of 44 trials. Knee Surg Sports Traumatol Arthrosc 2011;19(02):147–157

19 Searle H, Asopa V, Coleman S, McDermott I. The results of meniscal allograft transplantation surgery: what is success? BMC Musculoskelet Disord 2020;21(01):159

20 Rue JPH, Yanke AB, Busam ML, McNickle AG, Cole BJ. Prospective evaluation of concurrent meniscus transplantation and articular cartilage repair: minimum 2-year follow-up. Am J Sports Med 2008;36(09):1770–1778

21 Cook JL, Rucinski K, Crecelius CR, Stannard JP. Initial outcomes after unicompartmental tibiofemoral bipolar osteochondral and meniscal allograft transplantation in the knee using MOPS-preserved fresh (Viable) tissues. Am J Sports Med 2023;51(03):596–604

22 Rosso F, Bisicchia S, Bonasia DE, Amendola A. Meniscal allograft transplantation: a systematic review. Am J Sports Med 2015;43(04):998–1007

23 Stollsteimer GT, Shelton WR, Dukes A, Bomboy AL. Meniscal allograft transplantation: a 1- to 5-year follow-up of 22 patients. Arthroscopy 2000;16(04):343–347

24 Jauregui JJ, Wu ZD, Meredith S, Griffith C, Packer JD, Henn RF III. How should we secure our transplanted meniscus? A meta-analysis. Am J Sports Med 2018;46(09):2285–2290

25 Bhattacharyya R, Krishnan H, Bausch N, et al. Bone bridge technique for lateral meniscal allograft transplantation: no difference in clinical outcome compared to the soft tissue technique. Knee Surg Sports Traumatol Arthrosc 2023;31(10):4162–4170

26 Kelly BT, Potter HG, Deng XH, et al. Meniscal allograft transplantation in the sheep knee: evaluation of chondroprotective effects. Am J Sports Med 2006;34(09):1464–1477

27 Spang JT, Dang ABC, Mazzocca A, et al. The effect of medial meniscectomy and meniscal allograft transplantation on knee and anterior cruciate ligament biomechanics. Arthroscopy 2010;26(02):192–201

28 Schreiner AJ, Stannard JP, Cook CR, et al. Comparison of meniscal allograft transplantation techniques using a preclinical canine model. J Orthop Res 2021;39(01):154–164

29 Kelly SR, Stannard JT, Reddy J, Cook JL, Stannard JP, Nuelle CW. Meniscus allograft transplantation with bone plugs using knotless all-suture anchors and cortical button suspensory fixation. Arthrosc Tech 2023;12(10):e1707–e1714

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(05):23259671231160780

31 Schalet BD, Hays RD, Jensen SE, Beaumont JL, Fries JF, Cella D. Validity of PROMIS physical function measured in diverse clinical samples. J Clin Epidemiol 2016;73:112–118

32 Higgins LD, Taylor MK, Park D, et al; International Knee Documentation Committee. Reliability and validity of the International Knee Documentation Committee (IKDC) Subjective Knee Form. Joint Bone Spine 2007;74(06):594–599

33 O'Connor CM, Ring D. Correlation of Single Assessment Numeric Evaluation (SANE) with other Patient Reported Outcome Measures (PROMs). Arch Bone Jt Surg 2019;7(04):303–306

34 Delgado DA, Lambert BS, Boutris N, et al. Validation of digital visual analog scale pain scoring with a traditional paper-based visual analog scale in adults. J Am Acad Orthop Surg Glob Res Rev 2018;2(03):e088

35 Haff RE, Stoltzfus J, Lucente VR, Murphy M. The Surgical Satisfaction Questionnaire (SSQ-8): a validated tool for assessment of patient satisfaction following surgery to correct prolapse and/or incontinence. J Minim Invasive Gynecol 2011;18(06):S49–S50

36 Luo W, Ali MS, Limb R, Cornforth C, Perry DC. Use of the PROMIS mobility score in assessing function in adolescents and adults previously affected by childhood hip disease. Bone Jt Open 2021;2(12):1089–1095

37 Ogura T, Ackermann J, Mestriner AB, Merkely G, Gomoll AH. The minimal clinically important difference and substantial clinical benefit in the patient-reported outcome measures of patients undergoing osteochondral allograft transplantation in the knee. Cartilage 2021;12(01):42–50

38 Okoroha KR, Lu Y, Nwachukwu BU, et al. How should we define clinically significant improvement on Patient-Reported Outcomes Measurement Information System test for patients undergoing knee meniscal surgery? Arthroscopy 2020;36(01):241–250
39 Su L, Garcia-Mansilla I, Kelley B, et al. Clinical outcomes of meniscal allograft transplantation with respect to the minimal clinically important difference. Am J Sports Med 2022;50(12): 3440–3446
40 Wang D, Chang B, Coxe FR, et al. Clinically meaningful improvement after treatment of cartilage defects of the knee with osteochondral grafts. Am J Sports Med 2019;47(01):71–81
41 Winterstein AP, McGuine TA, Carr KE, Hetzel SJ. Comparison of IKDC and SANE outcome measures following knee injury in active female patients. Sports Health 2013;5(06):523–529
42 Parkinson B, Smith N, Asplin L, Thompson P, Spalding T. Factors predicting meniscal allograft transplantation failure. Orthop J Sports Med 2016;4(08):2325967116663185
43 Kunze KN, Davie RA, Ramkumar PN, Chahla J, Nwachukwu BU, Williams RJ III. Risk factors for graft failure after meniscal allograft transplantation: a systematic review and meta-analysis. Orthop J Sports Med 2023;11(06):23259671231160296
44 McCormick F, Harris JD, Abrams GD, et al. Survival and reoperation rates after meniscal allograft transplantation: analysis of failures for 172 consecutive transplants at a minimum 2-year follow-up. Am J Sports Med 2014;42(04):892–897
45 Jiménez-Garrido C, Gómez-Cáceres A, Espejo-Reina MJ, et al. Obesity and meniscal transplant failure: a retrospective cohort study. J Knee Surg 2021;34(03):267–272