Survivorship of Meniscal Allograft Transplantation in an Athletic Patient Population

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Background: There are limited data evaluating the clinical outcomes of meniscal allograft transplantation (MAT) in physically active cohorts.

Purpose: To determine the survivorship, complication rates, and functional outcomes of MAT in an active military population.

Study Design: Case series; Level of evidence, 4.

Methods: All military patients undergoing MAT between 2007 and 2013 were identified from the Military Health System. Previous/concomitant procedures, perioperative complications, reoperation rate, revision, and initiation of medical discharge for persistent knee disability were recorded. Univariate analysis was performed to identify associations between patient-based and surgical variables on selected endpoints.

Results: A total of 230 MATs (227 patients; 228 knees) were identified; the mean patient age was 27.2 years (range, 18-46 years), and the cohort was predominately male (89%). Approximately half (51%) of the patients had undergone prior, nonmeniscal knee procedures. Medial MATs were performed in 160 (69%) cases, and isolated MATs were most common (60%). A total of 51 complications occurred in 46 (21.1%) patients, including a secondary tear or extrusion (9%). At a mean clinical follow-up of 2.14 years, 10 (4.4%) patients required secondary meniscal debridement, while 1 (0.4%) patient required revision MAT and 2 (0.9%) patients underwent total knee arthroplasty. After MAT, 50 (22%) patients underwent knee-related military discharge at a mean of 2.49 years postoperatively. Tobacco use ($P = .028$) was associated with significantly increased risk of failure, and operation by fellowship-trained surgeons trended toward significance as a protective factor ($P = .078$). Furthermore, high-volume surgeons ($\geq$1 MAT/year; range, 9-35) had significantly reduced rates of failure ($P = .046$).

Conclusion: While reporting low reoperation and revision rates, this investigation indicates that 22% of patients with MAT were unable to return to military duty due to persistent knee limitations at short-term follow-up. Increased surgical experience may decrease rates of failure after MAT. Careful patient selection and referral to subspecialty-trained, higher-volume surgeons should be considered to optimize clinical outcomes after MAT.

Keywords: meniscus; allograft transplantation; tear; extrusion

The meniscus is critical to the form and function of the knee, with important contributions to load transmission, shock absorption, and overall mechanical stability.[1,26] When treating irreparable meniscal tears, subtotal meniscectomy ultimately leads to a predictable pattern of progressive joint degeneration, particularly within the lateral compartment.[5] These sequelae are even more concerning in active cohorts, where meniscal injuries occur at a rate 10-fold greater than the general population and impact activity may exacerbate secondary chondral disease.[11] As a result, several authors have recommended allograft transplantation for physically active individuals with meniscal insufficiency to diminish pain and potentially abate the onset of arthrosis.[10,12,15,25] Similarly, meniscal allograft transplantation (MAT) may be performed in conjunction with various ligamentous, chondral restoration, and realignment procedures to mitigate further articular damage common to these combined injuries.[8]

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Clinical series have documented variable results after MAT, with failure ranging between 0% and 87.5% in recent large systematic reviews.[4,9,16,21,25] However, adverse patient results are often vaguely described and inconsistently recorded. There has been widespread disagreement about the explicit criteria for failure after MAT, including poor patient-reported function, specific radiologic findings, subsequent meniscectomy, surgical revision, or conversion to total knee arthroplasty. In addition, graft sizing, methods for processing and sterilization, and surgical technique may influence the rate of graft complications with MAT, as well as individual surgeon experience, comorbid knee conditions, and postoperative physical demands.[20]

In general, there is a paucity of well-designed, contemporary research evaluating the clinical outcomes of MAT in physically active cohorts. This investigation sought to better characterize the complications and failure rates of MAT among US military servicemembers returning to an active lifestyle. In addition, the authors aim to identify risk factors associated with subsequent knee disability to inform surgical decision making for young, active patients with symptoms after prior subtotal meniscectomy.

METHODS

All active duty servicemembers receiving care through the Military Health System (MHS) are entered into the Military Health System Management Analysis and Reporting Tool (M2) database. The M2 database allows identification of large cohorts by using demographic information, surgical and clinical data, and coding and billing information. This process of defining cohorts has been described previously in clinical research performed on populations within the Department of Defense (DoD).[27]

With use of the identifying *Current Procedural Terminology* (*CPT*) code 29868, all MATs performed within the MHS between 2007 and 2013 were identified. All active duty military servicemembers with confirmed arthroscopic MAT were isolated for further review, and surgical indications included only patients with prior total or subtotal meniscectomy and chronic concordant joint line symptoms (eg, pain, mechanical sensation, recurrent effusions). An extensive chart review using the electronic medical record system, the Armed Forces Health Longitudinal Technology Application (AHLTA version 3.6.0; 3M Health Information Systems), was then performed. Demographic information, including age, race, sex, branch of military service, military rank, and tobacco use, was extracted, and the electronic medical record was analyzed to yield relevant clinical data such as operative surgeon, date of surgery, and previous and concomitant procedures. Clinical course was assessed to determine rates of perioperative complications (eg, arthrofibrosis, infection, neurovascular injury, and venous thromboembolism), subsequent procedures (ie, unplanned reoperation, revision surgery, or secondary knee arthroplasty), and functional limitations or inability to return to military service due to persistent knee disability. Arthrofibrosis was defined as postoperative limitations in knee range of motion due to excessive scar tissue requiring formal manipulation under anesthesia or arthroscopic lysis of adhesions. The Defense Manpower Data Center was cross-referenced to ascertain current military status and participation in postoperative combat deployments after index surgery.

TABLE 1
Demographic Parameters of Patients Undergoing Meniscal Allograft Transplantation

Variable	n (%)
Sex	
Male	203 (89)
Female	24 (11)
Race	
White	170 (75)
Black	22 (10)
Hispanic	30 (13)
Other	6 (3)
Branch of military service, n	
Army	142
Marine	52
Navy	22
Air Force	11
Enlisted military rank	197 (87)
Tobacco use	84 (37)

For the current study, failure of MAT was defined in several different contexts. Surgical failure was assigned to any patient with at least one of the following: symptomatic secondary tear or extrusion of the meniscal allograft requiring reoperation, revision MAT, or conversion to total knee arthroplasty. Alternatively, clinical failure was assigned to patients who required medical discharge from the military due to persistent knee disability or rate-limiting knee pain after MAT. The total failure rate represented the cumulative sum of patients with either surgical failure or clinical failure.

Statistical Analysis

Descriptive analyses were expressed with statistical means ± standard deviations or 95% confidence intervals. Univariate analysis was performed using SAS (version 9.3; SAS Institute) to identify any variables associated with surgical and/or clinical failures using odds ratios (ORs) with 95% CIs. A P value of $<.05$ was considered significant.

RESULTS

Demographic Variables

There were a total of 230 MATs identified, including 1 patient with bilateral MAT, 1 patient with subsequent revision MAT, and 1 patient with both medial and lateral MATs performed in the same knee. The cohort was predominantly male (89%) and of enlisted military rank (87%), with a mean age of 27.2 ± 5.5 years (range, 18-46 years). There was documentation of tobacco use in 84 (37%) patients. Demographic data can be viewed in Table 1.

TABLE 2
Surgical Variables of Patients Undergoing Meniscal Allograft Transplantation[a]

Surgical Variable	n (%)
Laterality	
Medial	159 (69)
Lateral	71 (31)
Right	125 (54)
Left	105 (46)
Previous procedure	
None	112 (49)
ACL reconstruction	93 (41)
High tibial osteotomy	30 (13)
Chondral procedure	10 (4.4)
PCL reconstruction	4 (1.8)
Other	4 (1.8)
Concomitant procedure	
None	137 (60)
ACL reconstruction	60 (26)
High tibial osteotomy	13 (5.7)
Chondral procedure	24 (11)
PCL reconstruction	3 (1.3)
Other	7 (3.0)
Surgeon	
High volume[b]	134 (59)
Low volume	96 (41)

[a]ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.
[b]Defined as performing more than an average of 1 meniscal allograft transplantation per year.

TABLE 3
Clinical Outcomes After Meniscal Allograft Transplantation[a]

Outcome	n (%)
Complications	
MAT tear/extrusion	21 (9.3)
Infection	11 (4.8)
Arthrofibrosis	9 (4)
Saphenous neuritis	4 (1.7)
RSD	3 (1.3)
VTE	2 (0.9)
Compartment syndrome[b]	1 (0.4)
Failures	
Surgical	13 (5.7)
MAT tear debridement	10 (4.4)
Revision	1 (0.4)
Total knee arthroplasty	2 (0.9)
Clinical	50 (22)
Occupational	
Return to military duty	180 (78)
Failure to return to military duty	50 (22)
Subsequent deployment	32 (14)

[a]MAT, meniscal allograft transplantation; RSD, reactive sympathetic dystrophy; VTE, deep venous thrombus or pulmonary embolism.
[b]Compartment syndrome was in the contralateral leg, resulting in 4-compartment fasciotomy.

Surgical Variables

Medial MATs (69%) occurred more frequently than laterally based procedures, and more than half (51%) of the patients had documentation of prior, nonmeniscal procedures in the affected knee, with anterior cruciate ligament (ACL) reconstruction (n = 93; 41%) being the most common. A total of 40% of patients had concomitant procedures performed at the time of MAT, including ACL reconstruction (n = 60; 26%), chondral restoration (n = 24; 11%), and high tibial osteotomy (n = 13; 5.7%). There were a total of 52 surgeons, with 7 surgeons responsible for most MATs (59%), performing between 9 and 35 transplants within the study period. These 7 individuals were designated as high-volume surgeons for subsequent statistical analyses. Surgical variables are summarized in Table 2.

Complications and Outcomes

A total of 51 perioperative complications occurred in 46 (21.1%) patients (Table 3). The most common complications included a secondary tear or extrusion of the MAT (9.3%), arthrofibrosis (4%), and surgical site infection (total 4.8%; superficial infection responsive to oral antibiotics, 2.2%; deep space infection requiring formal irrigation debridement, 2.6%). Other notable but less common complications were venous thromboembolism (0.9%), reflex sympathetic dystrophy (RSD; 1.3%), and contralateral compartment syndrome (0.4%). There were a total of 13 patients (5.7%) requiring secondary surgery to address graft complications at a mean clinical follow-up of 2.14 years. Of these identified surgical failures, secondary MAT debridement was performed in 10 (4.4%) patients, while 1 (0.4%) patient required revision MAT, and 2 (0.9%) patients underwent total knee arthroplasty. A total of 50 (22%) patients underwent separation from the military for secondary knee disability and were deemed clinical failures. This resulted in a cumulative failure rate of 25.9% (n = 59), as previously defined.

Risk Factors

Univariate analysis revealed several significant variables associated with clinical, surgical, and cumulative failure (Table 4). Tobacco use was associated with a statistically significant higher rate of short-term clinical failure (OR, 2.22; 95% CI, 1.19-4.17), as were concomitant ligamentous procedure (OR, 2.21; 95% CI, 1.12-4.39) and realignment osteotomy (OR, 2.36; 95% CI, 1.04-5.36). Furthermore, high-volume surgeons, or those who performed an average of $\geq$1 MAT per year during the study period, had rates of cumulative failure that were significantly lower than that of their lower-volume counterparts (OR, 0.53; 95% CI, 0.30-0.96; P = .046). Of note, fellowship-trained surgeons also had reduced rates of failure that approached statistical significance (OR, 0.51; 95% CI, 0.25-1.04; P = .078).

DISCUSSION

The current study sought to quantify objective clinical endpoints and functional outcomes after MAT in a moderate-

TABLE 4
Univariate Analysis Associated With Clinical Failure, Surgical Failure, and Cumulative Failure After Meniscal Allograft Transplantation[a]

	Clinical Failure		Surgical Failure		Cumulative Failure	
Variable	OR	95% CI	OR	95% CI	OR	95% CI
Age (continuous)	1.03	0.97-1.08	0.97	0.90-1.06	1.02	0.97-1.06
Female sex	1.02	0.67-1.54	0.97	0.49-1.91	1.0	0.67-1.49
Enlisted military rank	2.61	0.75-9.03	0.57	0.17-1.82	1.57	0.60-4.06
Tobacco use	2.22[b]	1.19-4.17	1.51	0.56-4.06	1.72	0.96-3.13
Laterality (meniscus)[c]	1.55	0.83-2.88	1.08	0.43-2.70	1.49	0.84-2.65
Laterality (extremity)[c]	0.6	0.31-1.15	0.57	0.22-1.46	0.5[b]	0.28-0.92
Ligament procedure	2.21[b]	1.12-4.39	1.0	0.35-2.89	1.69	0.88-3.22
Realignment osteotomy	2.36[b]	1.04-5.36	0.67	0.15-3.04	1.82	0.82-4.04
Cartilage procedure	1.64	0.70-3.85	1.63	0.51-5.25	1.54	0.69-3.46
Fellowship-trained surgeon	0.65	0.30-1.43	0. 5	0.18-1.37	0.51	0.25-1.04
High-volume surgeon	0.59	0.31-1.11	0.57	0.23-1.41	0.53[b]	0.30-0.96

[a]OR, odds ratio.
[b]Statistical significance with clinical failure (eg, knee-related military discharge), surgical failure (eg, graft tear requiring reoperation, revision, and/or conversion to total knee arthroplasty), and/or cumulative failure (eg, clinical and surgical) as an endpoint.
[c]Medial meniscus and right knee were considered the referent groups for laterality.

to high-demand, triservice military population. In this cohort, perioperative complications occurred in 21.1% of servicemembers undergoing MAT, including 9% with retear or extrusion at short-term follow-up. These rates are comparable with those previously reported in the literature, ranging from 0% to 26% in other historical series.[4,16,21,25] In a meta-analysis of 44 studies, El Attar[4] documented a cumulative complication rate of 21.3% after isolated or combined MAT, with secondary tear requiring repair or partial meniscectomy most frequently reported (7.2%). More recently, Rosso et al[21] calculated an overall complication rate of 10.6% in a systematic review of 1623 patients undergoing MAT (52% with combined procedures), of which nearly 60% involved allograft tear. McCormick and colleagues[17] identified a 32% reoperation rate among 172 patients at a mean 20 months postoperatively after index MAT, including 1.7% debridement or repair and 4.7% with revision. In addition, secondary surgical treatment was associated with an over 8-fold increased risk of progression to revision MAT or total knee arthroplasty.[17]

However, other perioperative complications may be anticipated after MAT, particularly when associated with other concomitant procedures or complex surgical history.[7,8] The current study documented infection (4.8%), arthrofibrosis (4%), and neurovascular complications (3.1%). Many of the patients in this cohort had undergone previous ipsilateral procedures (51%), with some patients having as many as 5 prior surgeries. Furthermore, with extensive coexisting injuries requiring operative management (60%), postoperative limitations in range of motion and significant delays in return to function may be inevitable due to conflicting rehabilitation goals. With a similar rate of concomitant procedures (60%), McCormick et al[17] indicated that nearly 1 in 4 patients required scar debridement or manipulation under anesthesia. Conversely, El Attar[4] showed a much lower rate of scar-related complications requiring a return to the operating room (4.5%) in a large meta-analysis. Rosso et al[21] also revealed a much lower rate of other complications, with only 12 patients experiencing infection (0.7%) and 5 with limited range of motion (0.3%) after MAT.

In terms of clinical outcomes, this investigation reported a surgical failure rate of 5.8%, which was defined as graft tear requiring reoperation, revision, and/or conversion to total knee arthroplasty for progression of chondral disease in the affected compartment. This rate falls near that summarized in current published literature, varying widely from 7% to 35%.[4,9,16,21,25] However, broader inconsistencies in the definitions of failure after MAT must be acknowledged, and this may fail to account for suboptimal functional outcomes or poor subjective, patient-reported scores. Furthermore, this investigation reveals that approximately a quarter of patients were unable to return to moderate- to high-demand military service due to persistent knee limitations, thus necessitating medical discharge. Adjunctive realignment osteotomy (eg, high tibial osteotomy, distal femoral osteotomy) and concomitant ligamentous reconstruction were associated with an inability to return to military duty at short-term follow-up, although this may fail to account for improved MAT survivorship and chondroprotective benefits anticipated at mid- to longer-term time points with these concomitant procedures.[25] While the literature is replete with clinical outcomes among less active cohorts, few studies have evaluated return to high-level athletics after MAT.[3,14] In a series of 13 young competitive athletes at a mean 3.3-year follow-up, Chalmers[3] showed that 77% returned to athletics and 70% returned to desired level of competition, and 4 patients required secondary surgery (31%). In a separate analysis of 12 male professional soccer players, Marcacci and colleagues[14] reported that 92% returned to soccer and 75% continued at a professional level

of play at 36 months postoperatively, whereas 1 patient was classified as having a failed result (8%). By contrast, only 14% of patients participated in a combat deployment after MAT in our military cohort, although this may reflect the short-term clinical follow-up, changes in operational tempo, or activity restrictions imposed by the treating orthopaedic surgeon rather than actual physical limitations.

In the current investigation, univariate analysis identified 2 important variables that were significantly associated with increased risk of failure: tobacco use and limited surgeon volume. Tobacco use has long been known to portend worse overall patient health and relative orthopaedic surgical outcomes,[19,23,28] although its role in meniscal healing has not been fully elucidated in previous works.[22] When choosing potential surgical candidates, the presence of tobacco use may warrant further risk stratification for failure and appropriate counseling on smoking cessation.

In addition, lower surgical volume or experience in the surgeon was associated with an increased risk of failure in this cohort. Seven surgeons performed nearly two-thirds of all MATs in this study period, and our results demonstrated that orthopaedic surgeons who performed 9 or more MATs during the study period, or an average of 1 a year, had significantly lower failure rates. Furthermore, sports medicine fellowship training conferred a lower rate of failure that approached statistical significance. Similar correlations between surgical volume and/or clinical experience have been established in multiple other technically demanding, reconstructive procedures of the knee[2,13,18] and shoulder.[6,24] Given the complexity of MAT and the documented complication profile among the most experienced surgeons, patients indicated for MAT may be best served by referral to higher-volume or tertiary referral centers. In addition, appropriate ancillary staff, physical therapy resources, and other variables intrinsic to these settings may further influence outcomes after MAT.

Certain limitations of this study should be acknowledged. The retrospective design limits our ability to collect patient-reported outcome measures, serial radiographic data, or other parameters not featured in the electronic medical record or other available data repositories (ie, permanent duty limitations). Consequently, presence or severity of chondral defects, mechanical alignment, allograft tissue processing, and surgical technique could not be fully articulated. Given the slight variability of the patient demographics and combined surgical procedures examined in this study, postoperative rehabilitation protocols and level of preinjury activity could not controlled for. Similarly, we cannot exclude the potential for secondary gains among patients pursuing postoperative medical discharge from the military for clinical failure. In addition, the definition of failure used may underestimate patient benefit for mid- to long-term follow-up and joint preservation. While many patients were unable to continue with the high demands of the military, MAT may yield greater symptomatic relief in activities of daily living and lower-impact exercise. The unique physical rigors of the military may limit the external validity of these results to an active civilian population.

CONCLUSION

The treatment of young, active patients with chronic pain after total meniscectomy remains clinically challenging. Meniscal allograft transplantation provides a potential solution for salvage in knees not suitable for joint arthroplasty. While this investigation demonstrated a modest complication profile with low rates of surgical revision (0.4%), total knee arthroplasty (0.9%), and secondary meniscal debridement (4.4%) that are comparable with previous studies, concerns about high-demand outcomes remain. At short-term follow-up, approximately 22% of patients were unable to return to military duty due to persistent knee complaints. Tobacco was associated with a significant risk of adverse outcomes in the current study, while higher-volume surgeons had significantly lower rates of failure. Despite these risks, MAT remains a moderately successful option for military patients with chronic pain after previous total meniscectomy. Careful patient selection and referral to subspecialty-trained, higher-volume surgeons should be considered to optimize clinical outcomes after MAT.

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