

RESEARCH ARTICLE

Outcomes of Meniscal Repairs in Patients Aged 40 Years or Older: A Retrospective Case Series Comparing Failure and Successful Repair

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Abstract

Objectives: Meniscal repair has become common as meniscectomies have fallen out of favor, yet the growing body of literature has not fully assessed outcomes in older patients. The purpose of this study is to report outcomes among patients aged 40 years or older following meniscus repair.

Methods: An administrative database from a single academic institution was queried using Current Procedural Terminology codes to identify patients who underwent meniscal repair between 2010 and 2018. Patients aged 40 years or older with a minimum two-year follow-up after primary meniscal repair were included. Complications, repair failure, and patient-reported outcomes were collected.

Results: Of the 179 included patients, 68 (38%) experienced meniscal repair failure, 41 (22.9%) underwent reoperation, and 9 (5%) were converted to total knee arthroplasty. The Knee Injury and Osteoarthritis Outcome Score (KOOS) Quality of Life subscale was lower in the repair failure cohort (odds ratio (OR) -14.33; 95% confidence interval (CI) -28.06 to -0.61; $P=0.041$). Patients with meniscal repair failure had higher complication rates (48 (70%)) than patients without meniscal failure (28 (18%)) (OR 7.11; 95% CI 3.62 to 13.97; $P<0.001$). On multivariate analysis, postoperative complications were significantly associated with meniscal repair failure (OR 6.22; 95% CI 3.1 to 12.47; $P<0.001$), and a cumulative effect analysis revealed a stepwise relationship between the risk of repair failure and the number of complications.

Conclusion: Patients aged 40 years or older experienced a 38% meniscal repair failure rate, with a significant association between postoperative complications and repair failure. Surgeons can anticipate that at least one-third of patients in this demographic will experience repair failure and consider the number of complications associated with repair failure risk.

Level of evidence: IV

Keywords: Age, Meniscus repair failure, Meniscus tear

Introduction

The meniscus plays a pivotal role in maintaining the knee's normal function through shock absorption, load bearing, friction reduction, and possibly proprioception.^{1,2} Meniscal tears can be caused by acute traumatic events, sports injuries, or as part of

insidious degenerative changes occurring over a chronic period.^{3,4} In a population study, Englund *et al.* reported the prevalence of meniscal tears in older adults and found rates to increase with age.⁵ A review of age-related changes in the meniscus found that alterations in tissue

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composition and the knee joint environment may increase susceptibility to meniscal tears, corroborating the findings of the above study.⁴

Studies reporting trends in meniscal procedures have found that cases of meniscal repairs have been increasing.^{6,7} At the same time, reported meniscectomies have decreased, reflecting the recent evidence favoring meniscal repairs.⁷⁻⁹ Due to the discovery of accelerated osteoarthritic and degenerative changes in the knee joint following meniscectomy, a growing body of literature advocates the benefits of meniscal preservation.^{2,10} Mixed evidence of outcomes and failure rates of meniscal repair concerning increasing age exists; earlier studies reported higher failure rates in older patients after meniscal repair,^{11,12} but recent studies and systematic reviews comparing clinical and patient-reported outcomes (PROs) of meniscal repair in patients above and below 40 years of age found no significant association between age and outcomes.¹³⁻¹⁶

Studies that observed the outcomes in patients aged 40 years or older with meniscal repair observed an 11-25% failure rate.^{17,18} Although Barrett *et al.* observed a 13.5% failure rate for patients 40 years or older who underwent meniscal repair, including patients with concomitant anterior cruciate ligament reconstruction (ACLR), they did not report PROs and had a small sample size ($n=27$).¹⁷ Studies examining isolated degenerative medial meniscus tear repairs observed an 11% and 25% failure rate with equally small sample sizes ($n=27$ and $n=24$, respectively).^{18,19} There remains a lack of high-powered studies evaluating clinical and subjective outcomes in patients aged 40 years or older who underwent meniscal repair. It is hypothesized that patients 40 years or older with meniscal repairs would have a low failure rate and good patient-reported outcomes. Thus, this study aims to report outcomes among patients aged 40 years or older following meniscus repair.

Materials and Methods

Study Design

Study approval was obtained from the Atrium Health Institutional Review Board (IRB#00083296). The outcomes of patients aged 40 years or older who underwent meniscus repair were reported in a retrospective case series.

Patient Identification

Patients were identified via querying the administrative database at a single academic institution from 2010 to 2018 using the Current Procedural Terminology (CPT) codes 29882 or 29883 for meniscus repair. Patients aged 40 years or older undergoing arthroscopic primary meniscal repair with a minimum follow-up of two years (clinical follow-up or completion of PROs) were considered for inclusion. Exclusion criteria were patients with index meniscal allograft transplantation, prior surgery on the ipsilateral knee, anterior/posterior root avulsion, postoperative traumatic injury to the operative knee (defined as a fall, motor vehicle collision, or other trauma before returning to regular activities), or postoperative septic arthritis.

Surgical Technique

Indications for meniscal repair procedures were collected. All patients underwent knee arthroscopy by one of five fellowship-trained sports medicine orthopedic

surgeons at a single academic institution. Overall patient health, including vascular status and ability to adhere to postoperative rehabilitation protocols, was assessed individually and used to determine patient appropriateness for surgery. Meniscal repairs were performed arthroscopically, but surgical approaches were not standardized in this study, so operative data were collected to control for this in the analysis.

Data Collection

Baseline patient demographic information was collected, including age, sex, body mass index (BMI), smoking status, Charleston Comorbidity Index (CCI), and the interval between the date of injury and the date of surgery. Operative reports were reviewed to record surgical factors, concomitant injuries, and concomitant procedures. Meniscal debridement procedures included shaving frays of the meniscus; meniscectomies required shaving tears, including the use of biters when necessary. Patients with meniscal root tears were not included.

Progress notes were reviewed for complications, reported repair failure, and repeat surgery. Complications included stiffness, wound dehiscence, deep vein thrombosis (DVT), persistent knee pain, neurologic complications, or chondral injury. Evidence of new chondral injury was evaluated through either postoperative (at least six months) magnetic resonance imaging (MRI), if obtained, or as noted during additional surgeries performed after the meniscal repair. Patients with six-month postoperative knee radiographs were reviewed to evaluate for evidence of arthritis using the Kellgren-Lawrence (K-L) grading system.

Failure criteria included patients who subsequently underwent an ipsilateral revision meniscal repair, reoperation on the ipsilateral meniscus (including meniscectomy or additional repairs), recurrent meniscal tear, evidence of unhealed meniscal tear on MRI, or conversion to total knee arthroplasty (TKA) after a minimum of two years. These comprehensive criteria for meniscal repair failure were chosen to include patients receiving secondary surgical intervention as well as patients with persistent symptoms who may choose not to undergo further surgery. Patients who had an MRI performed at least six months postoperatively for any indication were reviewed for evidence of meniscal healing. Study data were collected and managed using Research Electronic Data Capture (REDCap) (Vanderbilt University), a secure web-based software platform hosted at OrthoCarolina.²⁰

Patient Reported Outcomes

Patient-reported outcome (PRO) questionnaires were emailed to patients or collected over the phone to obtain postoperative outcome scores. Patients completed subjective questionnaires at least two years postoperatively, including the Knee Injury and Osteoarthritis Outcome Score (KOOS) and the International Knee Documentation Committee-Subjective Knee Form (IKDC-SKF).

Statistical Analysis

Descriptive statistics were calculated for all continuous and categorical variables. Continuous variables are reported as mean $\pm$ standard deviation (SD) and categorical variables as

frequencies with percentages. A bivariate analysis of non-meniscal repair failure versus meniscal repair failure was performed using the Wald chi-square (χ^2) test to analyze categorical variables, and a t-test was used to test the difference in means for continuous variables. $P \leq 0.05$ was considered statistically significant.

A multivariate analysis to predict the effect of significant variables from the bivariate analysis on meniscal repair failure was performed using a binary logistic regression model. Risk factors with a considerable likelihood ratio ($P \leq 0.1$) in the predictive model were included in the final model. All statistical analysis was performed using SAS/STAT software, Version 9.4 of the SAS System for Windows (SAS

and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA). An a priori power analysis was not performed because all eligible patients were included in the study.

Results

Demographic and Intraoperative Data

After applying the inclusion and exclusion criteria, 179 patients were included in the final analysis [Figure 1]. Of 179 patients 40 years or older who underwent primary meniscus repair, 86 (48%) were male, and 93 (52%) were female, with an average age of 47 ± 6.5 years [Table 1]. Average BMI was 28.5 ± 4.4 kg/m², and mean follow-up was 50 ± 38.3 months.

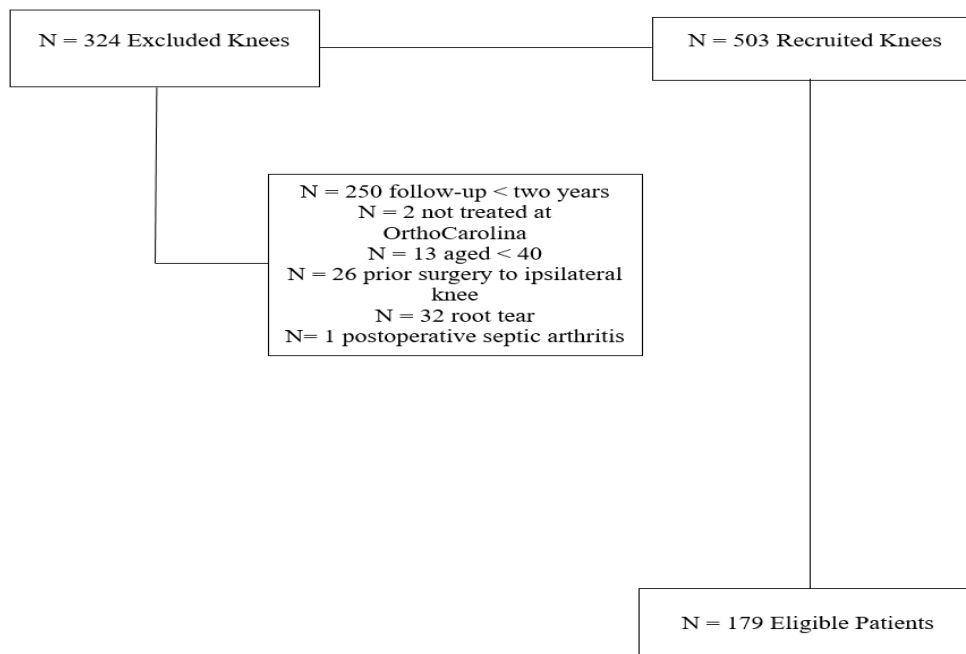


Figure 1. CONSORT (Consolidated Standards of Reporting Trials) diagram for outcomes of patients 40 years or older with meniscal repair

Table 1. Demographics of patients 40 years or older with primary meniscal repair ^a

	Total (n=179)
Male	86 (48%)
Female	93 (52%)
Age at surgery, y	47[6.5], (40-73)
BMI, kg/m ²	28.5[5.5], (18.8-52.3)
Follow-up, mo	50[38.3]
Current smoker*	12 (6.7%)
Former smoker*	37 (20.7%)
Never smoker*	124 (69.3%)
CCI	0.5[0.8], (0-4)
Time between injury and surgery, mo	3[5.5], (0.2-32.4)

^aData are presented as mean[standard deviation], (range) or n (%)

*6 patients did not have smoking data available

Abbreviations: BMI, body mass index; CCI, Charleston Comorbidity Index

There were 124 (69.3%) medial meniscal repairs, with 167 (93.3%) of repairs performed using the all-inside suture technique with the Fast-fix meniscal repair system (Smith & Nephew). 158 (88.3%) of the meniscal tears were traumatic and located in the anterior horn (13 (7.3%)), posterior horn (44 (24.6%)), and mid-body (53 (29.6%)) portion of the meniscus. The most common type of tear was a vertical/longitudinal tear (87 (48.6%)) followed by a bucket-handle tear (41 (22.9%)). Additional intraoperative data on concomitant additional meniscal repairs performed on the ipsilateral knee can be found in the appendix [Appendix A].

There were 118 (65.9%) patients with concomitant

ACLR, and 72 (40.2%) with concomitant meniscal debridement. Meniscectomies were concomitantly performed (separate from the repaired portion of the meniscus) in 54 (30.2%) patients. 52 (29.1%) patients had concomitant chondral debridement.

There were 68 (38%) patients who had meniscal repair failure, with 8 (4.5%) who underwent ipsilateral revision meniscus repair, 41 (22.9%) with reoperation on the ipsilateral meniscus (meniscectomy, additional meniscus repair), 45 (25.1%) with recurrent meniscal tear and unhealed tear on MRI, and 9 (5%) with conversion to TKA [Table 2].

Table 2. Failure rates of patients aged 40 years or older with primary meniscal repair ^a

	Total (n=179)
Underwent ipsilateral revision repair	8 (4.5%)
Underwent reoperation on ipsilateral meniscus	41 (22.9%)
Experienced re-tear	45 (25.1%)
Unhealed tear with MRI confirmation	45 (25.1%)
Underwent conversion to TKA at minimum two-year follow-up	9 (5%)
Total failure	68 (38%)

^aData are presented as n (%)

Abbreviations: MRI, magnetic resonance imaging; TKA, total knee arthroplasty

Bivariate Analysis of Demographics and Intraoperative Data

There were 111 (62%) patients who did not have meniscus repair failure (no-failure group), and 68 (38%) had primary meniscal repair failure (failure group) [Table 3]. The mean age for the no-failure cohort was 46.9 ± 6.3 years and 47.1 ± 6.8 years for the failure cohort (mean difference (MD) 0.26; 95% confidence interval (CI) -1.69 to 2.2; $P=0.794$). The failure cohort had a mean BMI of 30.0 ± 6.9 kg/m², which was

significantly higher than the no-failure cohort mean BMI of 27.5 ± 4.1 kg/m² (MD 2.47; 95% CI 0.85 to 4.09; $P=0.003$). The mean follow-up time was 45.6 ± 40.2 months for the no-failure group and 57.3 ± 34 months for the failure group (MD 11.69; 95% CI -0.03 to 23.42; $P=0.051$). The time from injury to surgery was 2.6 ± 4.7 months for the no-failure group and 3.9 ± 6.7 months for the failure group (MD 1.33; 95% CI -0.72 to 3.38; $P=0.205$) [Table 3].

Table 3. Bivariate analysis of demographics, concomitant injuries, and K-L grade of patients with and without meniscus repair failure ^a

	No Failure (n=111)	Failure (n=68)	OR (95% CI)	P-Value
Male	56 (50.5%)	30 (44.1%)	1.29 (0.7,2.36)	0.411
Female	55 (49.5%)	38 (55.9%)		
Age at surgery, y	46.9[6.3], (40-69)	47.1[6.8], (40-73)	MD 0.26 (-1.69,2.2)	0.794
BMI, kg/m ²	27.5[4.1], (19.9-42.0)	30[6.9], (18.8-52.3)	MD 2.47 (0.85,4.09)	0.003
Follow-up, mo	45.6[40.2]	57.3[34]	MD 11.69 (-0.03,23.42)	0.051
Current or former smoker	29 (26.1%)	20 (29.4%)	1.25 (0.64,2.47)	0.513
Never smoker	80 (72.1%)	44 (64.7%)		
CCI	0.4[0.7], (0.0-3.0)	0.6[0.9], (0.0-4.0)	MD 0.21 (-0.04,0.45)	0.096
Time between injury and surgery, mo	2.6[4.7], (0.2-29.5)	3.9[6.7], (0.2-32.4)	MD 1.33 (-0.72,3.38)	0.205
MCL or PCL injury	5 (4.5%)	0	N/A	N/A
Other ligamentous injury	2 (1.8%)	2 (2.9%)	1.65 (0.23,12.01)	0.62
Meniscal debridement	46 (41.4%)	26 (38.2%)	0.87 (0.47,1.62)	0.671
Meniscectomy	35 (31.5%)	19 (27.9%)	0.84 (0.43,1.64)	0.612
Chondral debridement	30 (27%)	22 (32.4%)	1.29 (0.67,2.49)	0.447

Table 3. Continued

Peroneal neurolysis	1 (0.9%)	0	N/A	N/A
Loose body excision	3 (2.7%)	2 (2.9%)	1.09 (0.18,6.7)	0.925
ACL reconstruction	80 (72.1%)	38 (55.9%)	0.49 (0.26,0.92)	0.028
<i>K-L grade 0-2</i>	39 (35.1%)	38 (55.9%)	1.45 (0.61,3.45)	0.396
<i>K-L grade 3-4</i>	12 (10.8%)	17 (25%)		

^aData are presented as mean[standard deviation], (range) or n (%)

Boldface P values indicate statistically significant difference between groups ($P \leq 0.05$)

Abbreviations: ACL, anterior cruciate ligament; BMI, body mass index; CCI, Charleston Comorbidity Index; CI, confidence interval; K-L, Kellgren-Lawrence; MCL, medial collateral ligament; MD, mean difference; N/A, not applicable; OR, odds ratio; PCL, posterior cruciate ligament.

There were no differences in the location of the meniscal tears, vascularity of the meniscal tears, or types of meniscal tears between patients with and without meniscal repair failures [Appendix B]. For patients with an additional concomitant meniscus repair on the ipsilateral knee at the index procedure, there were no differences in the tear location, tear type, or the number of sutures used for fixation between the no-failure group and the failure group [Appendix C].

In the no-failure group, more patients had a concomitant ACLR (80 (72.1%)) compared to the failure group (38 (55.9%)) (odds ratio (OR) 0.49; 95% CI 0.26 to 0.92; $P=0.028$) [Table 3]. There were no differences in the rate of concomitant multi-ligamentous injuries, meniscal debridement, meniscectomy, or chondral debridement between patients with and without meniscal repair failure.

When grouping patients by postoperative Kellgren-Lawrence (K-L) grades 0-2 and 3-4, no significant difference in odds of repair failure was appreciated (OR 1.45; 95% CI 0.61 to 3.45; $P=0.396$).

Bivariate Analysis of Outcomes

Patients with meniscal repair failure had significantly higher rates of complications (48 (70%)) than patients without meniscal failure (28 (18%)) (OR 7.11; 95% CI 3.62 to 13.97; $P<0.001$) [Table 4]. However, there were no differences in the rates of deep or superficial infection, DVT, persistent knee pain, neurologic complications, or chondral injury between patients with and without meniscal repair failure. Additionally, there were no differences in the K-L grade between patients with and without meniscal repair failure [Table 4].

Table 4. Bivariate analysis of complications in patients with and without meniscus repair failure ^a

	No Failure (n=111)	Failure (n=68)	OR (95% CI)	P-Value
Complications	28 (25.2%)	48 (70%)	7.11 (3.62, 13.97)	<0.001
Stiffness	20 (18%)	28 (41.2%)	0.48 (0.2, 1.18)	0.109
Deep infection	2 (1.8%)	1 (1.5%)	0.25 (0.02, 2.82)	0.26
Superficial wound dehiscence	3 (2.7%)	1 (1.5%)	0.16 (0.02, 1.59)	0.117
DVT	2 (1.8%)	1 (1.5%)	0.25 (0.02, 2.82)	0.26
Persistent knee pain	21 (18.9%)	42 (61.8%)	1.11 (0.44, 2.83)	0.825
Neurologic complication	2 (1.8%)	1 (1.5%)	0.25 (0.02, 2.82)	0.26
Chondral injury	4 (3.6%)	16 (23.5%)	2.45 (0.74, 8.12)	0.141

^aData are presented as n (%)

Boldface P values indicate statistically significant difference between groups ($P \leq 0.05$)

Abbreviations: CI, confidence interval; DVT, deep vein thrombosis; OR, odds ratio

There were 51 (45.9%) patients in the no-failure group and 23 (33.8%) in the failure cohort who completed the PROs [Table 5]. There were no significant differences in IKDC-SKF scores between patients with and without meniscal repair failure (OR -1.8; 95% CI -11.15 to 7.55; $P=0.706$) [Table 2]. The KOOS Quality of Life (QoL) subscale was significantly lower in the failure cohort compared to the no-failure group (OR -14.33; 95% CI -28.06 to -0.61; $P=0.041$), while the rest of the KOOS components were not significantly different

between patients with and without meniscal repair failure.

Multivariate Analysis

Based on the high significance in the bivariate analysis, the initial multivariate model contained ACLR, BMI (normal, overweight, obese), and total complications in predicting meniscal repair failure. After backward elimination variable reduction, the final reduced dependent model had obese BMI, overweight BMI, and complications as significant

factors related to meniscal repair failure. On multivariate analysis, postoperative complications were significantly associated with meniscal repair failure (OR 6.22; 95% CI 3.1 to 12.47; $P<0.001$). Obese BMI ($>30 \text{ kg/m}^2$) increased the risk for meniscal repair failure by 29% but not significantly

(OR 1.29; 95% CI 0.54 to 3.06; $P=0.562$), and an overweight BMI (25 to $<30 \text{ kg/m}^2$) reduced the risk of meniscal repair failure by 46% but not significantly (OR 0.46; 95% CI 0.21 to 1; $P=0.069$).

Table 5. Bivariate analysis of patient-reported outcomes in patients with and without meniscus repair failure ^a

	No Failure (n=51)	Failure (n=23)	MD (95% CI)	P-Value
IKDC-SKF	75.9[17]	74.1[23.1]	-1.8 (-11.14,7.55)	0.706
KOOS-Symptoms	75.8[18.8]	71.3[20.6]	-4.5 (-13.88,4.89)	0.348
KOOS-Pain	84.1[16.1]	76.2[20.2]	-7.86 (-15.99,0.28)	0.058
KOOS-ADL	89.2[13.8]	82.6[18.7]	-6.62 (-14.12,0.88)	0.083
KOOS-Sport	70.8[26]	65.2[34.4]	-5.59 (-19.05,7.87)	0.416
KOOS-QoL	64.9[25.3]	50.5[33.7]	-14.33 (-28.06,-0.61)	0.041

^aData are presented as mean[standard deviation]

Boldface P values indicate statistically significant difference between groups ($P\leq 0.05$).

Abbreviations: ADL, activities of daily living; CI, confidence interval; IKDC-SKF, International Knee Documentation Committee-Subjective Knee Form; KOOS, Knee injury and Osteoarthritis Outcome Score; MD, mean difference; QoL, quality of life.

Discussion

The overarching conclusion from this study is a 38% failure rate after primary meniscal repairs in patients aged 40 years or older, with postoperative complications demonstrating the strongest association with repair failure. Furthermore, increased repair failure was observed as the number of complications increased. However, when quantifying each complication between the failure and non-failure cohorts, there were no significant differences in the rates of each complication. One explanation could be the compounding effect of having multiple complications (i.e., patients with two or more complications) relating to meniscal repair failure. When analyzing the data to ascertain the effect of multiple complications, a significant relationship was observed. Relative to patients who did not experience a complication, patients with one complication (OR 14.35, 95% CI 4.83 to 42.63; $P<0.0001$) were significantly more likely to experience repair failure. This relationship was maintained in patients with two complications (OR 13.91, 95% CI 5.11 to 37.88; $P<0.0001$) but appeared synonymous with the one-complication cohort. However, patients who experienced three or more complications (OR 55.35, 95% CI 16.69 to 183.58; $P<0.0001$) had a much higher risk of repair failure, suggesting that a stepwise risk relationship may exist as complications progressively increase. This relationship was maintained when controlling for BMI.

While the current study sought to identify unique protective and risk factors for repair failure in patients aged 40 years or older, the number of complications remained the only significant finding. While greater BMI was initially identified as a significant risk factor in bivariate analysis, this relationship was not maintained in multivariate modeling. Higher BMI is believed to hinder healing by increasing inflammation from adiposity²¹ and increasing mechanical stress on repair.^{22,23} This may explain the 80% risk of

meniscal failure in patients with obesity that was observed on bivariate analysis. However, the lack of significance in multivariate modeling is likely multifactorial, but may be explained by a possible decrease in return to activities after surgery.^{14,24} In the literature, the relationship between BMI and meniscal repair failure is unclear. Sommerfeldt et al. found that patients with a BMI of 25 or greater did not demonstrate increased risk, while Laurendon et al. found that a BMI of 25 or greater was a significant risk factor for repair failure.^{22,23} No clear consensus has been reached regarding BMI and the subsequent risk of repair failure,^{25,26} warranting further study to reinforce or dispute the present finding.

Patients with ACLR also demonstrated significantly lower odds of failure in bivariate analysis, similar to prior studies' findings.²⁷⁻²⁹ However, this relationship was not maintained in the multivariate analysis. In a retrospective analysis of 918 meniscal repairs, Ronnblad et al. determined that concomitant ACLR is a protective factor in meniscal repair surgery, potentially secondary to increased blood flow and favorable growth factors associated with ACL reconstruction. Ronnblad et al. also suggested that activity modification among patients with concomitant ACL injury may be responsible, positing that such patients may be more careful and therefore less susceptible to retear.²⁹ Greater nutrient-rich blood and growth factors in conjunction with activity modification may result in fewer complications and, therefore, reduced failure rates, but a higher-powered study in this population will be required to fully elucidate the relationship between concomitant ACLR and meniscal repair in patients aged 40 years or older.

The failure rate in the current study (38%) is higher than in other studies that evaluated meniscal repair failure in patients 40 years or older (5.3-25%).^{17-19,30,31} In a similar study design to the present investigation, Barrett et al.

identified a 13.5% meniscal repair failure rate, but with a smaller sample size ($n=37$ vs. $n=179$, respectively).¹⁷ Failure was also higher in the current study than in studies that looked at isolated meniscus repairs (11-25%), with equally small sample sizes ($n=27$ and $n=24$, respectively).^{18,19} However, while the present study's greater sample size lends itself to greater statistical power and likely greater generalizability to the broader population of meniscal pathologies, the aforementioned studies were more niche in their populations and techniques and may be more representative and applicable to those groups.

The meniscal repair failure rate of 38% in the present study is also higher than the average failure rate of patients under age 40 in a prior comparative study.^{30,31} Poland et al. found that failure rates did not differ between patients under 40 (21%) and those 40 and over (18%).³⁰ While the present study used repair failure criteria similar to those of Poland et al., they evaluated outcomes in a smaller cohort of patients aged 40 years or older ($n=56$) with limited statistical power.³⁰ Steadman et al. reported even lower failure rates when comparing patients under 40 with those aged 40 years or older (5.5% (6/110) vs 5.3% (2/38), respectively).³¹ Similar to Poland et al., Steadman et al. evaluated a smaller cohort of individuals, but defined failure as patients who required revision surgery in the same location as the index procedure.³¹ Conversely, the failure criteria in the present study are broader and therefore capture more repair failures. In general, the failure rates in patients 40 years or older in the current study were noticeably higher than those in patients below 40 in other studies,^{30,31} and there was also diminished meniscal healing potential in patients 40 years or older.^{17,32}

The current study found that meniscal pathology subtypes do not affect repair failure rates. Most meniscal tears were due to traumatic injury, identified in the medial meniscus, posterior horn, vertical/longitudinal, or bucket-handle tear type, and were repaired in the red-red and red-white zone with an all-inside repair technique. This is consistent with previous population studies that identified the pathology of meniscal repairs.³³ Additionally, these results support the notion that all meniscal tears with healing potential should be attempted to repair.^{2,6,10} The worst KOOS-QoL score in the current study may be related to additional surgeries for response to meniscal failure or subsequent meniscectomies after an unhealed repair, which typically result in worse quality of life.¹⁴

While this study effectively assessed meniscus repair failure and PROs in patients aged 40 years or older, it has limitations. The present study did not use K-L grading in its inclusion or exclusion criteria. While 173 of 179 patients were postoperatively graded K-L 3 or lower, and no significant difference in failure rate was observed, more stringent inclusion criteria would remove heterogeneity introduced by differing preoperative osteoarthritic states. While the study found a significant association between the number of complications and risk of repair failure, specific complications, including stiffness and persistent knee pain, could be the result of repair failure rather than a causal etiology. As a result, further study is required to firmly

elucidate this relationship. Furthermore, it is important to acknowledge that our definition of meniscal repair failure was broad and may have contributed to the high failure rates observed in this study; in addition to including patients needing further surgery, we also classified recurrent or unhealed meniscal tears on postoperative MRI as repair failures. This study was also conducted retrospectively, which creates less reliable data collection than a prospective study and may introduce potential confounders. The large number of eligible patients limited the collection of PROs, as many patients who had surgery over 10 years ago were not responsive when contacted to complete PRO questionnaires. Thus, additional surgeries or complications could not be reported in this study because of the inability to contact all eligible patients. Additionally, many patients were excluded for lacking an adequate two-year follow-up (either clinically or by not completing the PROs). Logically, if patients choose not to follow up, it is because they do not see a need to. Therefore, there may be patients without meniscal repair failure who were not included in the present study, possibly skewing the results towards patients with meniscal repair failure. Postoperative rehabilitation adherence was not evaluated in this study due to its retrospective design; thus, the influence of rehabilitation compliance on the failure rate could not be analyzed. The impact of lower limb alignment on meniscus repair healing was not evaluated retrospectively due to the inconsistent use of full-length lower extremity films.

Conclusion

In this study, patients aged 40 years or older had a 38% meniscal repair failure rate, with a significant association between postoperative complications and meniscal repair failure. Surgeons should expect that at least one-third of meniscal repair patients aged 40 years or older can fail and have additional reoperation, leading to worse subjective outcomes. Thus, surgeons should balance the potential risk of meniscal repair failure with the risk of progressive osteoarthritis in performing a meniscectomy in this population.

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Appendix

Appendix A. Intraoperative data, ipsilateral concomitant meniscal repair ^a	
	Total (n=179)
Meniscus tear	14 (7.8%)
Lateral meniscus tear	12 (6.7%)
Medial meniscus tear	2 (1.1%)
Anterior horn tear	0 (0%)
Posterior horn tear	11 (6.1%)
Mid-body tear	2 (1.1%)
Intrasubstance incomplete tear	2 (1.1%)
Complex tear	1 (0.6%)
Vertical/longitudinal tear	8 (4.5%)

Appendix A. Continued	
Displaced bucket-handle tear	1 (0.6%)
1 suture for repair fixation	3 (1.7%)
2 sutures for repair fixation	2 (1.1%)
3 sutures for repair fixation	7 (3.9%)
4 sutures for repair fixation	0 (0%)
5 sutures for repair fixation	1 (0.6%)

^aData are presented as n (%)

Appendix B. Comparison of meniscus repair intraoperative data in patients with and without meniscal repair failure ^a				
	No Failure (n=111)	Failure (n=68)	OR (95% CI)	P-Value
<i>Left knee</i>	52 (46.8%)	31 (45.6%)	Referent	Referent
<i>Right knee</i>	59 (53.2%)	37 (54.4%)	1.05 (0.57,1.93)	0.87
<i>Lateral meniscus</i>	38 (34.2%)	17 (25%)	Referent	Referent
<i>Medial meniscus</i>	73 (65.8%)	51 (75%)	1.56 (0.8,3.07)	0.195
Repair technique				
<i>Inside-out repair</i>	1 (0.9%)	1 (1.5%)	Referent	Referent
<i>Outside-in repair</i>	4 (3.6%)	2 (2.9%)	0.5 (0.02,12.9)	0.676
<i>All-inside repair</i>	103 (92.8%)	64 (94.1%)	0.62 (0.04,10.11)	0.738
<i>Traumatic tear</i>	100 (90.1%)	58 (85.3%)	Referent	Referent
<i>Chronic/degenerative tear</i>	11 (9.9%)	10 (14.7%)	1.57 (0.63,3.92)	0.336
Tear location				
<i>Anterior horn tear</i>	9 (8.1%)	4 (5.9%)	0.71 (0.21,2.4)	0.579
<i>Posterior horn tear</i>	81 (73%)	54 (79.4%)	1.43 (0.69,2.94)	0.333
<i>Mid-body tear</i>	35 (31.5%)	18 (26.5%)	1.43 (0.69,2.94)	0.333
<i>Red-red (outer third)</i>	64 (57.7%)	36 (52.9%)	0.83 (0.45,1.52)	0.538
<i>Red-white (middle third)</i>	46 (41.4%)	29 (42.6%)	1.05 (0.57,1.94)	0.874
<i>White-white (inner third)</i>	6 (5.4%)	2 (2.9%)	1.05 (0.57,1.94)	0.874
Tear pattern				
<i>Intrasubstance/incomplete tear</i>	6 (5.4%)	3 (4.4%)	0.92 (0.37,2.33)	0.867
<i>Radial tear</i>	1 (0.9%)	1 (1.5%)	1.64 (0.1,26.69)	0.727
<i>Complex tear</i>	8 (7.2%)	2 (2.9%)	0.39 (0.08,1.89)	0.243
<i>Horizontal flap tear</i>	6 (5.4%)	3 (4.4%)	0.81 (0.2,3.34)	0.768
<i>Vertical/longitudinal tear</i>	52 (46.8%)	35 (51.5%)	1.2 (0.66,2.2)	0.548
<i>Displaced bucket-handle tear</i>	28 (25.2%)	13 (19.1%)	0.7 (0.33,1.47)	0.347
Number of sutures for repair fixation				
<i>1 suture</i>	25 (22.5%)	14 (20.6%)	Referent	Referent
<i>2 sutures</i>	39 (35.1%)	16 (23.5%)	0.73 (0.31,1.76)	0.486
<i>3 sutures</i>	17 (15.3%)	17 (25%)	1.79 (0.7,4.56)	0.226
<i>4 sutures</i>	7 (6.3%)	10 (14.7%)	2.55 (0.79,8.19)	0.116
<i>5 sutures</i>	3 (2.7%)	1 (1.5%)	0.6 (0.06,6.28)	0.666

^aData are presented as n (%)

Abbreviations: CI, confidence interval; OR, odds ratio

Appendix C. Comparison of ipsilateral concomitant meniscal repair intraoperative data in patients with and without meniscal repair failure ^a

	No Failure (n=111)	Failure (n=68)	OR (95% CI)	P-Value
<i>Meniscus tear</i>	8 (7.2%)	6 (8.8%)	1.31 (0.4,4.33)	0.655
<i>Lateral meniscus tear</i>	7 (6.3%)	5 (7.4%)	1.4 (0.07,28.12)	0.826
<i>Medial meniscus tear</i>	7 (6.3%)	5 (7.4%)	1.4 (0.07,28.12)	0.826
Tear location				
<i>Anterior horn tear</i>	0 (0%)	0 (0%)	N/A	N/A
<i>Posterior horn tear</i>	7 (6.3%)	4 (5.9%)	0.93 (0.26,3.3)	0.909
<i>Mid-body tear</i>	0 (0%)	2 (2.9%)	N/A	N/A
Tear pattern				
<i>Intrasubstance incomplete tear</i>	0 (0%)	2 (2.9%)	N/A	N/A
<i>Complex tear</i>	1 (0.9%)	0 (0%)	N/A	N/A
<i>Vertical/longitudinal tear</i>	4 (3.6%)	4 (5.9%)	1.67 (0.4,6.92)	0.478
<i>Displaced bucket-handle tear</i>	0 (0%)	1 (1.5%)	N/A	N/A
Number of sutures for repair fixation				
<i>1 sutures</i>	2 (1.8%)	1 (1.5%)	Referent	Referent
<i>2 sutures</i>	1 (0.9%)	1 (1.5%)	2 (0.05,78.25)	0.711
<i>3 sutures</i>	4 (3.6%)	3 (4.4%)	1.5 (0.09,25.39)	0.779
<i>4 sutures</i>	0 (0%)	0 (0%)	N/A	N/A
<i>5 sutures</i>	0 (0%)	1 (1.5%)	N/A	N/A

^aData are presented as n (%)

Abbreviations: CI, confidence interval; N/A, not applicable, OR, odds ratio