Patient-Specific Variables Associated with Failure to Achieve Clinically Significant Outcomes After Meniscal Allograft Transplantation at Minimum Five Years' Follow-Up

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Purpose: To determine the improvements in patient-reported outcome measures (PROMs) necessary to achieve minimal clinically important difference (MCID), patient-acceptable symptomatic state (PASS), and substantial clinical benefit (SCB) after primary meniscal allograft transplantation (MAT) at a minimum of 5 years' follow-up, while identifying variables predictive of achieving clinically significant outcomes (CSOs). **Methods:** A retrospective review was performed to identify patients undergoing primary MAT at a single institution from 1999 to 2016. Lysholm, International Knee Documentation Committee (IKDC), and Knee Injury and Osteoarthritis Outcome Score (KOOS) subscales were collected before surgery and at a minimum of 5 years' follow-up. A distribution-based approach was used to calculate MCID, whereas an anchor-based approach was used to calculate SCB and PASS. Multivariate logistic regression was performed to determine factors associated with CSO achievement. **Results:** A total of 202 patients undergoing MAT (56% medial, 44% lateral) were included with a mean follow-up of 9.8 ± 4.1 years, age of 29.7 ± 8.5 years, and body mass index (BMI) of 26.5 ± 4.7. Thresholds for achieving MCID, PASS, and SCB, respectively, at a minimum 5-year follow-up for Lysholm (10.3, 74.5, 32.5), IKDC (12.1, 55.6, 29.1), and KOOS subscales questionnaires (Pain [11.0, 70.7, 25.1], Symptoms [11.0, 60.8, 19.6], Activities of Daily Living [10.5, 90.3, 17.9], Sport [16.2, 47.4, 37.5], and Quality of Life [13.6, 40.5, 37.3]) were calculated. Reduced odds of achieving MCID were associated with higher preoperative PROM scores, BMI, patient age, concomitant osteotomy, male sex, and worker's compensation (WC) status. Reduced odds of achieving PASS were associated with lower preoperative PROM scores, higher BMI (particularly ≥30), patient age, and WC status. Reduced odds of achieving SCB were associated with higher preoperative PROM scores and WC status. **Conclusion:** This study established the MCID, PASS, and SCB at 5-year minimum follow-up for the Lysholm score, IKDC, and KOOS subscales in patients who underwent MAT. Increased BMI and patient age, male sex, performance of concomitant osteotomy, WC status, and preoperative PROM scores were associated with failure to achieve CSOs after primary MAT at a minimum of 5 years' follow-up. **Level of Evidence:** Level IV, therapeutic study, retrospective case series.

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Because of the role of the meniscus in maintaining appropriate load transmission, stability, and shock absorption in the knee, meniscal integrity is vital to overall knee health, function, and homeostasis.[1,2] Meniscal loss through trauma, degeneration, or after sub-total/total meniscectomy has been shown to decrease tibiofemoral contact area by 50% to 75%, elevating contact pressures by up to 350%, while increasing the risk for the development of osteoarthritis (OA).[3-5] This has led to increased awareness and advocacy for meniscal preservation; however, in the active, meniscal-deficient patient with unicompartmental pain and no evidence of OA, meniscal allograft transplantation (MAT) has emerged as a viable option to restore knee biomechanical stability, reduce pain, improve function, and delay the onset or progression of OA.[6-9] As a result, there has been a growing interest in better defining the indications for MAT, necessitating a better understanding of patient-related and clinical variables predictive of post-operative success and failure.[10,11]

An increasing emphasis has been placed on evaluating patient satisfaction and clinically significant outcomes (CSOs) after orthopaedic procedures using common patient-reported outcomes measures (PROMs).[10,12-15] The minimally clinically important difference (MCID), patient-acceptable symptomatic state (PASS), and substantial clinical benefit (SCB) are currently used thresholds that can be calculated from PROM indices to provide an assessment for determining whether a patient had clinically significant improvement after surgery.[16-18] Although prior investigations have reported statistically significant improvement in PROMs after MAT,[14,19-21] such metrics provide limited evidence regarding treatment efficacy.[15] Studies evaluating CSOs after primary MAT are currently limited by short-term follow-up, with Liu et al.[10] previously reported the MCID and PASS for Lysholm, International Knee Documentation Committee (IKDC), and Knee Injury and Osteoarthritis and Outcome Score (KOOS) subscales in 98 patients undergoing MAT with a minimum of 1 year of follow-up. Meanwhile, Frank et al.[14] evaluated CSO outcomes for MCID using IKDC and KOOS Symptoms subscale at minimum 2 years' follow-up. However, variables predictive of failure to achieve CSOs at midterm follow-up remains largely unknown.[13,14,19,21]

As such, gaining a better understanding of midterm CSOs after primary MAT and the variables associated with patient satisfaction and treatment success or failure is warranted. The purpose of this investigation was to determine the improvements in PROMs necessary to achieve MCID, PASS, and SCB after primary MAT at a minimum of 5 years' follow-up, while identifying variables predictive of achieving CSOs. We hypothesize that older patients, as well as patients with greater preoperative PROM scores, would be less likely to achieve CSOs after primary MAT.

Methods

Patient Selection

Before study initiation, approval was obtained from the Institutional Review Board at Rush University Medical Center. A prospectively collected database of patients who underwent primary MAT from a single institution by the primary author was queried for patients who had their procedure performed between 1999 to 2016 and had a minimum 5 years' follow-up. Follow-up was defined as updated interval surgical history within the index knee and completion of postoperative PROMs. Patients were included in the study regardless of concomitant procedures at the time of primary MAT. Inclusion criteria for medial or lateral MAT were symptomatic patients with meniscal insufficiency and had failed previous conservative management. Indications for concomitant OCA, osteotomy, or ACL reconstruction was a focal, full-thickness cartilage defect (International Cartilage Repair Society grade III or IV), malalignment, or a full-thickness ACL tear seen on preoperative magnetic resonance imaging, respectively. Exclusion criteria consisted of (1) patient age less than 18 years at index procedure, (2) presence of inflammatory arthropathy, and (3) patients with less than 5 years' follow-up. Written or electronic questionnaires were emailed by a PROM collection platform (PatientIQ, Chicago, IL) or provided to patients in-person by trained medical student research assistants. The PROMs were subsequently scored manually by research assistants or automatically by the PROM platform.

Surgical Technique and Rehabilitation Protocol

All MATs were performed by the senior author, a fellowship-trained orthopaedic surgeon (B.J.C.). The senior author prefers the bridge-in-slot technique for medial or lateral MATs with fresh-frozen, nonirradiated meniscal grafts and, if present, will treat associated abnormalities concomitantly (malalignment, focal cartilage defects, or ligamentous insufficiency). In brief, a diagnostic arthroscopy is performed using standard anteromedial and anterolateral portals. The meniscus is evaluated in addition to anterior cruciate ligament (ACL) integrity and chondral surfaces of the medial, lateral, and patellofemoral compartments. The meniscus is debrided until a bleeding peripheral rim of 1 to 2 mm is left, and anterior and posterior horns are subsequently resected. To prepare the meniscal slot, an initial slot guide is first made with a 4.5-mm burr, and a guide pin is then placed using the slot guide. A 7-mm

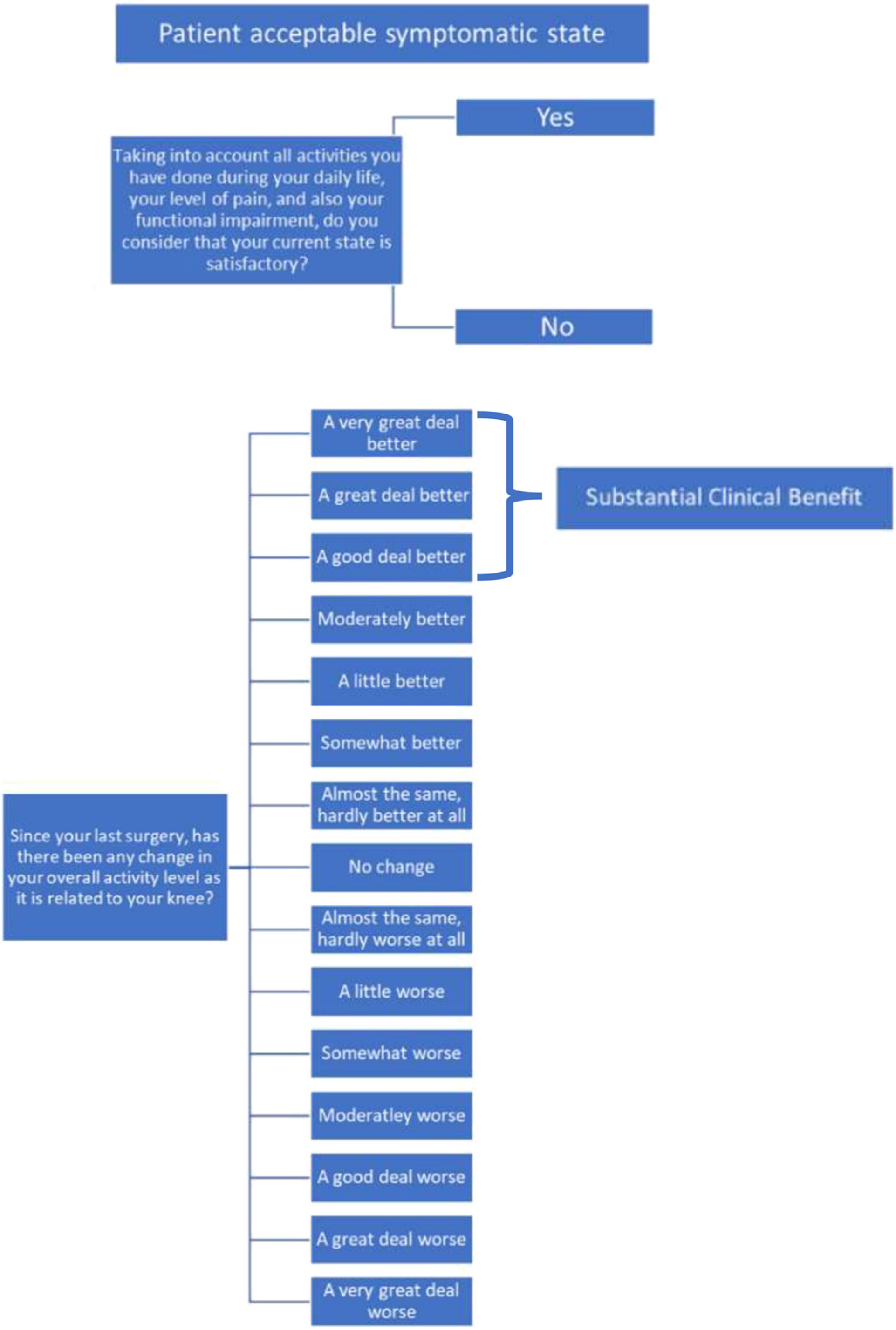

Fig 1. Anchor questions were used for determination of patient acceptable symptomatic state and substantial clinical benefit following meniscal allograft transplant. Patients were determined to have substantial or unsubstantial benefit based on their responses.

reamer is used to over-ream the guide pin, and the slot is refined using a box cutter, dilating rasp, and a bone-cutting shaver.

During tibial slot preparation, the allograft is thawed in normal saline on a surgical table. Once thawed, a bone bridge is created between the anterior and posterior horn of the donor allograft. A suture is placed through the posterior third of the meniscus, which is used for meniscal insertion into the joint and subsequently the tibial slot. With the knee in flexion, a bio-absorbable interference screw is used to secure the bone bridge within the tibial tunnel. Standard posterolateral and posteromedial incisions are used for lateral and medial meniscocapsular repair, respectively. For lateral meniscocapsular repair, care is taken to avoid the peroneal nerve and lateral collateral ligament. For medial meniscocapsular caution is used to avoid the saphenous nerve. Approximately 8 to 10 vertical mattress sutures are then used to secure the meniscus using an inside-out technique. After confirming satisfactory meniscus placement and stability, the incisions are closed in standard fashion.

After surgery, patients remained heel touch weightbearing in a knee braced locked in full extension for the first 2 weeks. At postoperative week 2, patients began heel touch weightbearing with crutches until week 6, whereby patients progressed to full weightbearing. At postoperative week 8, patients progressed through closed chain activities until they were cleared for sport-specific exercises by the senior author at a minimum 5 months after surgery.

Data Collection

Baseline demographics and surgical variable were collected and compared between patients who met inclusion or exclusion criteria. These patient variables consisted of age, body mass index (BMI), leg laterality (left or right), meniscal transplant laterality (medial or

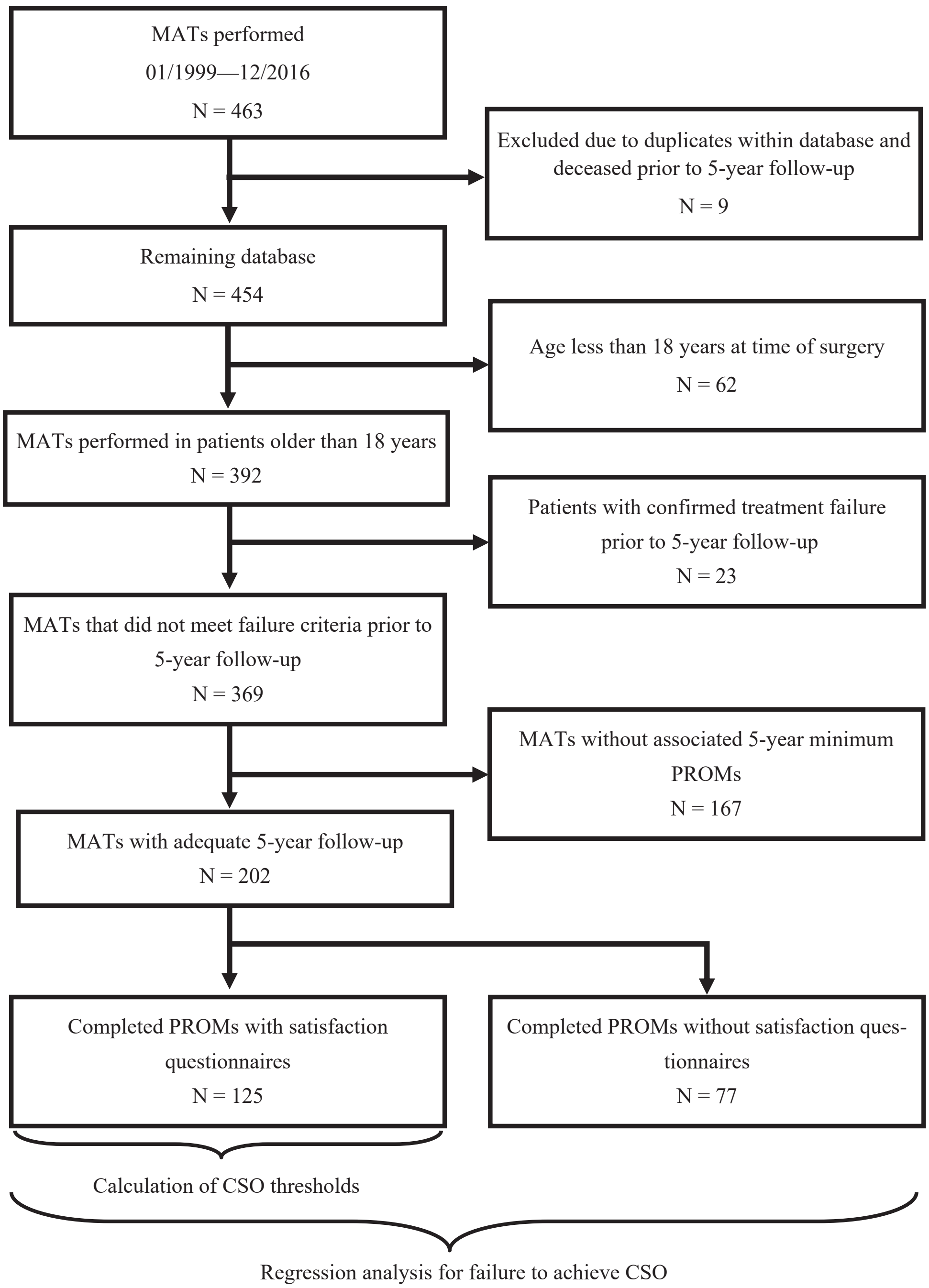

Fig 2. During the study period, 463 meniscal allograft transplantations (MATs) were performed. Eight MATs were found to be duplicates within the database, and 1 MAT was performed in a patient who died before the 5-year follow-up. Sixty-two patients were younger than 18 years of age at the time of their surgery, and 23 patients met criteria for failure before 5-year follow-up. Failure was defined as subsequent subtotal or total meniscectomy, revision MAT, or conversion to unicompartmental or total knee arthroplasty (TKA). Of the remaining 369 MATs available for inclusion, 201 met criteria (54.5% follow-up).

Table 1. Patient Demographics, Preoperative Outcome Scores, and Surgical Characteristics of Patients Undergoing Primary Meniscal Allograft Transplantation Included Versus Excluded in Analysis

	MAT Included (n = 202)	MAT Excluded (n = 252)	*P* Value
Sex			.856
Male	108	138	
Female	94	114	
BMI	26.5 ± 0.3 (25.8-27.2)	25.9 ± 0.3 (25.2-26.5)	.200
Range	18.2-39.2	18.6-38.4	
Age	29.7 ± 0.6 (28.5-30.9)	27.6 ± 0.6 (26.4-28.9)	**.020**
Range	18.1-53.7	13.1-54.0	
Preoperative Lysholm	46.4 ± 1.8 (42.7-50.1)	46.4 ± 1.8 (42.9-49.9)	.995
Preoperative IKDC	38.8 ± 1.6 (35.8-42.0)	37.3 ± 1.7 (33.9-40.7)	.506
Preoperative KOOS			
Preoperative Pain	55.8 ± 1.5 (52.9-58.7)	54.6 ± 1.7 (51.0-58.1)	.594
Preoperative Symptoms	56.7 ± 1.7 (53.3-60.0)	56.7 ± 1.6 (53.6-59.8)	.990
Preoperative ADL	69.7 ± 1.7 (66.4-73.1)	68.7 ± 2.1 (64.4-72.9)	.691
Preoperative Sport	30.4 ± 2.1 (26.3-34.6)	28.9 ± 2.2 (24.5-33.4)	.631
Preoperative QOL	24.7 ± 1.5 (21.7-27.8)	25.7 ± 1.7 (22.3-29.1)	.686
Meniscus transplanted (med:lat)			.350
Medial	114	130	
Lateral	88	122	
Prior surgeries	2.6 ± 0.1 (2.4-2.9)	2.5 ± 0.1 (2.3-2.7)	.405
Range	1-14	1-8	
Preop ICRS Grade	1.8 ± 0.1 (1.5-2.0)	1.6 ± 0.1 (1.4-1.8)	.222
Range	0-4	0-4	
Follow-up	9.8 ± 0.2 (9.4-10.3)		
Range	5.0-16.3		
Concomitant procedures			
Any	139 (68.8%)	166 (65.9%)	.574
OCA	91 (45.0%)	103 (40.1%)	.425
OAT	4 (2.0%)	3 (1.2%)	.768
MFX	22 (10.9%)	19 (7.5%)	.283
ACI	14 (6.9%)	10 (4.0%)	.233
DFO	5 (2.5%)	12 (4.8%)	.305
HTO	11 (5.4%)	13 (5.1%)	.999
ACLR	25 (12.4%)	32 (12.7%)	.999

ACLR, anterior cruciate ligament reconstruction; ADL, activities of daily living; BMI, body mass index; DFO, distal femoral osteotomy; F, female; HTO, high tibial osteotomy; ICRS, International Cartilage Repair Society; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; lat, lateral; M, male; med, medial; OCA, osteochondral allograft transplantation; OAT, osteochondral autograft transplantation; MFX, microfracture; QOL, quality of life.

Characteristics of patients who underwent primary meniscal allograft transplantation did not differ between included and excluded patients, with the exception of more female patients and concomitant autologous chondrocyte implantation in the included group. Two patients underwent bilateral meniscal allograft transplantation (one was included and the other was excluded). Binomial variables are presented as frequency (proportion of respective included or excluded group). Continuous variables are listed as mean ± standard error (95% confidence interval). *P* values are listed for χ-squared tests or Fisher's exact test when analyzing categorical variables, while numerical data was analyzed with unpaired *t*-tests. Bold indicates *P*-values <.05.

lateral), number of prior procedures, performance of concomitant procedures (ligament reconstruction, chondral restoration, or realignment procedures), preoperative PROM scores, sex, smoking status, and worker's compensation (WC) status. To provide comparisons with previous literature, validated questionnaires were selected based on previous CSO calculations for primary MAT.[10,14] Namely, Lysholm, subjective IKDC score, and KOOS subscales (Pain, Symptoms, Activities of Daily Living [ADL], Sport, and Quality of Life [QOL]) were completed at preoperative, 1-year, 2-year, and at a minimum 5-year follow-up. A satisfaction questionnaire containing an anchor question used for PASS and SCB calculation was administered simultaneously. The index compartment cartilage grades at time of surgery, as well as the incidence of failures, were recorded. Failure was defined as subsequent subtotal or total meniscectomy, revision MAT, or conversion to unicompartmental or total knee arthroplasty.

Statistical Analysis

Descriptive statistics for all continuous variables were reported as means with standard deviations unless otherwise stated. Binomial variables were presented as frequencies (proportions). One way repeat measurement analysis of variance was used for comparing preoperative and postoperative PROMs. The χ-squared

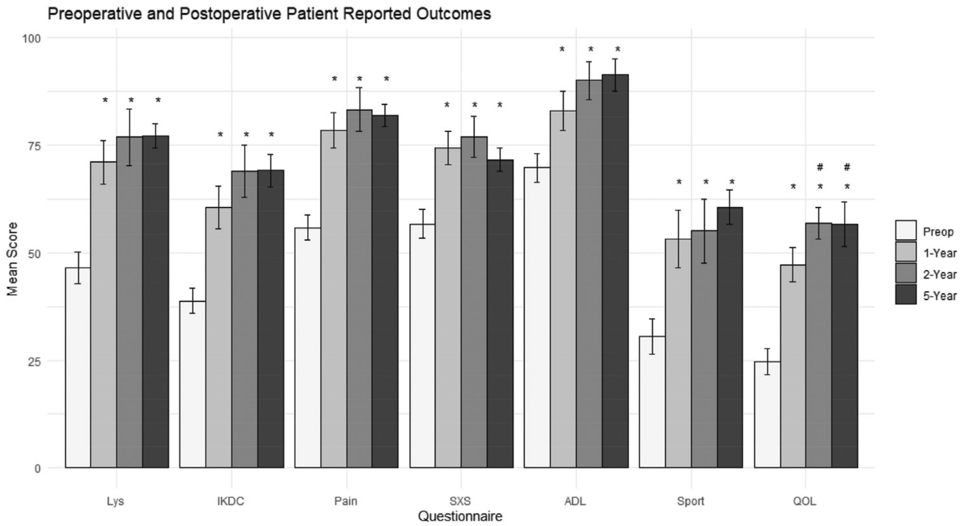

Fig 3. Preoperative and postoperative patient-reported outcomes after primary meniscal allograft transplantation were analyzed. Mean scores for Lysholm (Lys), International Knee Documentation Committee (IKDC), and Knee Injury and Osteoarthritis Outcome Score (KOOS) subscale questionnaires increased at 1-year, 2-year, and 5-year minimum follow-up when compared to baseline scores. The KOOS quality of life (QOL) subscale also had a significant increase in the 2-year and 5-year minimum scores when compared to the 1-year timepoint. ADL, activities of daily living; QOL, quality of life; SXS, symptoms. Error bars represent 95% confidence intervals.

test was used for comparing categorical preoperative or intraoperative variables, and Fisher's exact test was used if expected frequencies for any variable was <5. Shapiro-Wilk testing determined normality of the data and Mann Whitney U, Wilcoxon signed rank, and unpaired or paired *t*-tests were used accordingly for comparing continuous variables.

MCID, PASS, and SCB were calculated for Lysholm, IKDC, and KOOS subscales. The distribution-based method was used for MCID calculation. The distribution-based method has also been previously used for MAT MCID calculation, as well as other procedures such as hip arthroscopy and biceps tenodesis.[10,14,22,23] Both the anchor-based and distribution-based methods can be used for determining MCID; however, the anchor-based method may be limited by the number of patients who complete anchor-based questions and recall bias.[24,25] MCID was calculated as one half the standard deviation of the difference between preoperative and postoperative scores for each questionnaire. Anchor-based methods were used for calculation of PASS and SCB.[10,22,26] A response to the following "yes"/"no" anchor question was used for PASS: "Taking into account all the activities you have during your daily life, your level of pain, and also your functional impairment, do you consider that your current state is satisfactory?" (Fig 1). A receiver operating characteristic (ROC) curve was calculated using corresponding answers and final postoperative PROM scores. An area under the curve >0.7 and >0.8 was considered an acceptable and excellent predictor, respectively. The optimized sensitivity and specificity for each ROC were determined using the Youden index to select a final PASS threshold. Patients answered the following anchor question for SCB calculation: "Since your last surgery, has there been any change in your overall activity level as it is related to your knee?" Answers were selected from a range of 15 possible choices (Fig 1). A response of "A very great deal better," "A great deal better," or "A good deal better" were considered a substantial benefit. All other responses were determined to be less than substantial. The anchor question response and differences between preoperative and postoperative scores for each survey were used to generate a ROC curve, and thresholds were determined similarly to PASS.

Univariate and multivariate analyses were performed to determine factors associated with achieving MCID, PASS, or SCB for each questionnaire. Factors included in the analysis were age, BMI, performance of concomitant procedures, leg laterality, meniscal transplant laterality, number of prior procedures, preoperative PROM scores, sex, smoking status, and WC status. Multivariate regression analysis consisted of factors that were found to have a significance of $P < .15$ in univariate analysis.[10] On multivariate analysis, odds ratios and 95% confidence intervals were reported for variables significantly associated with achievement of CSO thresholds. Statistical significance was determined as $P < .05$. All statistical

Table 2. Established Thresholds for MCID, PASS, SCB at 5 Years

	MCID (N = 111)		PASS (N = 125)					SCB (N = 111)				
	Threshold	% Achieving	Threshold	% Achieving	SN	SP	AUC	Threshold	% Achieving	SN	SP	AUC
Lysholm	10.3	79.3	74.5	66.2	0.880	0.905	0.920	32.5	47.6	0.789	0.611	**0.701**
IKDC	12.1	75.0	55.6	69.4	0.917	0.905	0.945	29.1	42.0	0.719	0.676	**0.777**
KOOS												
Pain	11.0	72.0	70.7	72.8	0.897	0.759	0.882	25.1	44.0	0.719	0.737	0.800
SXS	11.0	61.3	60.8	70.3	0.842	0.727	0.867	19.6	45.3	0.709	0.743	0.811
ADL	10.5	58.2	90.3	59.1	0.821	0.818	0.892	17.9	41.2	0.589	0.611	**0.668**
Sport	16.2	59.3	47.4	62.6	0.810	0.773	0.850	37.5	40.1	0.769	0.789	0.817
QOL	13.6	67.0	40.5	63.0	0.832	0.864	0.900	37.3	35.8	0.742	0.825	0.813

ADL, activities of daily living; AUC, area under the curve; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; MCID, minimal clinically important difference; PASS, patient-acceptable symptomatic state; QOL, quality of life; SCB, substantial clinic benefit; SN, sensitivity; SP, specificity; SXS, symptoms.

Thresholds for MCID, PASS, and SCB were calculated for Lysholm, IKDC, and KOOS subscales. Bold indicates AUC values <0.800.

analyses were performed using RStudio software version 4.1.1 (RStudio, Boston, MA).

Results

Patient Demographics, Preoperative PROMs, and Surgical Details

During the study period, 463 primary MATs were performed (Fig 2). Eight patient records in the database were duplicates and thus excluded, whereas 1 patient had perished before the 5-year follow-up. Two patients underwent bilateral MAT, with 1 patient meeting inclusion criteria and the other being excluded. Sixty-two patients were younger than 18 years of age at the time of surgery, and 23 patients had met failure criteria before the 5-year follow-up. Therefore a total of 369 MATs performed in 371 patients were eligible for inclusion in the study (Fig 2). Five-year follow-up data were not available for 45.5% of MATs performed (n = 168/369), leaving a total of 201 MATs included in data analysis.

Mean patient age at time of surgery was 29.7 ± 8.5 years (range 18.1-53.7) with an average follow-up of 9.8 ± 4.1 years (range 5.0-16.3). No significant differences in patient sex, BMI, number of prior procedures, preoperative PROM scores, preoperative cartilage damage, or any concomitant procedures was observed between patients meeting inclusion criteria versus patients excluded (Table 1). Patients included in analysis were, however, older in age compared to those excluded ($P = .020$).

Medial MAT was performed in 56% (n = 114/202) of cases. Concomitant procedures were performed in 69% (n = 139/202) of cases at the time of primary MAT (Table 1). Seventy-six patients had an International Cartilage Repair Society grade IV in the index compartment, whereas 7, 13, and 8 patients had a grade III, II, and I lesion, respectively. Ninety-seven patients had no appreciable cartilage lesion.

Postoperative PROMs

Significant increases in all questionnaires for each timepoint analyzed (1-year, 2-year, and 5-year minimum follow-up) were appreciated when compared to baseline scores (Fig 3). Increases from preoperative and postoperative scores for Lysholm (46.4 and 74.0; $P < .001$), IKDC (38.8 and 65.7; $P < .001$), KOOS Pain (55.8 and 78.1; $P < .001$), KOOS Symptoms (56.7 and 70.2; $P < .001$), KOOS ADL (69.7 and 87.6; $P < .001$), KOOS Sport (30.4 and 54.6; $P < .001$), and KOOS QOL (24.7 and 51.2; $P < .001$), respectively. A significant increase in KOOS QOL scores at 2-year and 5-year minimum follow-up were observed when compared to 1-year follow-up scores ($P = .009$ and .046, respectively). No other significant increases were appreciated when postoperative timepoints were compared.

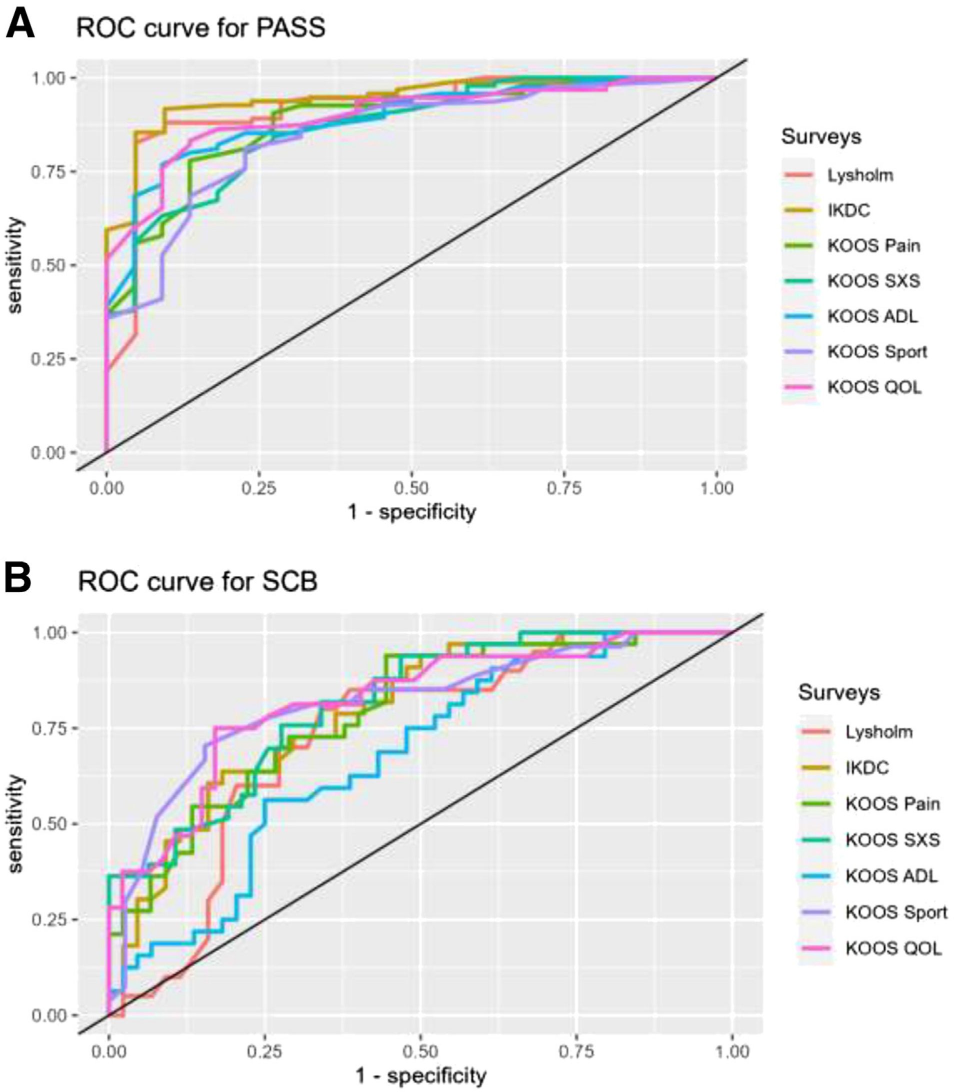

Fig 4. To determine thresholds for achieving a clinically significant outcome, a receiver operating characteristic (ROC) analysis fo Lysholm, International Knee Documentation Committee (IKDC), and Knee injury and Osteoarthritis Outcome Score (KOOS) were made for (A) patient-acceptable symptomatic state (PASS) and (B) substantial clinic benefit (SCB). The area under the curve was greater than 0.700 for all surveys with the exception of KOOS activities of daily living (ADL) for SCB (area under the curve = 0.692). QOL, quality of life; SXS, symptoms.

Clinically Significant Outcome Analysis

The calculated thresholds for achievement of MCID, PASS, and SCB for Lysholm, IKDC, and KOOS subscales are listed in Table 2, along with the percent of patients meeting each CSO threshold. The majority of ROC analyses met criteria for excellent prediction capabilities based on area under the curve. Acceptable and unacceptable predictive capabilities were met by 2 (Lysholm and IKDC questionnaires for SCB) and 1 (KOOS ADL subscale for SCB) ROC curves, respectively. ROC curves for PASS and SCB are presented in Figures 4A and 4B, respectively.

On multivariate analysis, higher preoperative scores were associated with failure to achieve MCID for all PROMs (Table 3). Male sex was associated with failure to achieve MCID for the subjective IKDC score and KOOS QOL survey while higher BMI and WC status was associated with failure to achieve MCID for the KOOS Pain and ADL subscales, respectively. Performance of a concomitant lower extremity realignment procedure was associated with failure to meet MCID for the KOOS Symptoms subscale.

A failure to achieve PASS for the Lysholm and KOOS Symptoms and QOL subscales was associated with lower preoperative scores (Table 4). WC status and increasing age were associated with failure to achieve PASS for the subjective IKDC score and KOOS Sport questionnaires. Increased BMI (particularly when >30.0) was associated with failure to meet PASS for KOOS ADL and Pain surveys.

Higher preoperative PROM scores were associated with failure to achieve SCB for all questionnaires (Table 5). WC status was associated with failure to achieve SCB for the Lysholm and KOOS Pain surveys Smoker status, leg laterality, MAT laterality, performance of concomitant ligament reconstruction or

Table 3. Logistic Regression of Variables Associated With Achieving MCID (N= 145)

	P value		Odds Ratio (95% CI)
	Univariate	Multivariate	
Lysholm			
Preoperative score	**.008**	**.006**	**0.956 (0.922-0.989)**
ACL	.121	.115	0.299 (0.066-1.421)
IKDC			
Preoperative score	**.005**	**.001**	**0.938 (0.900-0.972)**
Sex (F)	**.018**	**.016**	**3.886 (1.353-12.574)**
Age	.094	**.024**	**0.934 (0.878-0.989)**
KOOS Pain			
Preop score	**<.001**	**<.001**	0.885 (0.830-0.930)
ACL	.088	.520	0.574 (0.106-3.284)
BMI	**.027**	**.004**	**0.784 (0.655-0.916)**
BMI ≥ 25.0	**.014**	**.003**	**0.105 (0.020-0.433)**
BMI ≥ 30.0	**.005**	**.002**	**0.085 (0.016-0.360)**
Sex (F)	**.024**	.175	2.324 (0.700-8.286)
KOOS Symptoms			
Preoperative score	**<.001**	**<.001**	**0.930 (0.898-0.959)**
Realignment	.261	**.038**	**0.192 (0.037-0.877)**
KOOS ADL			
Preoperative score	**<.001**	**<.001**	0.913 (0.875-0.945)
WC	.350	**.012**	**0.116 (0.019-0.574)**
KOOS Sport			
Preoperative score	**<.001**	**<.001**	**0.953 (0.929-0.976)**
Sex (F)	.126	.117	2.201 (0.834-6.094)
KOOS QOL			
Preoperative score	**.020**	**.007**	**0.962 (0.934-0.988)**
Sex (F)	**.149**	**.043**	**2.552 (1.055-6.550)**

ACL, anterior cruciate ligament reconstruction; ADL, activities of daily living; BMI, body mass index; F, female; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; MCID, minimally clinical important difference; QOL, quality of life; WC, worker's compensation status.

Regression analysis of variables associated with meeting MCID was performed. Variables were included in multivariate analysis if they achieved an α value < 0.15 on univariate analysis. Bold indicates multivariate *P*-value <.05.

cartilage restoration procedures, and the number of previous procedures within the index compartment were not associated with failure to achieve CSOs.

Discussion

The primary finding from this investigation was the establishment of thresholds for MCID, PASS, and SCB, respectively, at a minimum 5-year follow-up for Lysholm (10.3, 74.5, and 32.5), IKDC (12.1, 55.6, and 29.1), KOOS Pain (11.0, 70.7, and 25.1), KOOS Symptoms (11.0, 60.8, and 19.6), KOOS ADL (10.5, 90.3, and 17.9), KOOS Sport (16.2, 47.4, and 37.5), and KOOS QOL (13.6, 40.5, and 37.3) questionnaires in patients following primary MAT. Failure to achieve CSO thresholds after primary MAT at 5-year follow-up was associated with increased patient age and BMI, male sex, performance of concomitant realignment procedure, and WC status. Higher PROM scores were associated with failure to achieve MCID and SCB whereas lower preoperative PROM scores were associated with failure to achieve PASS. Our hypothesis was partially confirmed because failure to achieve SCB and MCID was associated with higher preoperative PROMs, and increased age was observed with failure to achieve CSOs on multivariate analysis.

Defining patient success within the context of achievement of MCID, PASS, and SCB has become an important focus of orthopaedic literature.[15] Previous work by Nwachukwu et al.[22] in the area of hip arthroscopy for femoroacetabular impingement syndrome demonstrated that higher outcome scores may be required to successfully meet MCID, PASS, and SCB thresholds as follow-up time increases. We did not attempt to calculate CSO thresholds at 1 and 2 years after surgery in this study because these values have been previously reported using a cohort of patients from the same senior author.[10,14] With 98 patients completing questionnaires at a 1-year timepoint, Liu et al.[10] calculated MCID and PASS thresholds that were frequently lower than the values reported in the present study, with the exceptions of MCID for Lysholm (12.3 vs 10.3) and KOOS QOL (14.6 vs 13.6) and PASS for KOOS Symptoms (73 vs 60.8) and QOL (53 vs 40.5). In a 2-year minimum follow-up study that analyzed the associations of sex and age with MAT outcomes, Frank et al.[14] calculated MCID values for IKDC (11.2) and KOOS Symptoms (10.3). When collated from these separate studies, the MCID thresholds for IKDC (9.9, 11.2. and 12.1) and KOOS Symptoms (9.7, 10.3, and 11.0) increased at 1-year, 2-year, and most-recent follow-up after MAT, demonstrating an analogous trend to the findings of Nwachukwu et al.[22] Although the increase in MCID threshold calculated via the distribution-based method is logically correlated with an overall increase in PROM scores, increasing anchor-based PASS and SCB thresholds may that suggest higher patient expectations are required to maintain a clinically meaningful outcome at midterm follow-up.

With respect to proportion of each cohort that achieved CSOs, Liu et al.[10] reported 71%, 54%, 46%, and 36% of their cohort meeting PASS for Lysholm, IKDC, KOOS Symptoms, and KOOS QOL, respectively. A greater proportion of our cohort met PASS for IKDC (69%), KOOS Symptoms (70%), and KOOS QOL (63%), whereas a smaller proportion met PASS for Lysholm (66%). This finding may partially be explained by variations in sensitivities and specificities, as well as a trend toward increasing PROM scores at most-recent follow-up when compared to 1-year follow-up in our investigation. This was especially apparent for KOOS QOL (51.2 vs 43.8, respectively; $P = .043$). Although the proportion of patients who achieved 1-year MCID was not reported by Liu et al.,[10] Frank et al.[14] determined that 61.5% and 60% of patients met MCID for IKDC and KOOS Symptoms at 2 years minimum,

Table 4. Logistic Regression of Variables Associated with Achieving PASS (N = 201)

	P Value		
	Univariate	Multivariate	Odds Ratio (95% CI)
Lysholm			
Preop score	**.016**	**.031**	**1.032 (1.004-1.064)**
Leg laterality (R)	.068	.507	1.381 (0.530-3.620)
WC	**.049**	.562	0.643 (0.137-2.920)
IKDC			
Age	**.010**	.095	0.966 (0.927-1.005)
Leg laterality (R)	.070	.076	1.898 (0.939-3.897)
Sex (F)	**.044**	.152	1.674 (0.829-3.425)
WC	**.005**	**.024**	**0.284 (0.091-0.839)**
KOOS Pain			
Age	**.002**	**.022**	**0.949 (0.907-0.992)**
BMI	**.004**	.053	0.949 (0.827-1.001)
BMI ≥ 25.0	**.018**	.246	0.560 (0.225-1.444)
BMI ≥ 30.0	**.014**	**.047**	**0.393 (0.155-0.996)**
Laterality (R)	.140	.188	1.711 (0.771-3.861)
Sex (F)	**.030**	.509	1.336 (0.564-3.197)
WC	**.015**	.225	0.500 (0.161-1.553)
KOOS Symptoms			
Preop score	**.011**	**.018**	1.029 (1.005-1.055)
Realignment	**.048**	.193	0.418 (0.108-1.573)
KOOS ADL			
Preop score	**.020**	.139	1.020 (0.994-1.049)
BMI	**.010**	**.028**	0.875 (0.773-0.983)
BMI ≥ 25.0	**.011**	.061	0.560 (0.225-1.444)
BMI ≥ 30.0	**.033**	**.015**	0.216 (0.058-0.707)
Age	**.012**	.755	1.008 (0.956-1.066)
Leg laterality (R)	**.013**	.058	2.586 (0.984-7.157)
Sex (F)	**.029**	.130	2.135 (0.800-5.822)
WC	**.023**	.459	0.582 (0.128-2.386)
Meniscus laterality (lat)	**.047**	.810	0.882 (0.313-2.459)
KOOS Sport			
Age	**.018**	**.045**	0.962 (0.926-0.998)
WC	.061	.164	0.472 (0.158-1.355)
KOOS QOL			
Preop score	**<.001**	**.041**	**1.028 (1.002-1.057)**
Laterality (R)	.133	.981	1.010 (0.437-2.303)

ADL, activities of daily living; BMI, body mass index; F, female; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; lat, lateral; PASS, patient-acceptable symptomatic state; QOL, quality of life; R, right; WC, worker's compensation status.

Regression analysis of variables associated with meeting PASS was performed. Variables were included in multivariate analysis if they achieved an α value < 0.15 on univariate analysis. Bold indicates multivariate *P*-value <.05.

respectively. Similarly, a greater proportion of our cohort achieved MCID for IKDC (75%); however, a comparable proportion achieved MCID for KOOS Symptoms (61%). The large variation in proportion of patients who met MCID for IKDC may be due to lower baseline IKDC scores in our cohort (38.8) compared to those reported in Frank et al.[14] (43.1), whereas final follow-up scores were marginally higher in our study (65.7), compared to Frank et al.[14] (64.1). Accordingly, a small difference in the thresholds for meeting MCID for IKDC found in the present study (12.1) compared to Frank et al.[14] (11.2) may have resulted in a larger proportion of patients who achieved MCID.

Similar to Liu et al.[10] and other studies examining CSOs, the present study found higher preoperative PROM scores to be associated with failure to meet MCID and SCB, yet higher scores were associated with achieving PASS.[27,28] This may reflect the differences in how each CSO is calculated, because MCID is a measure of difference in preoperative and postoperative scores, whereas PASS is an absolute satisfaction threshold. As such, patients possessing higher level of function and CSO before surgery for primary MAT should be counseled that although improvement may be expected, a "ceiling effect" may be possible in which a clinically significant improvement in some CSO metrics may be difficult to attain.

Various patient demographics and intraoperative variables have been shown to be associated with inferior clinical outcomes. Unfortunately, there was a lack of homogeneity with regard to whether a variable was associated with failure to achieve more than 1 CSO. For example, BMI, particularly over the threshold of 30, was associate with failure to achieve both MCID and PASS. However, this relationship was not appreciated for failure to achieve SCB. Besides preoperative PROM

Table 5. Logistic Regression of Variables Associated with Achieving SCB (N = 145)

	P value		
	Univariate	Multivariate	Odds Ratio (95% CI)
Lysholm			
Preoperative score	**<.001**	**<.001**	**0.908 (0.866-0.943)**
WC	.371	**.008**	**0.073 (0.009-0.449)**
IKDC			
Preoperative score	**<.001**	**<.001**	**0.926 (0.890-0.957)**
Realignment	.131	.314	2.304 (0.465-13.208)
KOOS Pain			
Preoperative score	**<.001**	**<.001**	**0.873 (0.821-0.916)**
Sex (F)	.082	.066	3.016 (0.971-10.548)
WC	.309	**.004**	**0.077 (0.011-0.393)**
KOOS Symptoms			
Preoperative score	**<.001**	**<.001**	**0.926 (0.895-0.953)**
KOOS ADL			
Preoperative score	**<.001**	**<.001**	**0.904 (0.864-0.937)**
Realignment	.128	.079	5.197 (0.876-3.751)
KOOS Sport			
Preoperative score	**<.001**	**<.001**	**0.964 (0.939-0.986)**
Sex (F)	.126	.114	2.131 (0.844-5.596)
KOOS QOL			
Preoperative score	**<.001**	**<.001**	**0.945 (0.914-0.973)**

ADL, activities of daily living; BMI, body mass index; F, female; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; lat, lateral; QOL, quality of life; SCB, substantial clinical benefit; WC, worker's compensation status

Regression analysis of variables associated with meeting SCB was performed. Variables were included in multivariate analysis if they achieved an α value < 0.15 on univariate analysis. Bold indicates multivariate *P*-value <.05.

score, WC status was the only tested variable that was associated with failure to achieve MCID, PASS, and SCB. Previous studies have found mixed evidence regarding the influence of WC status on outcomes after MAT. A 2019 systematic review by Fanelli and colleagues[19] found that only 1 of 4 studies appreciated inferior PROMs among those with a WC claim. Liu et al.[10] described reduced odds of achieving the MCID for the subjective IKDC score and KOOS ADL questionnaires on multivariate analysis. In those who do achieve MCID or PASS, the presence of a WC has been associated with a delay in time to achieving these CSOs.[13] It should be noted that data regarding patient variables such as WC status and long-term CSOs are limited, however, and warrant further study. Given the findings in this study, surgeons should carefully consider patient's baseline status and demographic variables before counseling midterm outcomes after MAT.

Limitations

This study is not without limitations. Patients included in this study were treated by a single surgeon with a referral practice of post-meniscectomized, symptomatic patients and thus a high-volume MAT practice, which may limit generalizability of these findings for patients undergoing MAT at other institutions with other surgeons. A majority of included patients underwent a concomitant procedure, which is a limitation to generalizing failure to achieve CSOs to isolated, primary MAT, as resultant heterogeneity likely confounds the calculated CSO thresholds. Given the midterm follow-up, it is difficult to consistently collect patient data, because many of the patient included in our analysis were referred from distance geographic locations because of the expertise of the treating surgeon. As such, a major limitation of our study is the follow-up rate of 61%, because there is also potential for selection bias within the data. Furthermore, only 45% (n = 125/275) of patients completed satisfaction questionnaires, further increasing the risk of selection bias. A potential nonresponder bias is present because follow-up at the 10- and 15-year timepoints was limited, which may have influenced the long-term survival rates. MCID was calculated using the distribution method, which is less subjective than anchor-based methods, but likely inferior for assessment of actual patient-perceived postoperative changes.[29]

Conclusion

This study established the MCID, PASS, and SCB at 5-year minimum follow-up for the Lysholm score, IKDC, and KOOS subscales in patients who underwent MAT. Increased BMI, patient sex and age, performance of concomitant procedures, preoperative PROM scores, and WC status were associated with failure to achieve CSOs after primary MAT at a minimum of 5 years' follow-up.

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