Original Article

Arthroscopic Medial Meniscal Root Reconstruction With Gracilis Autograft Is Safe and Improves 2-Year Postoperative Patient-Reported Outcomes

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Purpose: To describe patient-reported clinical outcomes and complications of anatomic medial meniscal root reconstruction with gracilis autograft. **Methods:** Data on patients who underwent arthroscopic medial meniscal root reconstruction with gracilis autograft were prospectively collected between 2017 and 2021 and retrospectively reviewed. The inclusion criteria were symptomatic posterior medial meniscal LaPrade type 2 root tears with no more than Outerbridge grade 2 chondrosis of any knee compartment with a minimum follow-up period of 1 year. Patients with ligamentous instability and those with Workers' Compensation status were excluded. Patient-reported outcomes (12-item Short Form Survey [SF-12], visual analog scale [VAS], Western Ontario and McMaster Universities Arthritis Index [WOMAC], and Lysholm scores) were collected prospectively and analyzed retrospectively and were scored and recorded both preoperatively and at postoperative intervals. Data were analyzed using cubic spline regression models. The study was approved by the University of South Carolina Institutional Review Board. **Results:** A consecutive series of 27 patients treated by a single surgeon were evaluated. Twenty-one patients were included for data analysis (4 were excluded per criteria and 2 were lost to follow-up) with an average age of 48.1 years (range, 16-63 years). There were 18 female and 3 male patients. The average follow-up time was 25.2 months (range, 12-42 months). At the postoperative time points captured by the data examined, improvements in Lysholm, WOMAC, VAS, and SF-12 physical component summary scores were found to be statistically significant ($P < .001$, 95% confidence interval). Improvements in SF-12 mental component summary scores, however, did not reach the level of statistical significance ($P = .262$). Body mass index greater than 35 and age greater than 50 years were not found to be negative predictors of outcomes. Average patient-reported outcomes at 2 years' follow-up improved from preoperatively as follows: Lysholm score, from 50 to 82.9; WOMAC score, from 53.9 to 87.4; and VAS score, from 5.1 to 1.2. No serious complications were observed. **Conclusions:** Patients undergoing posterior medial meniscal root reconstruction showed statistically significant improvements in Lysholm, WOMAC, SF-12 physical component summary, and VAS scores but not SF-12 mental component summary scores at short-term follow-up. No serious complications or clinical failures occurred, and no patients required revision surgery. **Level of Evidence:** Level IV, case series.

The meniscus plays a significant role in overall knee biomechanics, including force transmission, load distribution, and stability.[1,2] Meniscal tears are one of the most common knee injuries, accounting for 12% to 14% of all orthopaedic presentations involving the knee.[3-5] Meniscal root tears were first described in 1991 by Pagnani et al.,[6] and meniscal root tears posteriorly constitute 7% to 9% of all meniscal injuries diagnosed.[7,8] Meniscal root tears have been highly studied. Studies have noted that complete tears lead to a nonfunctioning meniscus, leaving the condition of the injured side equivalent to a complete meniscectomy.[9] Subsequently, amplified tibiofemoral contact pressures will occur with a diminished contact surface area, which has been shown to strongly correlate with

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accelerated progression of symptomatic joint arthrosis.[10,11] Given the increasing recognition of these injuries and the known pathologic progression, there has been a growing effort to restore meniscal integrity and re-establish normal knee biomechanics via surgical intervention.[12,13]

Recently, there have been investigations into meniscal root anatomy and techniques to repair meniscal root injuries in hopes to restore normal knee mechanics. Performing meniscal root repair rather than meniscectomy is supported by the current literature, and this procedure has shown encouraging results of improved knee function at 5 years' follow-up.[14] Although encouraging results have been reported, the repair techniques do not provide any additional substance to stimulate biological healing directly at the meniscus-tibia interface. Li et al.[15] observed fibro-chondrogenic metaplasia and chondroprotective properties of the meniscus using tendon autograft in a rabbit model. In addition to repair techniques, reconstruction techniques using autograft have been developed.[16-18] To our knowledge, the clinical outcomes of these techniques have not been previously reported and therefore warrant further evaluation.

The purpose of this study was to describe patient-reported clinical outcomes and complications of anatomic medial meniscal root reconstruction with gracilis autograft. The primary focus was to evaluate whether reconstruction using tendon autograft changed patient-reported outcome (PRO) measures and knee function. We hypothesized that medial meniscal root reconstruction with gracilis autograft would result in statistically significant improvements in PROs with minimal complications.

Methods

Data were collected between 2017 and 2021. The inclusion criteria were symptomatic posterior medial meniscal root tears with no more than Outerbridge grade 2 chondrosis of any knee compartment. All patients meeting the inclusion criteria within the study period were treated with arthroscopic medial meniscal root reconstruction with gracilis autograft. The exclusion criteria included Workers' Compensation status and concomitant ligamentous repair. Neither age, body mass index (BMI), alignment, nor concomitant chondroplasty was an exclusion criterion.

Chondroplasty was performed with an arthroscopic shaver in patients with grade 2 chondromalacia with unstable articular cartilage. A consecutive series of patients with meniscal root tears were treated with the described procedure performed by a single surgeon (S.W.H.).[17] Four-view standing radiographs and a magnetic resonance imaging scan were obtained for each patient—the latter to establish the definitive diagnosis of a meniscal root tear and the former to determine the preoperative Kellgren-Lawrence (KL) score. Ligamentous stability was confirmed by physical examination and preoperative imaging findings. Five PRO measures were scored and recorded at both preoperative and postoperative intervals. This retrospective study of prospectively collected clinical quality measures received institutional review board approval.

PRO Instruments

Five PRO measures were used for subjective evaluation of postoperative functional progress, pain, and overall mental and physical well-being: Lysholm knee score,[19] Western Ontario and McMaster Universities Arthritis Index (WOMAC),[20,21] 12-item Short Form Survey (SF-12),[22] and visual analog scale (VAS) for pain.[23]

Surgical Technique

The basic concept of the arthroscopic surgical technique is to create a high-strength repair with sutures and an InternalBrace (Arthrex), followed by augmentation with gracilis autograft. The most challenging part of this surgical technique is working in the posterior aspect of the knee in the narrow space of the medial compartment with currently available instrumentation. All patients were treated by a single surgeon (S.W.H.) using the technique described by Holmes et al.[17]

The patient was positioned supine on the operating table, and arthroscopic portals were established. An examination under anesthesia was performed to confirm ligamentous stability. A "pie-crusting" technique was performed with an 18-gauge needle to release the superficial medial collateral ligament and improve visualization. Intraoperative inclusion criteria were (1) a confirmed LaPrade type 2 meniscal root tear[24] with no other tear or degeneration of the medial meniscus and (2) no greater than Outerbridge grade 2 chondrosis in any compartment. Provided that the inclusion criteria were met, the meniscal root reconstruction commenced.

To obtain the gracilis graft, a small incision was made over the anterior medial tibia, the sartorius was elevated, the gracilis was dissected free, and a tendon stripper was used to harvest the graft. The graft was prepared on the back table using No. 0 FiberLoops (Arthrex) to control each end. The final length of the graft was no more than 8 cm, and it was tapered to fit through 3-mm tunnels; the doubled or folded graft fit through a 6-mm tunnel.

A central transpatellar tendon portal was established for suture management. Through the incision used for graft harvest, a meniscal root guide was used to position a FlipCutter (Arthrex) for anatomic tunnel reaming. A 6-mm-diameter tibial tunnel was then reamed in a retrograde fashion in the anatomic position of the posterior medial meniscal root to a depth of 30 mm.

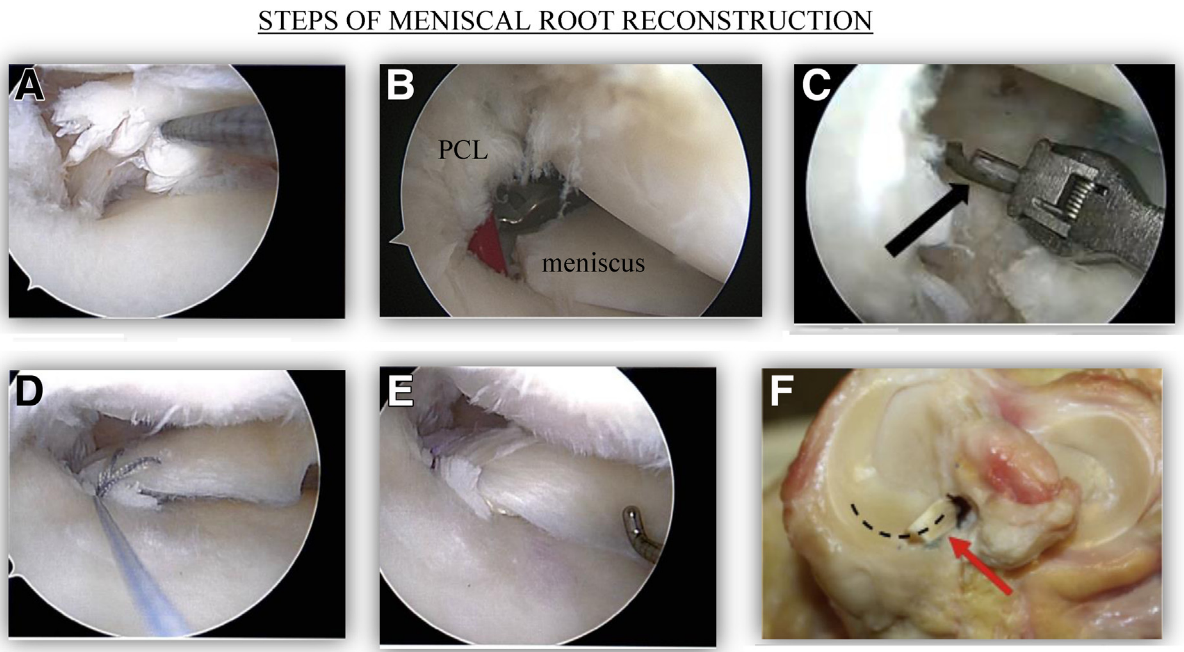

Fig 1. (A) Posterior medial meniscal root tear. (B) Tunnel placement viewed through anterolateral portal centered in posterior medial meniscal root insertion marked by red straw (Arthrex TigerStick). (C) Suture shuttle passage with Arthrex Knee Scorpion viewed through anterolateral portal. A white No. 0 FiberLink shuttle (black arrow) is used to shuttle all sutures and the InternalBrace through the meniscus. (D) Sutures and InternalBrace passed and shuttled into tibial tunnel. (E) Final construct with graft passed through meniscus and into tibial tunnel. (F) Disarticulated right knee showing anatomic positioning of graft (red arrow) in cadaveric specimen. The black dashed line indicates the restored meniscal contour. (PCL, posterior cruciate ligament.)

A TigerStick (Arthrex) was passed into the tunnel for suture shuttling (Fig 1B).

All suture passing through the meniscus was performed using a Knee Scorpion (Arthrex) (Fig 1C), and a No. 0 FiberLink (Arthrex) shuttle was used to shuttle the larger suture through the meniscus. A collagen-coated braided SutureTape (Arthrex) was passed in an inverted, longitudinal orientation. This was placed 1 to 2 mm from the meniscosynovial junction and 4 to 5 mm medially from the edge of the tear. The tails were retrieved from the inferior surface of the meniscus, shuttled through the tibial tunnel, and parked for later fixation. Next, a 1.3-mm SutureTape was passed in mattress fashion through the meniscus 3 to 4 mm from the edge of the tear; the tails were retrieved from the superior surface of the meniscus and then shuttled into the tibial tunnel.

The gracilis graft was passed through the meniscus about 8 to 10 mm from the torn edge of the tear 1 to 2 mm from the meniscosynovial junction. A soft-tissue “tunnel” was created through the meniscus by passing successively larger sutures through the meniscus. This was accomplished by passing the FiberLink shuttle and then shuttling a folded 2.0-mm FiberTape (Arthrex) from superior to inferior through the meniscus. The tails of the FiberTape were low-diameter suture, but the doubled FiberTape was relatively high diameter. By use of a back-and-forth sawing motion, the FiberTapes were worked back and forth several times until they would easily glide through the meniscus. The loop of the FiberTape was used to shuttle the graft suture and the graft itself through the meniscus. The lengths of graft superiorly and inferiorly were equalized; then, the tails were shuttled into the tibial tunnel. The SutureTapes and InternalBrace were fixed to the tibia outside the tunnel with a 4.75-mm SwiveLock suture anchor (Arthrex) while the meniscus was arthroscopically visualized to ensure it was in anatomic position. The graft was tensioned, and the graft suture tails were then fixed in the same manner under direct arthroscopic visualization. The knee was cycled through a 0° to 120° range of motion several times, and the construct was probed and visualized to ensure excellent fixation. An arthroscopic view of the final construct is shown in Figure 1E. In addition, for clarity, Figure 1F shows the final construct in a disarticulated knee specimen to orient the reader to the approximate dimensions and anatomic position of the graft.

Rehabilitation

Postoperatively, patients were restricted to toe-touch weight bearing for 6 weeks in a hinged brace, with the

Table 1. Patient Demographic Characteristics and Preoperative Findings (N = 21)

	Data
Age, yr	48.1 (45.0, 53.0)
BMI	31.9 (26.8, 38.4)
Sex: female	18 (85.7)
Laterality: right	9 (42.9)
Kellgren-Lawrence score	
0	10 (47.6)
1	8 (38.1)
2	3 (14.3)

NOTE. Data are reported as mean (interquartile range) or number (percentage).
BMI, body mass index.

Table 2. Concurrent Treatment and Intraoperative Findings (N = 21)

	Data
Chondromalacia	
Grade ≤ 1	10 (47.6)
Grade 2	11 (52.3)
1 Compartment	3
2 Compartments	4
3 Compartments	4
Concurrent treatment	
Lateral release	1 (4.8)
Plica excision	1 (4.8)
PRP injection	2 (9.5)
Debridement of synovitis	1 (4.8)
Chondroplasty	11 (52.4)
1 Compartment	3
2 Compartments	5
3 Compartments	3

NOTE. Data are reported as number (percentage).
PRP, platelet-rich plasma.

brace initially locked in full extension for 2 weeks. The brace settings were gradually liberalized thereafter based on patient tolerance, and use of the brace was discontinued at 6 weeks. Physical therapy was initiated by postoperative day 3, beginning with isometric and range-of-motion exercises. Patients were allowed to increase motion as tolerated with the physical therapist, but no forced passive flexion beyond 90° was allowed in the first 6 weeks. Patients were allowed weight bearing as tolerated after 6 weeks but were instructed to avoid deep squatting until a minimum of 4 months. Progressive resistance exercises were performed after 6 weeks. Impact-loading activities such as running or aerobics were discouraged until 6 months postoperatively.

Statistical Analysis

Independent variables were analyzed using a cubic spline regression model. For respective PRO instruments, a series of cubic spline models were generated, which considered different combinations of independent factors as predictors of the PROs. The following independent predictors of PROs were considered: time, preoperative KL score (dichotomized to a score of 0), BMI (dichotomized to 35), sex, age (dichotomized to 50 years), and whether the patient received intraoperative chondroplasty. A preferred model was selected for each PRO. Within the models, a coefficient was calculated to describe the effect (magnitude and direction) of each independent variable on the PRO in question. The *P* value was generated for each coefficient, determining the statistical significance of the effect of a given variable on the given PRO.

Results

Demographic Characteristics

Twenty-seven patients met the inclusion criteria for this study. No patient required revision surgery, nor were there any patients who received bilateral treatment. Four patients who received the operation were excluded from this study: 3 on the basis of concomitant ligamentous repair (posterior cruciate ligament in 2 and medial collateral ligament in 1), and 1 on the basis of worker's compensation status. Two patients were lost to follow-up. Table 1 includes demographic characteristics associated with the 21 knees that underwent the aforementioned operation. Overall, the PROs of 18 female and 3 male patients were analyzed. The mean age of participants was 48.1 years, ranging from 16 to 63 years. The entire cohort had an average BMI of 31.9, with an interquartile range of 26.8 to 38.4. On the basis of preoperative radiographs, 10 participants had a KL score of 0, 8 had a KL score of 1, and 3 had a KL score of 2. Table 2 presents intraoperative findings and subsequent procedures performed concurrently with the index surgical procedure. The most common concomitant procedure was chondroplasty.[11]

PRO Outcomes

For evaluation of average PRO scores at last follow-up, the cohort was considered separately as the group that achieved a postoperative follow-up period of 12 months or greater (entire group) and the group with a follow-up period of 24 months or greater. Table 3 presents average observed PRO scores for each of these groups, as well as all preoperative PRO scores recorded. Notably, all PRO scores in both groups improved over the study period except the SF-12 mental component summary (MCS) score.

Cubic Spline Regression: Observed Versus Predicted PROs

A cubic spline regression model was used to evaluate all participants in the study. Figure 2 graphically depicts the observed and predicted PRO scores. Notably, the improvements in all PRO scores, except the SF-12 MCS score, were statistically significant.

Table 3. PRO Scores

PRO Instrument	Preoperative PRO Score: All Participants Considered	PRO Score at Last Follow-up	
		Follow-up ≥ 12 mo (N = 21)	Follow-up ≥ 24 mo (n = 16)
Lysholm score	50.0 (12)	81.1 (74.0, 94.0)	82.9 (78.5, 94.3)
WOMAC score	53.9 (12)	87.4 (89.7, 97.0)	87.4 (87.9, 97.4)
SF-12 PCS score	32.9 (10)	49.4 (44.1, 56.0)	49.6 (44.9, 55.9)
SF-12 MCS score	52.8 (9)	56.2 (53.9, 60.8)	57.4 (54.5, 61.3)
VAS score	5.1 (8)	1.0 (0.0, 2.0)	1.2 (0.0, 2.3)

NOTE. Data are reported as mean (interquartile range).
MCS, mental component summary; PCS, physical component summary; PRO, patient-reported outcome; SF-12, 12-item Short Form Survey; VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

The magnitude and nature of several independent predictors' effect on PROs are presented in Table 4. Male sex was found to be a statistically significant predictor of improvements in the Lysholm score (18.3 points, $P < .001$) and WOMAC score (11.4 points, $P = .001$). Age of 50 years or younger predicted a negative impact on the WOMAC score (10.4 points, $P = .02$). The preoperative KL score predicted a positive impact on the Lysholm score (9.7 points, $P = .05$). All other independent predictors were not statistically significant in their impact on any of the other PROs collected.

Discussion

The primary findings of this study were as follows: (1) Medial meniscal root reconstruction with gracilis autograft significantly improved ($P < .001$) PROs (Lysholm, WOMAC, SF-12 physical component summary [PCS], and VAS scores) over our study's follow-up period. (2) This procedure had a low complication rate with no major complications observed during the study period. Changes in SF-12 MCS scores did not reach the level of statistical significance.

Owing to myriad factors within the intra-articular environment, meniscal healing rates and extrusion of all types of repairs are not ideal.[25,26] Thus, our rationale for adding a graft to our repair was to theoretically increase meniscus-to-bone healing by introducing additional collagenous tissue and reduce extrusion by potentially increasing the strength of the repair at time zero. In essence, a biological bridge is created with increased strength. Our initial research began with a search for higher-strength repairs and eventually lead us to the concept of reconstruction. Another goal was to create a repair strong enough to allow full weight bearing at an earlier stage than 6 weeks. However, although we believe that we can allow full weight bearing before 6 weeks, we have been reluctant to do so before we have more data and experience regarding the strength of the repair. We have performed biomechanical testing on 4 cadaveric specimens using our root reconstruction technique (S.W.H., January 2017). The ultimate load to failure of the 4 specimens averaged 208 N, which compares favorably with published data.[26,27] However, this evaluation was certainly not a rigorous study of the biomechanical properties of the root reconstruction construct.

The indications for the described procedure are essentially the same as those for medial meniscal root repair. That is, a symptomatic, medial meniscal root tear in a ligamentously stable knee with no more than Outerbridge grade 2 chondrosis is indicated for meniscal root reconstruction. Contraindications are ligamentous insufficiency, mechanical malalignment (>5°), inflammatory arthritis, bone collapse or deficiency, infection, and medial meniscal tear remote from the root tear. During the study period, we strictly adhered to the aforementioned indications. For example, during the study period, there were patients with meniscal root tears examined arthroscopically and found to have Outerbridge grade 3 or 4 chondromalacia or more extensive meniscal damage who did not undergo reconstruction and were instead treated with simple debridement. All meniscal root tears were LaPrade type 2 tears.[24] We did not subclassify the root tears by level of diastasis. A weakness of the study is the technical difficulty of the procedure and, therefore, the extended operative time compared with meniscal root repair.

Overall, at the postoperative time points captured by the data examined, improvements in Lysholm, WOMAC, VAS, and SF-12 PCS scores were found to be statistically significant ($P < .001$). Improvements in the SF-12 MCS score, however, did not reach the level of statistical significance ($P = .262$). All patients in this study underwent at least 12 months of follow-up (N = 21), and a subgroup was included that reached at least 24 months of follow-up (n = 16). Both the overall patient population and the subgroup with at least 2 years of follow-up showed improvements in PRO scores, suggesting that the initial improvement is durable past 2 years of follow-up. No negative trends were evident in our data. There was no control group comparing the described procedure with simple meniscal root repair. Further study will be needed to clarify the long-term outcomes.

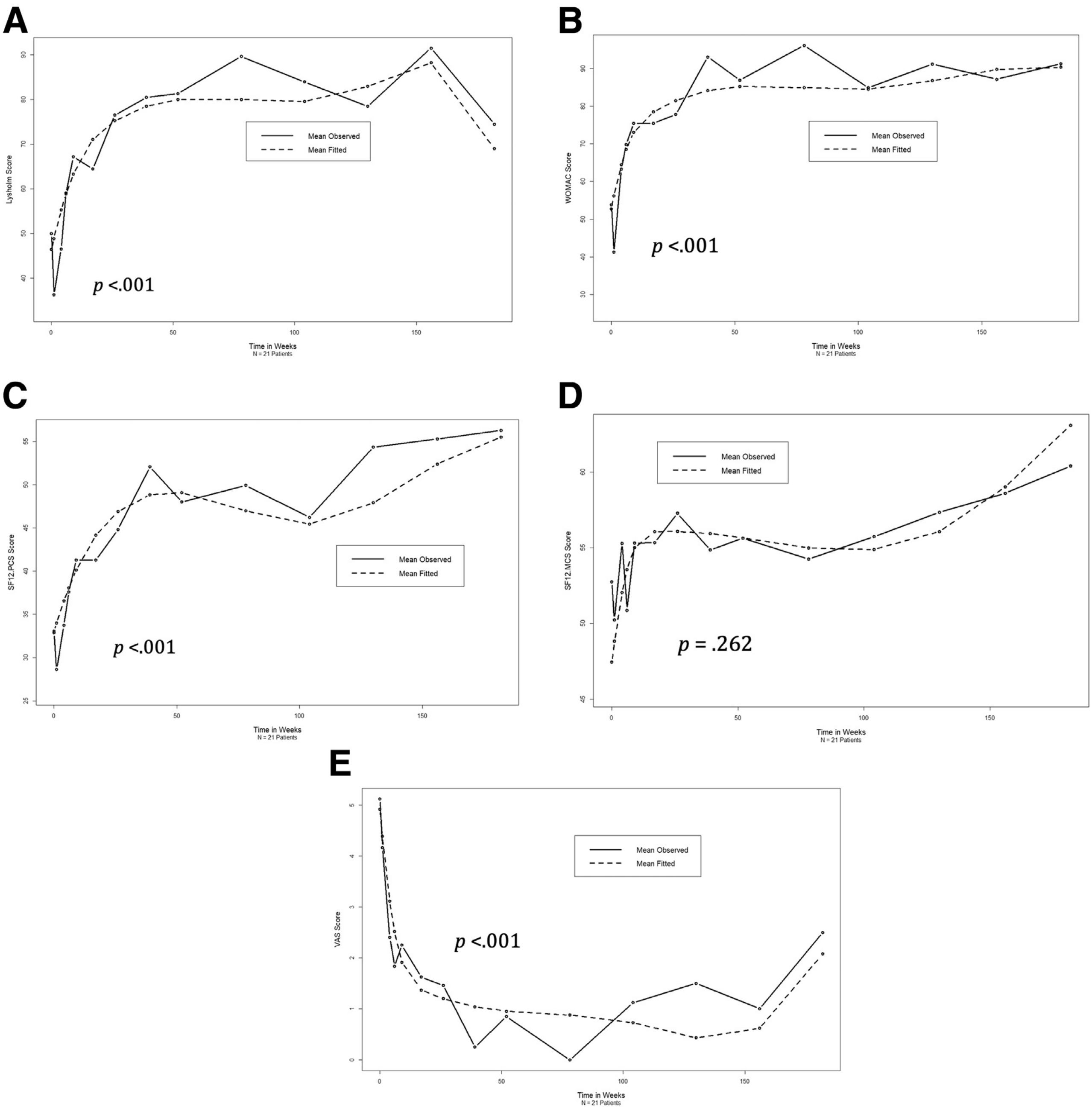

Fig 2. Mean and predicted longitudinal Lysholm scores (A), Western Ontario and McMaster Universities Arthritis Index (WOMAC) scores (B), 12-item Short Form Survey (SF-12) physical component summary (PCS) scores (C), SF-12 mental component summary (MCS) scores (D), and visual analog scale (VAS) scores (E) after medial meniscal root reconstruction with gracilis autograft. Superimposed on the average observed data at each postoperative time is the given patient-reported outcome's final model of generalized estimating equation linear regression with a cubic spline for time as the independent variable. The *P* value from the likelihood ratio test for the cubic spline time variable is included for each score.

Details concerning the impact of independent variables other than time on PROs were also investigated. The independent variables were sex, age of 50 years or younger, BMI greater than 35, and preoperative KL score. Other authors have found that an elevated BMI (>35) is a relative contraindication for root repair,[28] but we have not yet identified an overwhelmingly negative correlation with BMI. An increased preoperative KL score was not found to be a compelling predictor of a negative outcome. Likewise, increased age, overall, was not a negative predictor of patient outcomes. This finding correlates well with the findings of LaPrade et al.[29] on meniscal root repair, which showed good outcomes for age groups both above and below 50 years.

Table 4. Preoperative Predictors of PROs

	Independent Predictor: Male Sex		Independent Predictor: BMI > 35		Independent Predictor: Age ≤ 50 yr		Independent Predictor: Preoperative KL Score > 0	
PRO Instrument	Effect*	*P* Value†	Effect	*P* Value	Effect	*P* Value	Effect	*P* Value
Lysholm	18.3‡	<.001	4.0	.34	−7.7	.162	9.7‡	.05
WOMAC	11.4‡	.001	5.5	.25	−10.4‡	.02	6.5	.14
SF-12 PCS	5.5	.08	4.6	.09	−4.5	.07	7.3‡	.002
SF-12 MCS	6.0	.22	−3.1	.36	−1.8	.62	4.7	.17
VAS	0.65	.25	−0.65	.38	0.7	.34	−0.30	.65

MCS, mental component summary; PCS, physical component summary; SF-12, 12-item Short Form Survey; VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

*Coefficient for variable in linear regression with time modeled with a cubic spline and the other 3 variables in the model.

†*P* value for statistical test in which the null hypothesis is that the coefficient or effect is zero in the population sampled.

‡Statistically significant.

All patients were clinically evaluated during the postoperative period for complications including persistent pain, infection, neurologic injury, venous thrombosis, necessity for reoperation, and loss of motion. Patients typically required 10 to 12 weeks to regain full ROM (defined as ≤5° of contralateral-limb ROM), but no patient had persistent loss of motion beyond this interval. None of the other aforementioned complications were observed during the postoperative period. In summary, we believe that the described procedure is a safe procedure with few complications.

Future clinical investigations concerning medial meniscal root reconstruction should include, in addition to longer-term follow-up, objective measures such as postoperative magnetic resonance imaging to address extrusion and healing rates, as well as x-ray imaging to address progression of KL scores. In the future, it is our intent to complete rigorous biomechanical testing to assess cyclic displacement and ultimate failure loads with comparison to standard root repair.

Limitations

The limitations of this study include an incomplete preoperative data set (Table 3) and a relatively small sample size. The study population may not be representative of the general population, and a larger cohort will need to be studied. Within this study, no cohort undergoing debridement, conventional pullout suture repair, or nonoperative treatment was included to serve as a comparison group.

Conclusions

Patients undergoing posterior medial meniscal root reconstruction showed statistically significant improvements in Lysholm, WOMAC, SF-12 PCS, and VAS scores but not SF-12 MCS scores at short-term follow-up. No serious complications or clinical failures occurred, and no patients required revision surgery.

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