Technical Note

Clinical Outcome of Meniscus Centralization with Medial Meniscus Root Repair for the Extruded Medial Meniscus

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Purpose: The purpose of this study was to 1) describe the patient-reported clinical outcomes following medial meniscus root repair with meniscus centralization, and 2) identify common complications and detail provisional results. **Methods:** Patients undergoing medial meniscus root repair with meniscus centralization from 2020 to 2022 were identified using an institutional database. Patients were followed prospectively using postoperative Tegner Activity Scale, visual analogue scale (VAS) for pain, Knee Injury and Osteoarthritis Outcome Score, Joint Replacement (KOOS Jr.), International Knee Documentation Committee (IKDC) score, a Likert score for improvement, surgery satisfaction, and subsequent surgeries at minimum 1 year follow-up with mean 2-year follow-up. Demographics, injury characteristics, and surgical details were also collected. **Results:** Twenty-five patients (age: 50 ± 11 years; sex: 76% female; body mass index: 33 ± 8 kg/m^2) were included in this study. Postoperative Tegner score was maintained at preoperative levels ($P = .233$), while VAS at rest, VAS with use, KOOS Jr., and IKDC improved significantly postoperatively ($P = .003$; $P < .001$, $P < .001$, $P = .023$, respectively). Eighty-eight percent of patients reported subjective improvement in their knee at final follow-up. Postoperative radiographs did not show any significant OA progression, and no patients had undergone a revision meniscus surgery or total knee arthroplasty (TKA) at the time of follow-up. **Conclusion:** At minimum 1-year follow-up and mean 2-year follow-up, patients undergoing medial meniscus root repair with meniscus centralization demonstrated significant postoperative improvements in pain, function, and quality of life and reported high rates of surgery satisfaction. There was no evidence of significant arthritic progression on postoperative imaging, and no patients underwent revision meniscus surgery or TKA. **Level of Evidence:** Level IV, case series.

Introduction

The disruption of the medial meniscus posterior root has been shown to have deleterious effects on meniscus hoop stress leading to altered tibiofemoral mechanics.[1] Repair of medial meniscus posterior root tears (MMPRTs) has been shown to be effective at improving clinical outcomes;[2,3] however, medial meniscus extrusion (MME), generally defined as 3 mm or greater of extrusion of the meniscus outside of the border of the medial tibial plateau,[4] can persist even after well-performed anatomic repair.[5-7] Importantly, there is increasing recognition that MME may

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predispose individuals to MMPRTs, providing rationale of why MME is not always correctable with medial meniscus root repair.[8] Additionally, medial meniscus extrusion (MME) is an independent risk factor for knee osteoarthritis (OA).[1] Thus, there is now a focus on techniques to reduce MME.

Biomechanical studies have demonstrated that meniscus centralization with root repair may help reduce extrusion and protect the root repair.[5] Additionally, there is promising early clinical results in the centralization of the medial meniscus.[9] However, there is a paucity of data on patient outcomes after medial meniscus root repair with concomitant meniscus centralization. Therefore, the purpose of this study was to 1) describe the patient-reported clinical outcomes following medial meniscus root repair with meniscus centralization, and 2) determine common complications and provide provisional results at mean 2-year follow-up. It was hypothesized that by treating both the medial meniscus posterior root tear and the meniscus extrusion, patients would have significant improvements in pain and function.

Methods

After Institutional Review Board approval was obtained from the Mayo Clinic (15-000601), patients who underwent medial meniscus posterior root repair and meniscus centralization at the Mayo Clinic, Rochester, MN, from 2020 to 2022 were identified from a prospectively generated institutional database. MMPRT has been defined in the literature as a tear in the medial meniscus within 10 mm from the posterior root, with further categorization depending on tear characteristics.[10] All patients at our institution with suspected MMPRT received MRI imaging within 1 year of symptom onset, with specific timing contingent on severity and further exacerbation of symptoms. The diagnosis of MMPRT was established preoperatively through a combination of clinical suspicion based on patient-reported symptoms; MRI imaging demonstrating characteristic radiographic signs, signal intensity aberrancies, and anatomical abnormalities; and plain radiographs of the knee to assess for pathology, such as joint space narrowing, misalignment, and progression of arthritis.[10] Diagnosis was confirmed intraoperatively through arthroscopic visualization. Thirty-six patients who met inclusion criteria were initially identified. Exclusion criteria consisted of patients with less than 1-year follow-up, which left 25 patients in the final cohort included in this study.

Indications for Surgical Intervention Versus Conservative Treatment

Management algorithm is contingent on the timing of MMPRT. In chronic cases, nonsurgical approaches, such as physical therapy, are preferred where significant concomitant meniscal pathologies are present. Surgical intervention is considered in cases in which joint space and cartilage are preserved in a patient demonstrating high likelihood of success with rigorous postoperative rehabilitation. In the acute setting, surgical intervention is the preferred treatment option barring any absolute contraindications. Time from symptom onset to repair is critical in preventing irreversible cartilage degeneration, particularly within 3 months of injury. Absolute contraindications for surgical intervention include diffuse grade 3 chondromalacia, substantial osteoarthritic changes, such as Kellgren-Lawrence grade 3 or 4, and misalignment $\geq 5°$.[11]

Indications for Centralization With MMPRT Repair

Krych et al.[8] demonstrated meniscotibial ligament extrusion and disruption to precede the development of MMPRTs in an MRI study of 27 knees of 26 patients. All patients demonstrated meniscal extrusion and significant progression of the defect prior to developing MMPRTs with a mean time from extrusion identification to MMPRT of 1.7 years (SD $\pm$ 1.6 years), suggesting a potential causal correlation. In addition, previous techniques of root repair do not reverse meniscus extrusion, so although there may be clinical improvement, the function of the meniscus cannot be completely restored. Thus, centralization conducted simultaneously with MMPRT repair serves to augment the root repair and theoretically improve the extrusion, which will biomechanically improve the function of the meniscus to be more chondroprotective.

Patients at our institution underwent centralization along with MMPRT in the following circumstances: notable extrusion (>3 mm) on preoperative MRI, extrusion detected prior to MMPRT, and subjective intraoperative extrusion determined by the surgeon.

Arthroscopic Centralization

The surgical technique has been described in depth previously.[12] In brief, standard arthroscopy portals are used. A knotless FiberTak (Arthrex, Naples, FL) curved drill guide is used through the accessory anteromedial (AM) portal. The guide is positioned at the posteromedial aspect of the medial meniscus (MM) body central to the peripheral rim of the tibial article surface. A 1.8-mm drill hole is made and after deploying the suture anchor, the meniscus is sutured to the meniscus in a mattress fashion and the centralization suture is tensioned down using an arthroscopic knot pusher (Figs 1 and 2). The steps are repeated 1 to 2 more times along the medial tibial rim.

Arthroscopic Medial Meniscus Posterior Root Tear

The technique for root repair has been described in depth by Krych et al.[13] In brief, after tibial bone socket

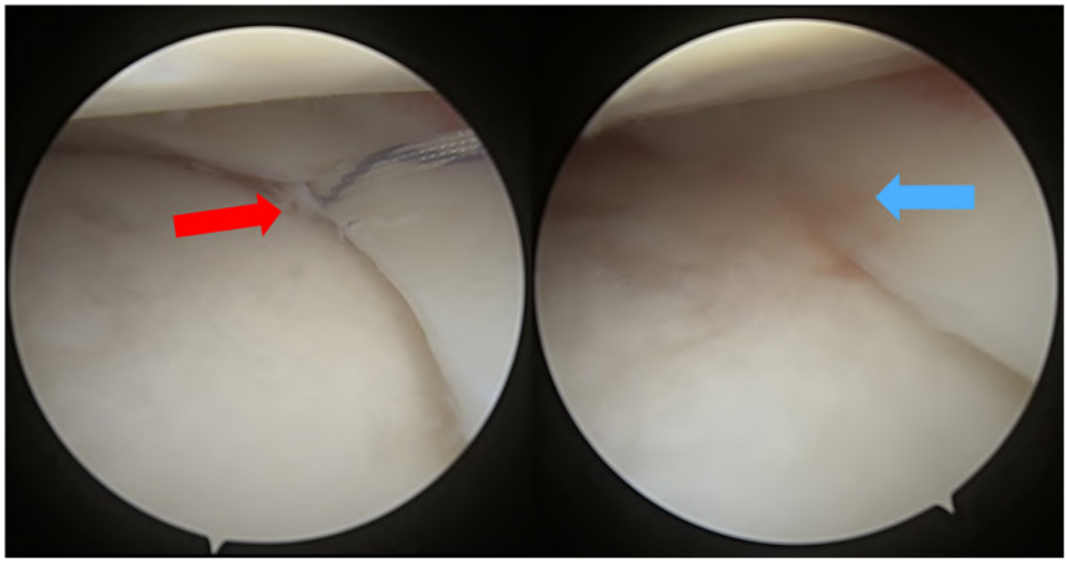

Fig 1. An arthroscopic anteromedial portal view of the right knee medial compartment. The meniscus is shown before (left) and after (right) centralization.

drilling at the meniscus root footprint, a cannula is introduced to aid in suture management and soft-tissue bridge prevention. First a cinch suture configuration is created over the meniscus and then repeated for a total 2 cinch sutures spanning the posterior root. After sufficient tensioning, a simple stitch is placed at the edge of the root, which represents the "leader stitch, which functions to reduce the apex of the root to the tibial socket. All the sutures are passed, appropriately tensioned, and then tibial fixation is obtained with BioComposite SwiveLock anchor (Arthrex, Naples, FL).

Postoperative Rehabilitation Protocol

Patients in our study adhered to a standard postoperative meniscal repair protocol.[14] Patients were instructed to refrain from weight bearing for the first 4 weeks postoperatively with the use of knee braces while ambulating. During this time, range of motion was restricted to 90° of flexion. Full weight bearing, as tolerated, was permitted starting from 4 to 6 weeks postoperatively. Patients returned to full activity without restriction between 8 and 16 weeks postoperatively contingent on individual clinical

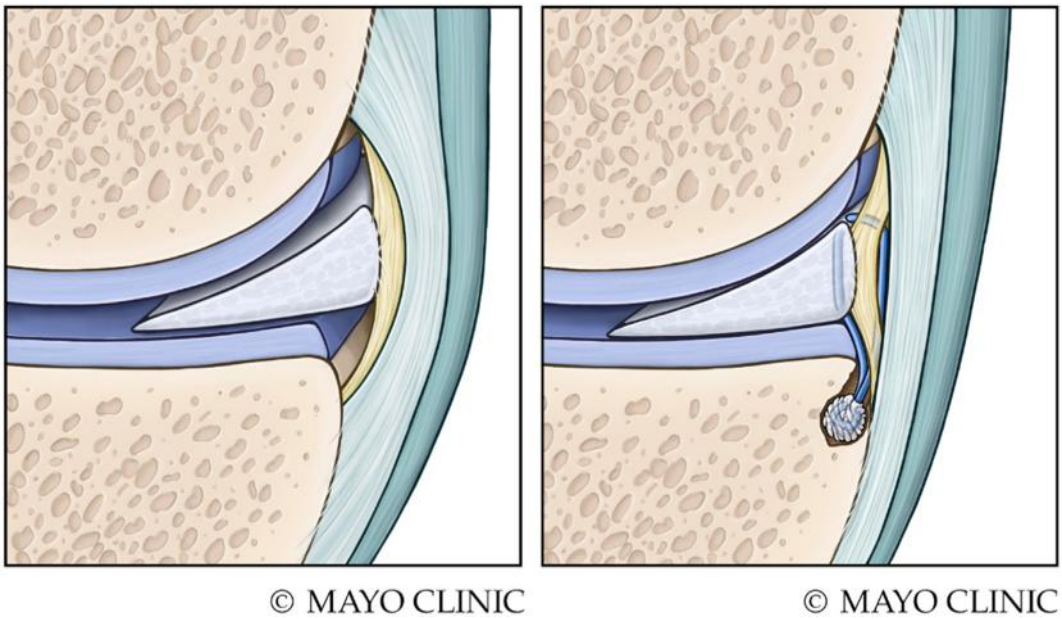

Fig 2. Schematic illustration of meniscus centralization.

improvement. In patients with concomitant anterior cruciate ligament (ACL) reconstruction, ACL recovery protocol took precedence, and patients were allowed full weight bearing immediately postoperatively.

Outcome Collection

Electronic patient medical records were reviewed to collect demographics, injury characteristics, surgical details and intraoperative findings, and preoperative patient-reported outcome (PRO) scores, including Tegner Activity Score, visual analogue scale (VAS) at rest, VAS with use, the Knee Injury and Osteoarthritis Outcome Score Jr. (KOOS Jr.), and International Knee Documentation Committee (IKDC) score.[15] These patient PROs were chosen for their previous validation in the literature for meniscus injury and repair.[16-18] Anterior-posterior (AP) standing knee radiographs were reviewed for medial compartment Kellgren and Lawrence (KL) grade.[19] Joint alignment was measured using hip-knee-ankle full-length radiographs. Meniscus extrusion was measured on MRI as the distance from the furthest edge of the medial meniscus to the most lateral edge of the medial tibial plateau on T2 coronal MRI cross section showing the apex of the medial tibial spine.[20] All imaging was reviewed and interpreted by one of the authors (A.J.K.), a board-certified, fellowship-trained orthopedic surgeon. The results from a study by Wang et al.[21] affirms imaging interpretation fidelity, as meniscal body extrusion grading demonstrated excellent intra-class correlation among both intrareader (0.98 and 0.97) and interreader agreement (0.99). Operative notes were reviewed to determine the Outerbridge[22] grade of each compartment (medial, lateral, patellofemoral, and trochlear), as well as to confirm medial meniscus root pathology with subsequent meniscus centralization.

Patients were contacted electronically via Research Electronic Data Capture (REDCap, Vanderbilt University, Nashville, TN) to collect postoperative PROs, including Tegner Activity Score, VAS for pain at rest and with use, KOOS Jr., IKDC, Likert score for improvement, and surgery satisfaction.[15] A patient-acceptable symptom state (PASS) measurement of 69.0 was used for IKDC, which was obtained from a previously published study by Maheshwer et al.[16] Information regarding reoperations, revision surgeries, conversion to arthroplasty, and postoperative imaging was also collected.

Statistical Analyses

PROs were collected using the REDcap online database, and data were organized and stored in Microsoft Excel (2010; Microsoft Corp). Statistical analyses were conducted in BlueSky 7.4 software (BlueSky Statistics, Inc., Chicago, IL). Continuous variables were reported as means with ranges and standard deviations. Preoperative and postoperative scores were compared using paired *t*-tests. Wilcoxon rank-sum (Mann-Whitney *U*) tests were used to evaluate nonparametric, continuous variables between two groups, and Kruskal-Wallis tests were used to analyze nominal variables across more than 2 groups. Fisher exact tests were used to evaluate nonparametric data with nominal independent and dependent variables. Continuous variables were evaluated using linear regression. Fisher exact tests were used to test for statistically significant differences in clinical and surgical failure between groups. A post hoc power analysis was conducted using previously published minimal clinically important difference values for IKDC and KOOS Jr.[16,23] In our cohort of 24 patients, the post hoc power for detecting MCID in KOOS Jr. was 90% and for detecting MCID in IKDC was 84%. All statistical tests were two-sided, and *P* values of $<.05$ were considered statistically significant. Statistical analysis was conducted with consultation from a professional statistician.

Results

Demographics

Twenty-five patients (age: 50.1 ± 11.3 [range: 19.5-67.4]; sex: 19 females [76]%]; body mass index [BMI]: 32.9 ± 7.6 kg/m2) were included in this study and followed for mean 2.0 ± 0.6 years (range: 1.0-3.1) (Table 1). All but one patient (96.0%) experienced an acute injury leading to the onset of symptoms, and 2 patients (8.0%) had undergone previous ipsilateral knee surgery—one ACL reconstruction and one tibial tubercle osteotomy (Table 2). Preoperative radiographs revealed 18/25 (72%) patients demonstrated a KL grade of I preoperatively, 7/25 (28%) patients demonstrated a KL grade of II preoperatively, and a mean alignment of 2.9° ± 0.9° of varus for this cohort. Notably, all patients had an incidental preoperative varus alignment of their injured knee, which was not part of the inclusion criteria. Preoperative MRIs showed mean MME of 3.2 ± 0.3 mm and revealed bone marrow edema in 11 patients (40.0%). Eight of these 11 patients demonstrated bone marrow edema in the proximal tibia or medial compartment adjacent to the

Table 1. Patient Demographics

Parameter	Value
Age	50.1 ± 11.3 (range: 19.5-67.4)
Sex	
Male	6 (24.0%)
Female	19 (76.0%)
BMI	32.9 ± 7.6
Laterality	
Right	8 (32.0%)
Left	17 (68.0%)
Follow-up	2.0 ± 0.6 years

Table 2. Preoperative Injury Characteristics

Acute Injury	Value
Yes	24 (96.0 %)
No	1 (4.0 %)
Prior Ipsilateral Knee Surgery	
Yes	2 (8.0 %)
No	23 (92.0 %)
KL Grade	1.3 ± 0.5
1	18 (72.0 %)
2	7 (28.0 %)
Alignment	2.9 ± 0.9
Valgus	0 (0.0 %)
Varus	25 (100.0 %)
Medial Meniscus Extrusion	3.2 ± 0.3
BM Edema	
Yes	11 (40.0 %)
No	14 (60.0 %)

meniscus root tear, while 3 patients had isolated bone marrow edema involving either the patella or trochlear groove. The average time from the onset of symptoms to the time of surgery was 133.3 ± 87.8 days (Table 3). Intraoperative findings included a mean medial compartment Outerbridge grade of 2.4 ± 0.9, mean lateral compartment Outerbridge grade of 0.8 ± 1.0, and mean patellofemoral Outerbridge grade of 1.5 ± 1.1 for this cohort.

Clinical and Radiographic Outcomes

Mean preinjury Tegner score, preoperative VAS at rest, and preoperative VAS with use were 3.5 ± 2.0, 2.2 ± 2.5, and 7.3 ± 2.3, respectively (Table 4). At final follow-up, mean Tegner score was 4.0 ± 1.6, mean VAS at rest was 0.5 ± 0.9, and mean VAS with use was 2.4 ± 2.0. The increase in Tegner score was not found to be statistically significant ($P = .233$); however, the improvements in both VAS at rest and with use were significant ($P = .003$, $P < .001$, respectively). Mean preoperative KOOS Jr. was 58.2 ± 9.3, and mean postoperative KOOS Jr. was 81.3 ± 12.8. Patients reporting both preoperative and postoperative KOOS Jr. and IKDC scores experienced significant improvement in both measures ($P < .001$ and $P = .023$, respectively). Of the 25 patients, 15 (60%) achieved an IKDC PASS. At final follow-up, 88% patients reported that their knee was better than before surgery, compared to 2 patients (8%) who reported "no change" and 1 patient (4.0%) who reported their knee was "slightly worse." Eighty-three percent of patients reported being "very satisfied" or "satisfied" with their surgery, with the remaining 17% reporting "neutral satisfaction". No patients were "dissatisfied" or "very dissatisfied" with their surgery.

Postoperative radiographs within 1 year of operation were available for 23 patients (92.0%). There was no significant OA progression or postoperative change in alignment between preoperative and postoperative imaging for these patients. Postoperative MRIs within 6 months after surgery were available for 3 patients, which showed an average reduction in meniscus

Table 3. Intraoperative Findings and Surgical Intervention

Nonoperative Treatment Time (days)	133.3 ± 87.8
Medial Outerbridge	2.4 ± 0.9
0	0 (0.0 %)
1	5 (20.0 %)
2	7 (28.0 %)
3	12 (48.0 %)
4	1 (4.0 %)
≥1	25 (100.0 %)
≥2	20 (80.0 %)
Lateral Outerbridge	0.8 ± 1.0
0	13 (52.0 %)
1	6 (24.0 %)
2	4 (16.0 %)
3	2 (8.0 %)
4	0 (0.0 %)
≥1	12 (48.0 %)
≥2	6 (24.0 %)
Patellar Outerbridge	1.5 ± 1.1
0	6 (24.0 %)
1	6 (24.0 %)
2	8 (32.0 %)
3	5 (20.0 %)
4	0 (0.0 %)
≥1	19 (76.0 %)
≥2	13 (52.0 %)

Table 4. Patient-Reported Outcome Scores

PRO	Score	*P* Value
Mean follow-up	2.0 ± 0.6	
Likert Scale (compared to presurgery)	4.4 ± 0.8	
5: Much better	15 (60.0 %)	
4: Slightly better	7 (28.0 %)	
3: No change	2 (8.0 %)	
2: Slightly worse	1 (4.0 %)	
1: Much worse	0 (0.0 %)	
VAS pain at rest		**.003**
Preop	2.2 ± 2.5	
Postop	0.5 ± 0.9	
VAS pain with use		**<.001**
Preop	7.3 ± 2.3	
Postop	2.4 ± 2.0	
IKDC		**.023**
Preop	46.3 ± 10.8	
Postop	70.4 ± 16.8	
KOOS Jr.		**<.001**
Preop	58.2 ± 9.3	
Postop	81.3 ± 12.8	
Tegner score		.233
Preop	3.5 ± 2.0	
Postop	4.0 ± 1.6	
Surgery satisfaction		
1. Very satisfied	12 (50.0 %)	
2. Satisfied	8 (33.3 %)	
3. Neutral	4 (16.7 %)	
4. Dissatisfied	0 (0.0 %)	
5. Very Dissatisfied	0 (0.0 %)	

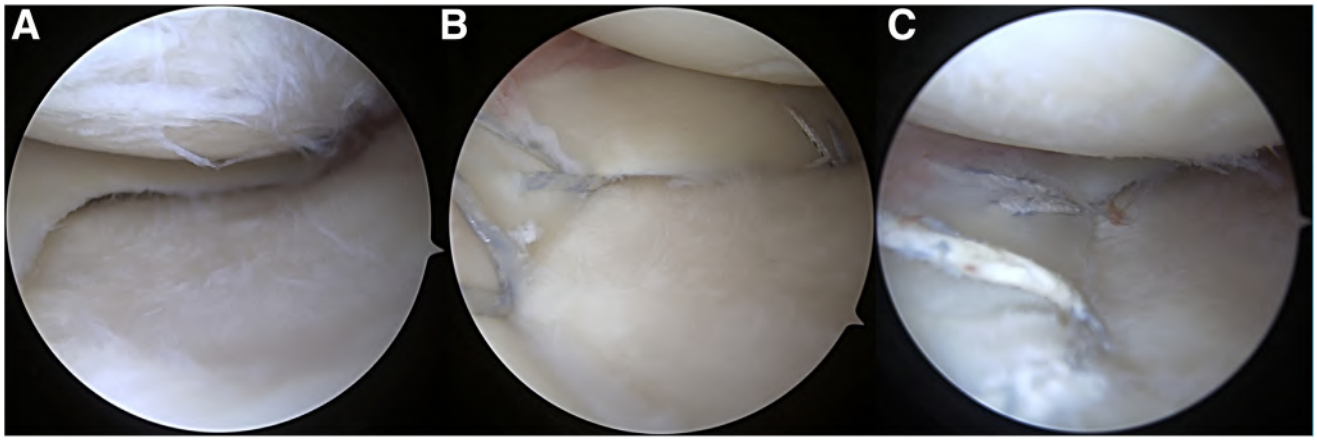

Fig 3. An arthroscopic view of the left knee medial compartment from the patient who underwent medial meniscus posterior root tear repair before centralization (A), after centralization (B), and 4.3 months postoperatively during lysis of adhesions (C). Images were obtained from the anteromedial portal view.

extrusion of 1.7 mm from mean 3.3 mm preoperatively to 1.6 mm postoperatively. One patient received an MRI for research purposes (5.3 months); another received an MRI for suspected meniscus injury following an episode of acute pain (5.0 months), although MRI results did not demonstrate pathological changes; and the third patient received an MRI for an acute flare of pain (5.7 months), but MRI results showed an intact construct and only mild effusion and chondrosis of patellofemoral and medial compartments.

Retear and TKA

No patients had progressed to TKA or undergone a revision medial meniscus surgery at the time of final follow-up. One patient underwent a subsequent surgery for lysis of adhesions 4.3 months after initial surgery for arthrofibrosis (Fig 3). The meniscus root was healed and stable to probing, and the meniscus maintained its centralized appearance. There were no new cartilage injuries and no tearing of the meniscus at the suture interface.

Outcomes Analysis

A 1-year increase in age correlated with a 0.060-point decrease in postoperative Tegner score ($P = .040$), and a one-point increase in BMI at the time of surgery correlated with a 0.145-point increase in pre-operative VAS with use ($P = .018$). There were no other significant correlations or differences in any postoperative PROs based on patient age, sex, or BMI. Nonoperative treatment time was positively correlated with higher postoperative VAS at rest, with each day of additional nonoperative treatment time correspondingto a 0.041-point increase in postoperative VAS at rest. There were no other significant correlations or differences in any postoperative PROs based on preoperative meniscus extrusion, KL grade, knee alignment, bone marrow edema, or medial, lateral, or patellofemoral Outerbridge grades.

Discussion

The purpose of the present study was to report patient outcomes at minimum 1-year follow-up, with a mean follow-up time of 2 years, after medial meniscus root repair with meniscus centralization, determine the revision and conversion to arthroplasty rates, and identify risk factors for failure to achieve IKDC PASS. The primary finding of this study is that patients demonstrated significant improvements in postoperative pain and function, presurgery activity levels, high surgery satisfaction, and no incidences of revision meniscus surgery or conversion to arthroplasty.

The patients in our study on average demonstrated an interval of 133.3 ± 87.8 days from symptom onset to date of surgery. To our knowledge, there is no consensus on the absolute threshold beyond which further nonoperative management would be detrimental, although previously published literature suggests early intervention to be preferrable. A study of 35 patients by Furumatsu et al.[6] demonstrated that significant progression of medial meniscus extrusion within the subacute (30-90 day) and chronic (120-365 days) with relative medial meniscus extrusion of 49.2% and 60.3%, respectively. Additionally, Bernard et al.[24] documented that patients who did not undergo surgical repair demonstrated progression to TKA at a rate of 27% at a mean of 74 months compared to 0% in those who underwent meniscus root repair in addition to significantly increased arthritic progression. Moreover, Moon et al.25 determined from two cohorts of MMPRT patients, one that demonstrated significant extrusion ($n = 41$) progression and one that did not ($n = 21$), that the optimal timeline for surgical intervention was 13

weeks from time of symptom onset. None of our patients delayed surgical intervention more for more than 1 year, although the mean interval to surgery in our was beyond the suggested 13 week cut-off by Moon et al.25 We had a limited number of failures in our cohort, and therefore, no analyses pertaining to time from injury to surgery was conducted. The acute timing of surgical intervention is an individualized decision based on patient characteristics, activity level, injury pattern, and risk for rapid clinical deterioration. At our institution, there is, indeed, a preference for surgery earlier rather than later to prevent cartilage wear that may negatively impact patient outcomes.

This study demonstrates significant postoperative improvements in VAS at rest and with use, KOOS Jr., and IKDC. To our knowledge, no previous studies have reported the postoperative outcomes of IKDC, Tegner, VAS, or KOOS Jr. in patients undergoing medial meniscus repair with meniscus centralization. However, these data suggest that patients experience significant improvements in pain, function, and quality of life. This reflects the findings of a 2022 systematic review and meta-analysis of 24 studies investigating medial meniscus posterior root tear (MMPRT) repair without centralization published by Perry et al., which showed significant improvements in postoperative IKDC and VAS for pain at mean 27.7 months follow-up.[25] This meta-analysis also found nonsignificant improvements in postoperative Tegner score, as was also observed in the present study. Notably, the mean BMI in these studies (25.8 kg/m2) was much lower than in the present study, and multiple studies in the review used concomitant high tibial osteotomy (HTO) at the time of meniscus repair, which could represent a significant confounding variable compared to isolated meniscus root repair.26 No patients in the present study underwent concomitant HTO or unicompartmental knee arthroplasty (UKA). Previously published literature described a varus alignment of greater than 3 to 5 degrees may warrant consideration for concomitant HTO.[26,27] At our institution, the decision to undergo HTO is dictated by the presence of medial knee osteoarthritis with a large degree of varus misalignment, typically greater than 5°, in conjunction with the determination that it contributes significantly to medial compartment load. Additionally, indications for UKA are isolated advanced joint space narrowing of the medial compartment with severe, disabling osteoarthritis symptoms refractory to conservative management. In our study population, chronic and degenerative MMPRT augmented with centralization was conducted independently of HTO and UKA due to a lack of severe medial osteoarthritis and only minimal varus misalignment. Although this was not intentionally selected for, this may reduce confounders influencing patient-reported outcomes.

Another systematic review of mid-term outcomes after MMPRT repair also showed statistically significant improvements in IKDC, with a mean postoperative score of 71.4 across 23 studies at mean 42.3 month follow-up.[28] The present study also found that 88% of patients reported subjective improvement in their knee, compared to only 1 patient (4.0 %), who indicated his knee was "slightly worse," and 83% of patients reported satisfaction with their surgery, while no patients were dissatisfied. The use of these contemporary outcome measures expands upon the available literature regarding clinical outcomes in this patient population undergoing a novel arthroscopic procedure.

The present study determined no significant OA progression or postoperative change in alignment for the 92% of patients with postoperative radiographs. This supports work published in 2021 by Mochizuki et al. that similarly found no difference in knee alignment in any of the 26 patients and OA progression in only 1 patient at minimum 2-year follow-up.[9] Notably, this 2021 study excluded patients with preoperative varus knee alignment, whereas the present study reports on patients with varus alignment exclusively. Osteotomy for alignment adjustments and MMPRT repair are often discussed in conjunction. However, no short-term or long-term clinical differences have been demonstrated in the literature when osteotomy is conducted alone versus in conjunction with MMPRT repair.[29,30] Because our patient population only demonstrated a mild varus without significant clinical relevance and none of the patients underwent osteotomy, we were unable to comment on the necessity of alignment adjustments in conjunction with MMPRT repair and centralization.

Regarding MMPRT repair without centralization, meta-analysis has shown that ~6% of patients had increased from KL grade 0 or 1 to KL grade 3 at mean 27.7 months follow-up.[25] Another 2022 systematic review published by Krivicich et al. reported that 22% of patients who underwent MMPRT repair surgery demonstrated significant OA progression at mean 5-year follow-up.[31] Similarly, a third systematic review reported that 49% of patients across 10 studies saw progression of at least 1 KL grade at mean 4-year follow-up.[28] The difference in rates of arthritic progression may be the result of longer follow-up in the meta-analyses compared the follow-up in our study, as patients may refrain from load bearing in the immediate postoperative recovery period and return to normal activity could take numerous months. Alternatively, it may reflect the natural progression of knee OA after meniscus repair surgeries without meniscus centralization, which has been shown not to significantly reduce meniscus extrusion.[25] Conversely, prior investigation has demonstrated that meniscus centralization procedures effectively reduce or correct meniscus

extrusion postoperatively, and the present study reports a decrease of 1.7 mm of extrusion; however, postoperative MRIs were available for only 3 patients at the time of final follow-up.[9,32]

Regarding subsequent surgeries, one patient did require a lysis of adhesions surgery (Figure 3) at 4 months postmeniscus repair, but no patients in this study required revision meniscus surgery or converted to total knee arthroplasty at the time of follow-up. Mochizuki et al. reported that 2 patients progressed to TKA during the study period, corresponding to a survival rate of 92.3% at mean follow-up of nearly 3 years.[9] Regarding, MMPRT repair without mensicus centralization, meta-analysis of 3 studies demonstrated a 9.8% conversion to arthroplasty rate, which occurred between 47 and 131 months.[31] Similarly, a review of 6 studies demonstrated a 5% progression to TKA at mean 76.0-month follow-up.[28] Revision rates after MMPRT repair without centralization are not as well described at this time; however, analysis of 50 knees at minimum 2-year follow-up revealed a revision rate of 6.7%, and mean time to failure was 11.0 months.[2] As the utilization of this technique increases, it will be important to identify rates of revision over time, as well as rates of conversion to arthroplasty, in comparison to medial meniscus root repair alone.

Demographic, injury, and surgery characteristics were evaluated as risk factors for worse outcome of IKDC. However, no statistically significant risk factors were identified. Further outcomes analysis revealed that a 1-year increase in age correlated with a 0.060-point decrease in postoperative Tegner score ($P = .040$), and a one-point increase in BMI at the time of surgery correlated with a 0.145-point increase in preoperative VAS with use ($P = .018$). The inverse relationship between age and Tegner score has been previously established, with activity level generally declining as patients age. Higher BMI has been identified as a risk factor for medial meniscus posterior root tears and imparts a greater stress across the injured meniscus, which may explain the higher preoperative pain scores.[33,34] Notably, there was no significant relationship between BMI and postoperative pain scores, which reflects previous studies demonstrating no impact of BMI on postoperative clinical outcomes after meniscus root repair.[35] Finally, nonoperative treatment time was positively correlated with higher postoperative VAS at rest, with each day of additional nonoperative treatment time corresponding to a 0.041-point increase in postoperative VAS at rest. Prior investigation reported that longer duration of preoperative symptoms was asssociated with progression of medial meniscus extrusison and higher postoperative radiographic OA progression, but the authors did not find any differences in clinical outcomes.[36] It is possible that the much larger sample size in the present study provided the power to detect significant differences in postoperative pain scores that were previously not observed in smaller cohorts.

Limitations

This study has some limitations. First, the follow-up is relatively short, as patients were assessed at minimum 1-year postoperatively with a mean follow-up of 2 years. However, centralization is an emerging technique, and there is little published in the literature. Second, this study does not have a control group, which limits the ability to evaluate the degree to which postoperative outcomes are attributed to the centralization procedure rather than the meniscus repair. Finally, there was a low rate of postoperative MRI follow-up, which limits the ability to evaluate the effectiveness of the centralization technique and the relationships between clinical and radiographic outcomes.

Conclusion

At minimum 1-year follow-up and mean follow-up of 2 years, patients undergoing medial meniscus root repair with meniscus centralization demonstrated significant postoperative improvements in pain, function, and quality of life and reported high rates of surgery satisfaction. There was no evidence of significant arthritic progression on postoperative imaging, and no patients underwent revision meniscus surgery or TKA.

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