

Original Research

# Outcomes Following Repair of Radial, Mid-Body Tears of the Lateral Meniscus in Adolescents

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## Abstract

**Background:** Radial tears of the lateral meniscus result in increased contact forces in the knee and may expedite the development of arthritis. Due to the technically difficult repair and poor healing potential, partial or complete lateral meniscectomy is often performed, even in young, active patients. There is a paucity of literature regarding clinical outcomes after repair of radial tears of the lateral meniscus. The purpose of this study is to review outcomes of a cohort of adolescent patients who have undergone repairs of mid-body radial lateral meniscus tears. Our hypothesis is that the repairs will be successful in terms of PRO outcomes, return to an active lifestyle, and low rate of re-operation in short-term follow-up.

**Methods:** A retrospective review of subjects under the age of 18 years that underwent repair of mid-body, lateral meniscus tears with potential for 2 years of follow-up were identified. These patients were identified by CPT code and subsequent chart review for tear pattern and repair technique. Patients were then prospectively contacted by email or phone and completed patient-reported outcome surveys including the International Knee Documentation Committee (IKDC) score, the Knee Osteoarthritis Outcome Score (KOOS), Marx activity scale, and SPORTS score.

**Results:** Of the 17 total patients retrospectively reviewed, eight completed the prospective portion of PROs which were collected at a mean of 55.8 months postoperatively. Six knees (35.3%) had postoperative MRI at mean 14 months postop, with five of the six (83.3%) suggestive of preserved integrity of the repair. There were five (29.4%) complications, all requiring subsequent surgical procedures. Four patients had meniscus tears at locations distinct from initial injury requiring partial meniscectomies at mean 13.8 months (range, 7-35 months); however, all radial mid-body tears from index procedures were completely healed under arthroscopic visualization. Mean 2-year IKDC score was  $91.67 \pm 10.72$ , and the mean Marx score was  $11.63 \pm 3.25$ . Six of eight (75%) reported performance at the same level

of sport with one reporting pain during sport. Three respondents of the SPORTS score reported continued participation in organized sport with one patient participating at the collegiate intramural level.

**Conclusions:** Repairs of radial mid-body tears in the lateral meniscus may provide a clinical benefit in the adolescent population. The majority of patients were able to return to their prior activity levels without complication, with evidence of healing on repeat evaluation.

**Level of Evidence:** Level IV, case series

### Key Concepts

- Return to sport is feasible for the majority of adolescent patients undergoing lateral, mid-body meniscal repair at approximately 6 months following surgery.
- Re-operation was common with 5/17 (29.4%) patients undergoing re-operation with 4/5 returning for partial meniscectomy. Two of these were at sites distinct from the initial repair with complete healing of repair at radial tear site from index procedure. One showed a majority healed radial repair. One was completed at an outside hospital with insufficient detail to characterize.
- If feasible, repair of radial tears of the mid-body of the lateral meniscus in adolescent patients should be attempted.

## Introduction

The meniscus functions by increasing the contact surface area from the femoral condyle to the tibial articular surface and decreasing contact pressures in both the medial and lateral knee compartments during loading.<sup>1</sup> If the integrity of the meniscus is compromised, the ability to disperse these forces is affected and may eventually result in degenerative arthritis that could limit the playing career of an athlete and become disabling in later years.<sup>2-4</sup> Due to these significant downstream sequela, there has been increased emphasis on meniscus preservation and surgical repair when indicated.<sup>5,6</sup>

Radial tears of the lateral meniscus body lack consensus on management.<sup>7-10</sup> Radial tears are particularly challenging, as they often lack the requisite vascularity for healing due to their location in the white-white zone of tissue perfusion.<sup>11-13</sup> Compounding the issue is the radial tear pattern in the lateral meniscus effectively negates the hoop-stress forces relayed onto the meniscus during axial loading of the lateral femoral condyle onto the articular surface of the tibial plateau, resulting

in increased transmission of forces onto the cartilage surfaces.<sup>14</sup>

Due to the technically difficult repair and anatomic considerations for healing, partial or complete meniscectomy is often performed in these cases but may not be the most optimal option in the young, active patient who may go on to early joint arthritis or may require a salvage operation, such as a meniscal transplant in the case of a complete meniscectomy.<sup>2</sup> The purpose of this study is to review outcomes of a cohort of adolescent patients who have undergone repairs of radial, mid-body lateral meniscus tears. Our hypothesis is that the repairs will be successful in terms of return to an active lifestyle with low rates of re-operation.

## Materials and Methods

### *Patient Selection*

With institutional review board (IRB) approval, this retrospective case series was performed at a single academic institution. The study included patients

between the ages of 10-18 who underwent lateral meniscal repair for a mid-body radial tear pattern between January 1, 2001, and April 1, 2020, and had potential for 2 years of follow-up from index procedure. Meniscal repairs were performed by one of three sports medicine fellowship-trained orthopaedic surgeons. Exclusion criteria included concomitant ACL tears, discoid meniscus, and patients with complex meniscal tears that involved a root tear component. One patient was lost to clinical follow-up after 2 weeks and was removed from analysis as well.

### ***Surgical Technique***

Patients underwent either inside-out or all-inside repair based on surgeon preference. Inside-out repairs were performed with a 70-degree arthroscope in the anterolateral portal. A 4 cm incision was made anterior to the LCL, and the incision was carried down from the lateral joint line distally in a vertical fashion. Layers 1 and 2 were split vertically distal to the IT band in line with the skin incision. A zone-specific cannula system was used for repair with 2-0 Ethibond double-armed sutures with Keith needles. Suture configuration was variable based on surgeon preference and tear (Figure 1). All-inside repairs were performed with individual surgeons' repair device of choice through the anteromedial portal. Postoperative protocol varied between the three surgeons, however, with minimal variance. A sample protocol from one provider (AT) has been provided in the Appendix section. A schematic of the repair process is provided in Figure 2. Note that the procedure can be done entirely all-inside, entirely inside-out, or a combination of the two techniques based on surgeon preference.

### ***Data Collection***

A retrospective chart extraction was performed using an electronic medical record query tool.<sup>15</sup> Clinical findings and imaging were obtained via chart review from preoperative evaluation through final follow-up. Demographic data included patient age, sex, laterality, tear type, and BMI. Objective clinical examination findings included range of motion,

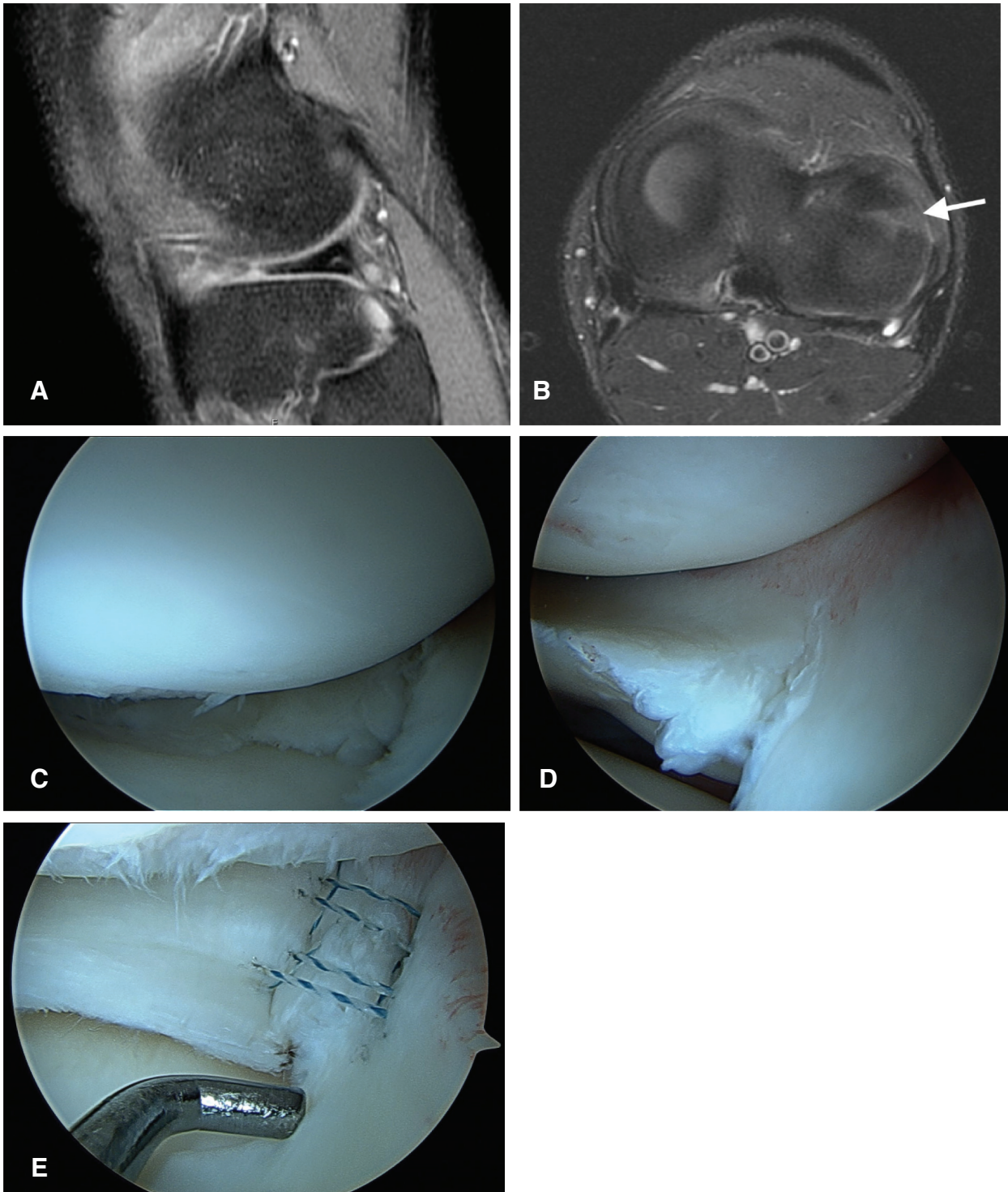
tenderness, McMurray test results, time to return to sport, complications, and any re-operations or advanced imaging obtained after index procedure. Postoperative advanced imaging was not standard and thus performed on a per patient basis when clinically indicated. Similar to Choi et al., the meniscus was considered healed if fluid signal on sagittal and coronal views was absent, partially healed if there were a decreased number of cuts with fluid signals compared to preoperative imaging.<sup>10</sup> Subjective data collection included preoperative visual analog scale (VAS) scores and post-surgical patient-reported outcome (PRO) questionnaires sent via email and completed online using REDCap<sup>16,17</sup> at minimum 2-year status post day of surgery. Measures included in the survey were the International Knee Documentation Committee (IKDC) score,<sup>18</sup> the Knee Osteoarthritis Outcome Score (KOOS),<sup>19,20</sup> Marx activity rating scale,<sup>21</sup> and SPORTS score.<sup>22</sup>

### ***Statistical Analysis***

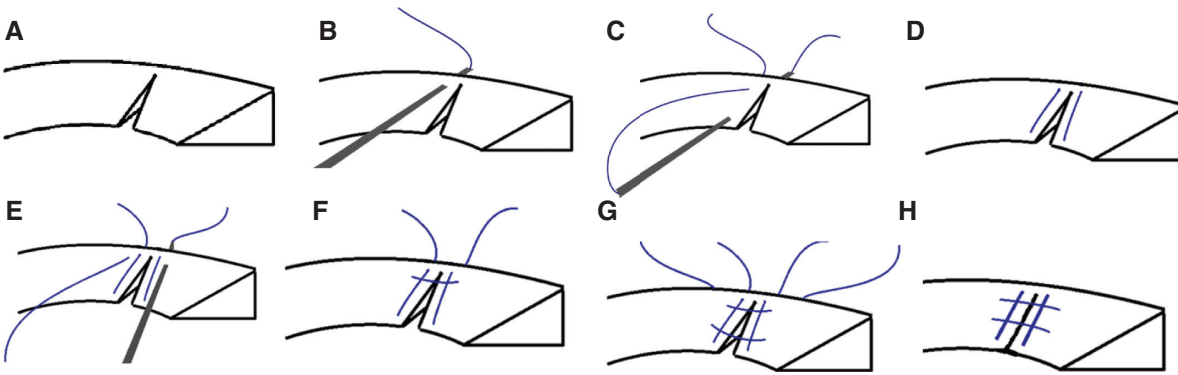
Descriptive statistics were calculated for variables of interest. The mean and range were presented for continuous demographic variables, and the mean and standard deviation (SD) were utilized for continuous outcome variables. A Wilcoxon signed-rank test was conducted on patients with complete preoperative and postoperative variables. Three patients with 'normal' or 'full' range of preoperative motion were assumed to have 135 degrees of flexion. A p-value of 0.05 was the threshold for statistical significance. Microsoft Excel, SPSS software (IBM SPSS Statistics for Windows, Version 28; IBM Corp), and RStudio v 2023.03.0 (Posit Software, PBC) with R version 4.1.3 (2022-03-10)<sup>23</sup> was used for data analysis.

### **Results**

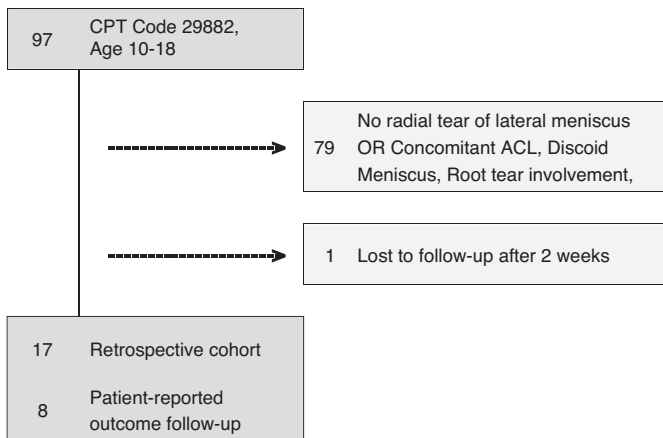
A total of 17 patients (17 knees) met inclusion criteria (Figure 3), including 11 males and 6 females. The mean age of the patients at time of surgery was 15.8 years (range, 12-18 years), and average BMI at time of surgery was 28.6 (range, 20.7 – 42.8 kg/m<sup>2</sup>). All injuries were sustained during athletic activity: seven football, six basketball, two volleyball, one lacrosse, and one dancing



**Figure 1.** Preoperative (A) sagittal and (B) axial T2-weighted MRI images demonstrating (C) mid-body, radial tear of the lateral meniscus with (D) extension to the red-white zone. (E) Intraoperative image of completed inside-out repair using hashtag suture technique.



**Figure 2.** Schematic of step-by-step repair process including both all inside and inside-out components. (A) Radial tear pattern, (B-D) Placement of inside-out rip stop sutures, (E-G) Placement of inside-out reduction sutures, H) Final tied construct.



**Figure 3.** Patient selection diagram.

injury. There were 10 right knees and seven left knees. Inside-out repair was performed in 14/18 (82.4%) of cases with the remaining three repaired with an all-inside technique. Concomitant procedures performed at the index procedures included one cyst removal, one synovectomy, two plica excisions, one loose body removal and two microfracture procedures.

Final postoperative clinical follow-up was at mean of  $6.8 \pm 2.1$  months. Fourteen of the 17 patients returned to sport at an average of  $189 \pm 47$  (130-297) days with two others returning against advice in half that time and requiring reoperation. Mean VAS score at final follow-up was  $0.625 \pm 2$ . (Table 1). There was no statistically significant difference in mean injury and postoperative

ROM at final follow-up ( $130.0 \pm 12.3$  vs  $130.3 \pm 8.0$ ;  $p=1$ ; 95% CI= -15 - 10). Additionally, positive McMurray's and tenderness at the lateral joint line were identified in 2/15 (12.5%) with documentation, with one of these patients not adhering to postoperative weight-bearing restrictions and two not reported.

Patient-reported outcomes were collected at mean 55.8 months (range, 24.4-103.6 months) postop with a 47% (8/17) survey completion rate. The mean IKDC subjective knee evaluation score was  $91.67 \pm 10.7$ , and the mean Marx activity rating scale was  $11.63 \pm 3.3$ . Six of eight (75%) patients reported being able to perform at the same level of sport performance with only one of the six reporting pain during sport. Additionally, 3/8 (37.5%) respondents reported continued participation in organized sport or activity with one patient reporting continued play at the collegiate intramural level. Additional outcome data, including KOOS subscores, are described in Table 2. No preoperative PROMs were available for comparison.

Six of the 17 knees (35.3%) experienced symptoms requiring postoperative MRI at mean 14 months (range, 5-35 months) postop. Five of the 6 (83.3%) studies obtained were suggestive of preserved integrity of prior repair. There were five (29.4%) total complications, all requiring subsequent surgical procedures. One patient had an additional lateral meniscus tear. However,

**Table 1. Patient Demographics, Examination, Imaging, and Operative Details**

|                                |              | % (n) 25%/50%/75% |
|--------------------------------|--------------|-------------------|
| <b>Sex</b>                     |              |                   |
|                                | Female       | 35.3% (6)         |
|                                | Male         | 64.7% (11)        |
| <b>Age</b>                     |              |                   |
|                                |              | 15/16/17          |
| <b>BMI</b>                     |              |                   |
|                                |              | 21.5/27/34.6      |
| <b>Laterality</b>              |              |                   |
|                                | Left         | 41.2% (7)         |
|                                | Right        | 58.8% (10)        |
| <b>Sports Injury</b>           |              |                   |
|                                | Football     | 41.2% (7)         |
|                                | Basketball   | 35.3% (6)         |
|                                | Volleyball   | 11.8% (2)         |
|                                | Lacrosse     | 5.9% (1)          |
|                                | Dancing      | 5.9% (1)          |
| <b>Repair Type</b>             |              |                   |
|                                | All-Inside   | 17.6% (3)         |
|                                | Inside-Out   | 82.4% (14)        |
| <b>Time to Final Follow-up</b> |              |                   |
|                                |              | 5.0/6.6/7.4       |
| <b>Time to Return to Sport</b> |              |                   |
|                                |              | 5.0/6.0/7.2       |
| <b>Pain at Final Follow-up</b> |              |                   |
|                                | 0            | 81.2% (13)        |
|                                | 1            | 12.5% (2)         |
|                                | 8            | 6.2% (1)          |
|                                | Not reported | (1)               |

BMI = body mass index; mo = months.

they underwent workup and meniscectomy at an outside institution. Documentation provided to this institution was inadequate to determine location and character of retear. Two patients had meniscus tears at locations distinct from initial injury requiring partial meniscectomies at mean 1.6 years (range, 0.5-2.6 years). These demonstrated complete healing of radial mid-body tears from index procedures (Figure 4). The

**Table 2. Postoperative Patient-Reported Outcome Data**

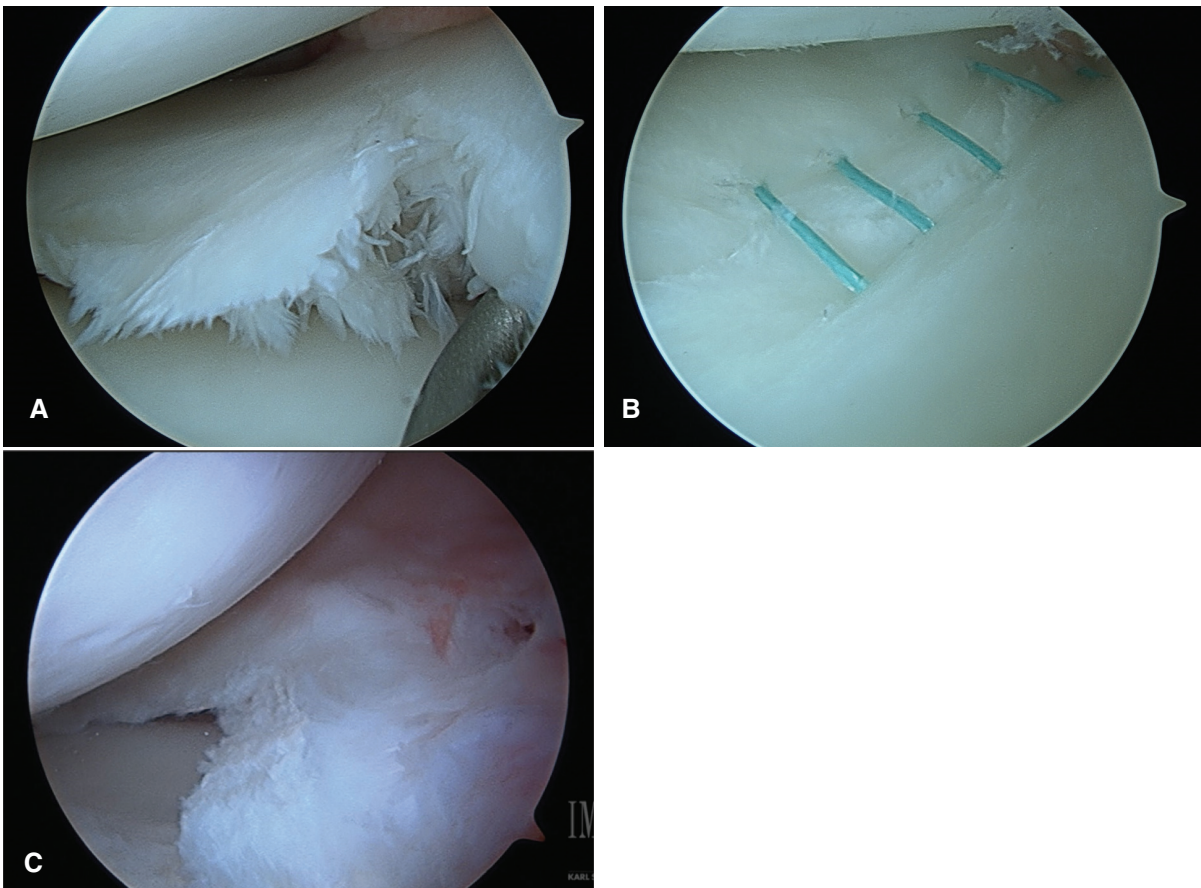
|                          |         | % (n) 25%/50%/75% |
|--------------------------|---------|-------------------|
| <b>Gender</b>            |         |                   |
|                          | Female  | 62.5% (5)         |
|                          | Male    | 37.3% (3)         |
| <b>Time to follow-up</b> |         |                   |
|                          |         | 33.0/60.5/66.8    |
| <b>IKDC</b>              |         |                   |
|                          |         | 90.5/94.3/99.1    |
| <b>KOOS</b>              |         |                   |
|                          | Symptom | 88.4/91.1/93.8    |
|                          | Pain    | 95.8/97.2/100     |
|                          | ADL     | 99.3/100/100      |
|                          | Sport   | 80/97.5/100       |
|                          | QOL     | 71.9/81.3/100     |
| <b>Marx Activity</b>     |         |                   |
|                          |         | 8.8/11.5/13.8     |

IKDC = International Knee Documentation Committee score; KOOS = Knee Osteoarthritis Outcome Score; ADL = Activities of Daily Living; Sport = Sport Subscore; QOL = Quality of Life Subscore.

fourth patient demonstrated well-healed radial tear at the periphery. However, debridement of 20% of more central meniscus was required at this site. One patient required an irrigation and debridement for a surgical site infection 1 month after initial surgery. Their reoperation showed necrotic subcutaneous fat at the lateral meniscus wound that extended into the knee joint. A few meniscus sutures were loose and were debrided. The wound was thoroughly debrided.

## Discussion

The main finding in our study of 17 adolescent patients who underwent repair of a lateral mid-body radial meniscal tear was that the majority of patients (82.4%) were able to return to sport at a mean of 189 days following surgery. Additionally, of the eight respondents to the PRO survey completed at mean 55.8 months, 6/8 (75%) stated that they were able to play at their pre-injury level of sport without limitations. In review of the literature, there has been a paucity of



**Figure 4.** Intraoperative imaging of a (A) radial, mid-body lateral meniscus tear and (B) subsequent inside-out repair with parallel horizontal mattress sutures. Second-look arthroscopy performed 2.6 years status post index procedure with interval healing and maintained repair.

studies investigating these injury patterns in the youth population.<sup>8-10,15,24,25</sup>

Although our study also demonstrated that re-operation was common, with 5/17 (29.4%) patients undergoing re-operation, 4/5 returning for partial meniscectomy, approximately 70% of patients went on to successful healing without reoperation. For those that underwent reoperation, the context of these situations must be considered. Of the reoperation patients, one was released for full activity at 3 months, and another patient deviated from the early postoperative weight-bearing protocol. This suggests that longer weight-bearing and ROM restrictions may be required to protect radial repairs, which are particularly vulnerable to distraction forces with axial load in the early postoperative period.<sup>14,26,27</sup> However, both postoperative MRIs and second look

arthroscopy were suggestive of healing and preserved integrity of the index repair. When re-injury was identified, the tears were often complex and located at a location distinct from the initial site of injury. Tsujii et al. performed second look arthroscopy on 18 patients who underwent inside-out repair of the same injury pattern and found complete healing in only 22% of patients, partial healing in 39%, and no healing in 39%.<sup>9</sup> While the age range of 13-31 years in their cohort may appear to confound results, they did not find any significance in age relating to repair success, only tear zone.<sup>9</sup> These differences in healing rates may be reflective of increased capacity for healing in the youth population.

The widely accepted treatment for this injury pattern has traditionally been meniscectomy, despite the well-established biomechanical impacts of increased joint

loading pressures in the lateral compartment with a compromised meniscus.<sup>1</sup> Meniscus repair for these tears has been limited by anatomic considerations. With a limited blood supply to the innermost region and a peripheral blood supply that has been shown to become even more peripheral with age, the prevailing thought was that repair would fail due to the lack of adequate vascular perfusion and that the patient would endure a prolonged period of immobilization, only to result in later meniscectomy.<sup>28</sup> However, prior studies looking at repairs in the white-white zone of the meniscus have shown success, particularly when performed in combination with anterior cruciate ligament reconstruction or a marrow venting procedure by allowing for increased intraarticular healing factors, further suggesting a blanket treatment recommendation for meniscal tears, regardless of injury zone, may no longer be appropriate.<sup>29,30</sup> It would make further sense then, that younger patients are the best candidates for repair based on the increased meniscus healing capacity conferred with younger age combined with the added long-term risk of knee degeneration with a deficient meniscus.

In evaluating the literature in conjunction with our data, it appears that radial mid body tears of the lateral meniscus have good potential for healing, particularly in the adolescent age group which counteracts the widely accepted treatment of meniscectomy for this injury pattern. In our study, there was only one repair failure in patients who followed the rehabilitation protocol, and each of the successful patients were able to return to their sports and activities. The results suggest that repair of lateral meniscus mid body radial tears in the adolescent age group may provide functional benefit to the patient and allows for return to sports and activities at a desired level.

### Limitations

Limitations include cohort size and lack of long-term follow-up. Patient data was retrospectively reviewed, and no preoperative patient-reported outcome measures were available for analysis. Only 8 of 17 patients completed

PROMS at least 2 years after surgery which introduces selection bias for this outcome measure. Additionally, follow-up MRI was only available for six patients and although five of six MRI studies suggested meniscal healing, the true rate of healing after radial meniscal tear repair cannot be assessed in this cohort. Although each surgeon included in the study is a sports medicine fellowship-trained provider, there are slight variations in surgical technique and rehabilitation protocols in use that were not controlled for in this study design.

### Conclusion

The majority of patients in this study were able to return to their prior activity levels. Repairs of radial mid body tears in the lateral meniscus may provide a clinical benefit in the adolescent population who would otherwise have been treated with meniscectomy. Repair of radial tears of the mid-body of the lateral meniscus in adolescent patients should be attempted if technically feasible.

### Disclaimer

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## Appendix

### Lateral Meniscal Repair Protocol

#### GENERAL PROGRESSION OF ACTIVITIES OF DAILY LIVING

Patients may begin the following activities at the dates indicated (unless otherwise specified by the physician):

- Bathing/Showering without brace after suture removal in 2 weeks
- Sleep with brace locked in extension for 8 weeks
- Brace locked in extension for 8 weeks for ambulation
- Use of crutches continued for 6 weeks
- No weight-bearing for 4 weeks
- Driving at 4 weeks postop

#### PHYSICAL THERAPY ATTENDANCE

The following is an approximate schedule for supervised physical therapy visits:

|                         |                                                                                                                     |
|-------------------------|---------------------------------------------------------------------------------------------------------------------|
| Phase I (0-8 weeks):    | 2 visits/week                                                                                                       |
| Phase II (8-12 weeks):  | 1-2 visits/week                                                                                                     |
| Phase III (3-4 months): | 1 visit/week first month, reduce to<br>One visit every 2 weeks<br>based on patient<br>Goals and access to equipment |
| Phase IV (4-6 months+): | Discontinue PT on completion of<br>Functional progression                                                           |

#### REHABILITATION PROGRESSION

The following is a general guideline for progression of rehabilitation following meniscal transplant surgery. Progression through each phase should take into consideration patient status (e.g. healing, function) and physician advisement. Please consult the physician if there is any uncertainty concerning advancement of a patient to the next phase of rehabilitation.

#### PHASE I

Begins immediately postop through approximately 8 weeks.

##### Goals:

- Protect meniscus fixation and surrounding soft tissues
- Control inflammation
- Minimize the effects of immobilization through ROM exercises (heel slides and flexing over side of table)
- Educate patient regarding limitations and the rehabilitation process

##### Brace:

- 0-8 weeks: Brace locked in full extension for gait and sleeping, unlock for therapeutic exercises

##### Weight-bearing Status:

- 0-4 weeks: No weight-bearing
- 4-6 weeks: Weight-bearing as tolerated with two crutches and brace locked in extension
- 6-8 weeks: Weight-bearing as tolerated with brace locked in extension, no crutches

##### Therapeutic Exercises:

- Quad sets
- Ankle pump, progress to resistive TheraBand exercises
- Limit flexion to 60 degrees x 4 weeks, then progress to 90 degrees. Advance past 90 degrees after 6 weeks
- Non-weight-bearing calf, hamstring stretches
- SLR in flexion, abduction, flexion, adduction, extension with brace in full extension until quadriceps strength is sufficient to prevent extension lag

- Patellar mobilizations as needed
- Begin aquatic therapy at 4 weeks with emphasis on normalization of gait

## PHASE II

Begins at approximately 8 weeks postop and extends to approximately 3 months. Criteria for advancement to Phase II:

- Good quad set, SLR without extension lag
- Approximately 90° of flexion
- Full extension
- No signs of active inflammation

### Goals:

- Increase flexion range of motion
- Increase quadriceps strength
- Restore normal gait
- Avoid over stressing the graft

### Brace:

Discontinue use of brace at 8 weeks postop as allowed by physician

### Weightbearing status:

At 8 weeks may discontinue use of crutches if following criteria are met:

- No extension lag with SLR
- Full extension
- Flexion 90°
- Non-antalgic gait pattern (may use one crutch or cane until gait is normalized)

### Therapeutic Exercises:

- Wall slides 0-45-degrees, progressing to mini-squats
- 4-way hip for flexion, extension, abduction, adduction

- Stationary bike
- Leg press 0-60° flexion
- Step-ups (Begin at 2" and progress towards 8")
- Knee extensions 50°-90°
- Toe raises
- Balance exercises (e.g. single-leg balance)
- Elliptical at 8 weeks postop

## PHASE III

Begins at approximately 3 months postop and extends through approximately 4 months. Criteria for advancement to Phase III

- Full knee extension, at least 100° of flexion
- Good quadriceps strength
- No patellofemoral or soft tissue complaints
- No signs of active inflammation

### Goals:

- Restore full range of motion
- Continue improvement of quadriceps strength
- Initiate isolated hamstring strengthening
- Improve functional strength and proprioception

### Therapeutic Exercises:

- Progression of closed kinetic chain and balance activities
- Closed kinetic chain terminal knee extension with resistive tubing or weight machine
- Hamstring curls 0-60° of flexion
- Swimming-no breaststroke
- Jogging in pool with wet vest or belt
- Stairmaster (small steps initially)

## **PHASE IV**

Begins approximately 4 months postop and extends until the patient has returned to work or desired activity.

Criteria for advancement to Phase IV:

- Physician clearance to initiate functional progression
- No patellofemoral or soft tissue complaints
- Necessary joint range of motion, strength, endurance, and proprioception to safely return to work or athletics

### **Goals:**

- Sport-specific training or work hardening program as appropriate
- Maintenance of strength, endurance, and proprioception
- Patient education with regards to any possible limitations

### **Therapeutic Exercises:**

- Continue strength, endurance, proprioception program
- Functional progression, including but not limited to:
  - Slide board
  - Jog/run progression
  - At 6 months
    - Forward, backward, running, cutting, carioca, etc.
    - Sport specific drills

### **Return to full activity:**

The patient may resume full activity level including sports participation when he/she completes an appropriate functional progression and has clearance from the physician. This usually occurs at approximately 6 months postop.