Original Article

Most Patients Older Than 40 Years of Age Who Underwent Meniscal Root Repair Presented With an Effusion, a Positive McMurray Test, and a Positive Hyperflexion Test

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Purpose: To analyze the presenting symptoms and clinical examination findings of patients undergoing meniscal root repairs to aid physicians in diagnosing this injury. **Methods:** All patients undergoing isolated arthroscopic meniscal root repair from January 1, 2016, to September 1, 2021, were identified. Patients younger than the age of 40 years were excluded. Clinical notes were reviewed for presenting symptoms and physical examination findings. Preoperative radiographs were graded using the Kellgren-Lawrence (KL) scale for osteoarthritis. Root tears were graded using the radiographic criteria of Chung et al. and articular cartilage injury was graded using a validated system, AMADEUS (mean total Area Measurement And Depth & Underlying Structures). **Results:** In total, 221 patients met inclusion criteria; 65.6% of patients reported that their pain began after an acute injury, with 39.4% of patients reporting a "pop." On examination, an effusion was present in 71% of knees. McMurray test was reported positive in 85.5% and a positive hyperflexion test in 53.8% of knees. In total, 49.5% of knees were graded KL 1. 154 had medial root tears, 10 had lateral root tears, and 24 suffered both root tears. In total, 44.1% of tears occurred at the midsubstance of the root, with 28.0% occurring at the enthesis and 28.0% occurring at the root-posterior horn junction. The mean AMADEUS score was 94.4 ± 11.4. **Conclusions:** Although most patients reported pain began after acute injury, less than one-half reported hearing a "pop." When patients were evaluated, an effusion, positive McMurray test, and positive hyperflexion test were present in most meniscal root tears. **Level of Evidence:** Level IV, diagnostic case series.

The posterior root of the medial meniscus plays an important role in biomechanical stability. Tears to this structure are clinically significant because they are highly disruptive to normal joint functioning.[1] These tears can either be avulsion injuries or complete radial tears. Unfortunately, radial tears of the posterior root of the medial meniscus are difficult to diagnose as the result of vague symptoms and occasional masking by osteoarthritis flareups in the setting of degenerative root tears. Furthermore, the traditional signs associated with meniscal body tears, such as locking, may not be present. Magnetic resonance imaging (MRI) yields high rates of false-negative results with sensitivity rates as low as 66%.[2,3] Time between initial MRI and subsequent MRI that shows the presence of a root tear can take over a year. This time brings the repairability of the root tear into question.[4] That said, obtaining a thorough patient history can provide valuable information that can assist with the diagnosis. These patients often report experiencing a "popping" sensation followed by the acute onset of pain. Some studies have shown that the presence of these symptoms yields a high positive predictive value.[3]

Previous studies have described presenting symptoms in patients with meniscal root tears.[5-8] Most recently, Krych et al.[8] compared medial root tears with lateral

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Received January 12, 2024; accepted April 7, 2024.

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2666-061X/2431

https://doi.org/10.1016/j.asmr.2024.100949

root tears and found that lateral root tears typically occur in patients who are male, have a lower body mass index (BMI), are younger, have less cartilage degeneration, and have less extrusion on MRI. These patients also presented more commonly with a ligament injury. However, our study will broadly analyze presenting symptoms and clinical examination findings to aid physicians in diagnosing meniscal root tear. Therefore, the purpose of this work is to analyze the presenting symptoms and clinical examination findings of patients undergoing meniscal root repairs to aid physicians in diagnosing this injury. The authors hypothesized that most patients would not present with the classic signs of meniscal injury upon physical and radiographic examination.

Methods

This study was approved by our institutional review board of Thomas Jefferson University (#21E.1100). All patients undergoing arthroscopic meniscal repair from January 1, 2016, to September 1, 2021, were retrospectively identified at our institution using Current Procedural Terminology codes 29882 and 29883. From this cohort, patient operative notes were manually reviewed by 2 independent authors (M.S. and A.L.C.), and those with definitive documentation of a meniscal root repair performed by sports medicine fellowship-trained orthopaedic surgeons at our institute were included in the study. Patients younger than the age of 40 years were excluded to focus on the difficult to diagnose population of patients with potential degenerative root tears.

Physician clinic notes for each included patient were then reviewed. Specifically, preoperative notes documenting the initial patient presentation were screened manually. Each note was assessed to determine whether the patient was presenting after an acute injury or as a result of chronic, insidious-onset knee pain. In cases of an acute injury, the following findings were documented: (1) mechanism of injury, (2) presence of a "pop" during the injury, (3) ability to bear weight, (4) use of cane or walker, (5) subjective anterior knee pain, (6) subjective posterior knee pain, (7) subjective medial knee pain, and (8) subjective lateral knee pain. The following physical examination findings also were screened for (1) medial joint line tenderness, (2) lateral joint line tenderness, (3) effusion, (4) positive/negative hyperflexion (Steinman) test, and (5) positive/negative McMurray test. The method and modifications of performing the McMurray test can vary between surgeons; therefore, the documentation of a McMurray test was accepted as the original McMurray test described by Hing et al.[9] unless otherwise stated.

Imaging findings also were reviewed. Preoperative radiographs were graded using the Kellgren-Lawrence (KL) scale for osteoarthritis. When available, preoperative MRIs were evaluated. Root tears were graded using the radiographic criteria of Choi et al.,[10] and articular cartilage injury was graded using a validated system, AMADEUS[11] (mean total Area Measurement And Depth & Underlying Structures, a scale from 0 to 100; 100 = no injury). Operative notes and arthroscopic images also were reviewed to assess for grade (using the Outerbridge classification) and location of concomitant chondral injury.

All statistical analyses were performed using R Studio (version 4.1.2). Continuous parametric and nonparametric data are presented as mean (standard deviation) for easier interpretation. Categorical variables are presented as a percentage (%) of those that were reported.

Results

Overall, 1199 patients older than the age of 40 years were screened using Current Procedural Terminology codes 29882 and 29883. Of these, a total of 221 patients were found to have meniscal root repair, as opposed to other types of meniscal repair (154 medial root; 10 lateral root; 24 both medial and lateral meniscal roots). The study population consisted of 71 men and 150 women. The mean age was 54.9 years (range, 40-75 years), and the mean BMI was 32.1 (range, 18.7-63.7). Most cases (65.6%) were acute injuries. Further, 85.5% of cases were caused by a low-energy mechanism, and patients heard or felt a "pop" in only 39.4% of cases. Most patients were able to bear weight (76.5%) and reported medial joint line pain (63.3%) (Table 1).

Physical examination findings are displayed in Table 2. Overall, 85.5% of patients had a positive McMurray test, 53.8% had pain with hyperflexion, and 71% had a documented effusion.

Radiographically, 118 patients (53.4%) had an MRI available for review. The root tears are characterized in Table 3. Within the cohort of patients who had an MRI available for review, 42.4% had articular cartilage damage. Chondral damage was graded using the AMADEUS system and is displayed in Table 3.

Arthroscopic findings are displayed in Table 4. The majority of tears were to the medial meniscal root (81.9%). Outerbridge classification of chondral injury, and concomitant pathology, is displayed in Table 4.

Discussion

Our primary findings were that 65.6% of patients reported that their pain began after an acute injury, but only 39.4% of patients reported a "pop," whereas mild (KL1) arthritis (49.5%), effusion (71%), medial joint line pain (91.4%), and a positive McMurray test (85.5%) were reliable indicators. With increasingly common occurrences of meniscal-related injuries, the attention of studies such as an investigation by Bhan et al.[12] and a study by Raj and Bubnis[13] have increased focus on meniscal tears in order to better understand risk factors associated with, presentation of, and

Table 1. Subjective Findings

Finding	Total, n (%)	Medial, n (%)	Lateral, n (%)
Laterality			
LT	116 (52.5)	75 (48.7)	6 (60)
RT	105 (47.5)	79 (51.3)	4 (40)
Acute injury?			
No	69 (31.2)	44 (28.6)	4 (40)
Yes	145 (65.6)	108 (70.1)	6 (60)
Not reported	7 (3.2)	2 (1.3)	0 (0)
Twisting injury			
No	166 (75.1)	114 (74)	6 (60)
Yes	48 (21.7)	38 (24.7)	4 (40)
Not reported	7 (3.2)	2 (1.3)	0 (0)
Walking downstairs?			
No	197 (89.1)	139 (90.3)	9 (90)
Yes	17 (7.7)	14 (9.1)	1 (10)
Not reported	7 (3.2)	1 (0.6)	0 (0)
High or low energy?			
Low	189 (85.5)	134 (87.1)	9 (90)
High	7 (3.2)	3 (1.9)	1 (10)
Not reported	25 (11.3)	17 (11)	0 (0)
Felt a "pop?"			
No	127 (57.5)	87 (56.5)	6 (60)
Yes	87 (39.4)	65 (42.2)	4 (40)
Not reported	7 (3.2)	2 (0)	0 (0)
Able to bear weight after injury?			
No	6 (2.7)	5 (3.2)	0 (0)
Yes	169 (76.5)	118 (76.7)	6 (60)
Limping	39 (17.6)	29 (18.8)	4 (40)
Not reported	7 (3.2)	2 (1.3)	0 (0)
Required crutches/cane?			
No	189 (85.5)	132 (85.7)	9 (90)
Yes	24 (10.9)	20 (14.3)	1 (10)
Not reported	8 (3.6)	2 (1.3)	0 (0)
Medial joint line pain			
No	81 (36.7)	50 (32.5)	4 (40)
Yes	140 (63.3)	104 (67.5)	6 (60)
Not reported	0 (0)	0 (0)	0 (0)
Lateral joint line pain			
No	203 (91.9)	144 (93.5)	8 (80)
Yes	18 (8.1)	10 (6.5)	2 (20)
Not reported	0 (0)	0 (0)	0 (0)
Anterior knee pain			
No	202 (91.4)	140 (90.9)	10 (100)
Yes	20 (9)	14 (9.1)	0 (0)
Not reported	0 (0)	0 (0)	0 (0)
Posterior knee pain			
No	136 (61.5)	92 (59.7)	6 (60)
Yes	85 (38.5)	62 (40.3)	4 (40)
Not reported	0 (0)	0 (0)	0 (0)

NOTE. n (%) reported as a percent of those that were documented in the physical examination note.

LT, left; RT, right.

Table 2. Physical Examination Findings

Finding	Total, n (%)	Medial, n (%)	Lateral, n (%)
Effusion			
No	48 (21.7)	34 (22.1)	1 (10)
Yes	157 (71)	113 (73.4)	9 (90)
Not reported	16 (6.2)	7 (4.5)	0 (0)
Medial joint line tender			
No	9 (4.1)	4 (2.6)	1 (10)
Yes	202 (91.4)	147 (95.5)	9 (90)
Not reported	10 (4.5)	3 (1.9)	0 (0)
Lateral joint line tender			
No	164 (74.2)	120 (77.9)	5 (50)
Yes	44 (19.9)	28 (18.2)	5 (50)
Not reported	13 (5.9)	6 (3.9)	0 (0)
Both joint lines tender?			
No	169 (76.5)	121 (78.6)	6 (60)
Yes	39 (17.6)	27 (17.5)	4 (40)
Not reported	13 (5.9)	6 (3.9)	0 (0)
Pain on deep flexion (aka Steinman or hyperflexion test)			
No	70 (31.2)	48 (31.2)	1 (1)
Yes	119 (53.8)	86 (55.8)	9 (9)
Not reported	32 (14.5)	20 (13)	0 (0)
Positive McMurray			
No	5 (2.3)	4 (2.6)	0 (0)
Yes	189 (85.5)	136 (88.3)	10 (100)
Not reported	27 (12.2)	14 (9.1)	0 (0)

NOTE. n (%) reported as a percent of those that were documented in physical examination notes.

outcomes after these injuries. The information collected in this study can aid physicians in the diagnosis of patients with meniscal root tears and contribute to the understanding of typical and atypical presenting symptoms and concomitant factors that contribute to these presentations.

In their study including 58 adolescent patients with meniscal root tears (mean age 16.01, 58.6% male, mean BMI 25.2), Wilson et al.[14] highlight 70.4% of meniscal root tears being attributed to noncontact injuries, 24.1% resulting from contact injuries and 5.2% the result of high-velocity injury. In addition, investigators reported the most common physical examination findings such as joint line tenderness in 95.6% of patients, the presence of effusion in 50%, and limited range of motion in 24.1%. Comparatively, our study with an older population of 221 patients (54.9 mean age) described injuries as acute (67.8%) and high energy (3.57%), with 22.4% being attributed to twisting and 7.9% occurring while walking downstairs. In this study, 95.7% of patients were found to have medial joint line pain, 21.2% were found to have lateral joint line pain, 18.8% were found to have both, and 76.6% were found to have effusion present. Notably, patients in both studies had comparable rates of physical examination findings, etiology of injury, and presence of chondral injury (36.2% vs 42.4% in this study), despite patients in both studies differing substantially in terms of age, sex, BMI, and rate of lateral root tears (79.3% vs 5.29% in this study).

Table 3. Imaging Characteristics and AMADEUS Grading

MRI Finding	Total, n (%)	Medial, n (%)	Lateral, n (%)
Grade			
Degenerative	13 (11.0)	6 (7.3)	1 (14.3)
Partial	42 (35.6)	32 (39)	2 (26.6)
Full	63 (53.4)	44 (53.7)	4 (57.1)
Location			
Enthesial	33 (28.0)	22 (26.8)	4 (57.1)
Midsubstance	52 (44.1)	35 (42.3)	1 (14.3)
Junction	33 (28.0)	25 (30.5)	2 (26.6)
Orientation			
Radial	101 (85.6)	70 (85.4)	6 (85.7)
Longitudinal/ vertical	9 (7.63)	7 (8.5)	1 (14.3)
Longitudinal/ horizontal	8 (6.78)	5 (6.1)	0 (0)
Articular cartilage injury on MRI			
No	68 (57.6)	48 (58.5)	9 (90)
Yes	50 (42.4)	34 (41.5)	1 (10)
Location			
MFC	45 (90.0)	16 (80)	1 (100)
LFC	1 (2.00)	1 (5)	0 (0)
MTP	4 (8.00)	3 (15)	0 (0)
Cartilage injury on MRI			
Signal alteration	1 (2.00)	1 (2.9)	0 (0)
Partial	34 (68.0)	22 (64.7)	1 (100)
Full	15 (30.0)	11 (32.4)	0 (0)
Size of articular cartilage injury, mm^2	32.8 (74.3)	32.8 (74.3)	27.9 (65.5)
Size of articular cartilage injury, mm^2	0.33 (0.74)	0.33 (0.76)	0.28 (0.66)
Subchondral bone defect			
No defect	49 (98.0)	33 (97.1)	10 (100)
Bony defect <5 mm depth	1 (2.00)	1 (2.9)	0 (0)
Bone edema			
No	39 (78.0)	23 (67.6)	10 (100)
Yes	11 (22.0)	11 (32.4)	0 (0)
AMADEUS total:	94.4 (11.4)	94.4 (11.4)	95.2 (10.8)
AMADEUS total cat:			
50	1 (0.45)		
60	7 (3.17)		
65	3 (1.36)		
70	7 (3.17)		
75	6 (2.71)		
80	13 (5.88)		
85	11 (4.98)		
90	1 (0.45)		
100	171 (77.4)		

AMADEUS, Area Measurement And Depth & Underlying Structures; LFC, lateral femoral condyle; MFC, medial femoral condyle; MRI, magnetic resonance imaging; MTP, medial tibial plateau.

Other studies have pointed to the common association between patients reporting a "pop" and the discovery of meniscal injury.[3,5] However, a "pop" can be heard in other injuries to the knee, such as with anterior cruciate ligament injury, which can follow sports injury or major trauma, as well as a discoid meniscus, which can present with recurrent nonpainful popping.[3,15] In a study of 936 Asian patients (mean age 41 years, 25.5% male), 237 with confirmed posterior root tear of medial meniscus, 86 of the 936 reported a painful pop at injury, with 83 (96.5%) of these patients being categorized as having isolated posterior root tear of the medial meniscus.[5] In their cohort, the authors found the positive predictive value of the painful pop to identify medial meniscus posterior root tear was 96.5%, the negative predictive value was 81.8%, sensitivity was 35.0%, and specificity was 99.5%, with diagnostic accuracy of 77.9%. This highlights the application of such questions in establishing clinical care from patient-reported symptoms. The rate of patients with root tears hearing a pop was 35.0% compared with 39.4% in our study, despite members within the cohort of the other study being on average younger (41 years vs 54.9 years), only being of Asian descent, and the authors only examining isolated posterior root tears of the medial meniscus as opposed to isolated and nonisolated medial and lateral root tears as was examined in this study. This highlights the potential usefulness of patient-reported symptoms in increasing clinical suspicion of meniscal root tear.

Meniscal injuries have a known association with arthritis and chondral injuries in the years after initial injury; however, the association between meniscal injuries and chondral damage at the time of initial presentation remains unclear.[16] In a study of 103 patients with isolated medial meniscus tears (mean age 48 years, BMI 28.8, 74% male), 21 (20.4%) of which were root tears (52 years old, mean BMI 30.4), the authors found that root tear was associated with significantly greater degeneration on the medial femoral condyle when compared with bucket handle/ vertical meniscal tears.[17] Another study of 50 patients (36.5 years old, 46% male) with medial (n = 23), lateral (n = 26), or both medial and lateral (n = 1) meniscal root tears found those with medial meniscus root tears were 5.8 times more likely to have chondral defects than those with lateral meniscus root tears ($P = .021$).[18] The rate of chondral defects in the 49 patients who had either medial or lateral meniscus root tears was 55% compared with this study, where the frequency of chondral injury was 42.4%. Notably, in their study all chondral defects were Outerbridge grade 2 or greater.[18,19] Although further investigation is needed in order to draw specific conclusions about the value of these preoperative characteristics in identifying other concomitant pathologies, location of root tears, and frequency in specific populations, the insight from this study allows for potential associations to be determined.

Table 4. Arthroscopic Findings

Arthroscopic Finding	Total, n (%)	Medial, n (%)	Lateral, n (%)
Medial or lateral tear of meniscus	188 (85.1)*		
Medial	154 (81.9)		
Lateral	10 (5.3)		
Both	24 (12.8)		
Concomitant articular cartilage injury	165 (74.6)*	141 (91.6)*	8 (80)*
Outerbridge - MFC (1-4)	159 (96.3)†	131 (92.9)†	8 (100)†
1	29 (18.2)	21 (16)	3 (37.5)
2	66 (41.5)	56 (42.7)	3 (37.5)
3	55 (34.6)	46 (35.1)	2 (25)
4	9 (5.66)	8 (6.1)	0 (0)
Outerbridge - LFC (1-4)	17 (10.3)†	10 (7.1)†	3 (37.5)†
0	1 (5.88)	1 (10)	0 (0)
1	3 (17.6)	3 (30)	0 (0)
2	4 (23.5)	1 (10)	2 (25)
3	6 (35.3)	3 (30)	1 (12.5)
4	3 (17.6)	2 (20)	0 (0)
Outerbridge - medial tibial plateau (1-4)	63 (38.1)†	52 (36.9)†	2 (25)†
0	1 (1.59)	1 (1.9)	0 (0)
1	11 (17.5)	10 (19.2)	0 (0)
2	33 (52.4)	30 (57.7)	0 (0)
3	13 (20.6)	7 (13.5)	1 (12.5)
4	5 (7.94)	4 (7.7)	1 (12.5)
Outerbridge - lateral tibial plateau (1-4)	30 (38.2)†	22 (15.6)†	3 (37.5)†
0	1 (3.33)	1 (4.5)	0 (0)
1	12 (40.0)	11 (50)	1 (33.3)
2	12 (40.0)	6 (27.2)	2 (66.6)
3	3 (10.0)	2 (9.1)	0 (0)
4	2 (6.67)	4 (18.2)	0 (0)
Concomitant arthroscopic findings			
Ligament tear	5 (2.3)*	2 (1.3)	0 (0)

NOTE. Patients with articular cartilage injury may have 1 or more lesions and thus may account for greater than one location of injury.

LFC, lateral femoral condyle; MFC, medial femoral condyle.

*Calculated as a percentage of total patients (total; N = 221) (medial; N = 154), (lateral; N = 10).

†Calculated as a percent of patients with documented cartilage injury.

Limitations

This study has several limitations. First, these limitations include its retrospective nature, which contributes to the limited information available for some patients in terms of responses to certain questions or identifying additional information related to patients, their injuries, and other pertinent medical history. Our study only included those older than the age of 40 years, which portends to root tears likely of degenerative origin. Degenerative tears are often not repairable, which is why identifying presenting signs and symptoms in acute nonarthritic root tears are essential for the clinical to recognize and appropriately diagnose. Repairability criteria among operating physicians was not standardized or documented, allowing for variability in which patients were deemed eligible for root repair. Moreover, data collection was limited to the documentation provided in the patient's medical record; therefore, surgeon-specific variations in physical examination techniques such as the McMurray and hyperflexion test, may not be accounted for if they were not documented. Documentation was ultimately reviewed and signed by the operating physician; however, it may have been prewritten by a resident, physician assistant, or nurse practitioner. This may have potentially introduced error in documentation. The limited cohort size reduces our ability to perform subgroup analysis on meniscal root tears in patients and their clinical findings depending on factors such as whether root tears were isolated, were found in the medial or lateral meniscus, or the patient had received any additional procedures. Without a comparative group, we were unable to calculate the negative or positive predictive value of our findings. No patient-reported outcomes were presented in this study, as the focus was primarily on clinical history and examination findings in this study group. Radiographically, the isolation of root tear patients predisposes to selection bias when considering KL grading. Almost one-half of the population had a KL grade of 1, which may not be representative of the average root tear population that presents to an orthopaedic office. Only approximately 50% of patients had MRI available for review. This was attributed to the lack of access to these images if an outside imaging center was used. Lastly, our study only looked at those who underwent meniscal root repair. It is possible that patients who underwent repair may have presented differently than those who were treated conservatively for a root tear or had a different final diagnosis.

Conclusions

Although a majority of patients reported pain began after acute injury, less than one-half reported hearing a "pop." When patients were evaluated, an effusion, positive McMurray test, and positive hyperflexion test were present in most meniscal root tears.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: K.B.F. reports board or committee membership with the American Orthopaedic Society for Sports Medicine; paid consultant for DePuy, A Johnson & Johnson Company and Vericel; a grant from Vericel Corporation; consulting fees from Vericel, Innocoll, and Medical Device Business Services;

education, travel and lodging, and food and beverage expenses from Liberty Surgical; honoraria from Vericel; and compensation from Vericel for services other than consulting, including serving as faculty or as a speaker at a venue other than a continuing education program. S.B.C. reports board or committee membership for the American Orthopaedic Society for Sports Medicine and International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine; research support from Arthrex, Inc and Major League Baseball; paid consulting from CONMED Linvatec; publishing royalties, financial or material support from Slack, Inc; and IP royalties, paid consultant, paid presenter or speaker for Zimmer. All other authors (A.R.P., C.C., A.J.., M.S., A.L.C.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors thank John Hayden Sonnier, MD and Michael P. Campbell, MD for the assistance with completion of the study.

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