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Influence of Baseline Magnetic Resonance Imaging Features on Outcome of Arthroscopic Meniscectomy and Physical Therapy Treatment of Meniscal Tears in Osteoarthritis

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Abstract

Background: Arthroscopic partial meniscectomy (APM) is used to treat meniscal tears, though its efficacy is controversial.

Purpose: This study used magnetic resonance imaging (MRI) to determine characteristics that lead to greater benefit from APM and physiotherapy (PT) than from PT alone among patients with meniscal tear and knee osteoarthritis (OA).

Study Design: Secondary analysis of data from a randomized clinical trial.

Methods: Using data from the Meniscal Tear in Osteoarthritis Research (MeTeOR) trial, we first assessed whether the effect of treatment on pain scores at 6 months differed according to baseline MRI features (bone marrow lesions, cartilage and meniscal damage). Second, we summed MRI features associated with differential pain relief between APM and PT to create a 'Damage Score'. The Damage Score included BML number and cartilage damage size with possible values of 0 (least damage), 1 and 2 (greatest damage). We used linear models to determine whether the association between Damage Score and pain relief at 6 months differed for APM vs. PT.

Results: We included 220 participants; 13% had the least damage, 52% moderate damage, and 34% greatest damage. Though treatment type did not significantly modify the association of

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Damage Score and change in pain (p interaction=0.13), those with least and moderate damage had greater improvement in KOOS Pain with APM than with PT, by 15 and 7 points respectively. Those with greatest damage had similar improvement with APM and PT.

Conclusion: In patients with OA and meniscal tear, those with less intra-articular damage on MRI may have greater improvement in pain with APM and PT than with PT alone. However, these results should be interpreted cautiously due to limited sample size.

What is known: Several studies of patients with mild to moderate OA did not document a statistically or clinically significant difference in pain relief between APM and physiotherapy for the treatment of meniscal tear.

What this study adds: We use magnetic resonance imaging to predict treatment outcomes in operative and non-operative treatment of meniscal tear in patients with knee osteoarthritis. We identify of a subgroup of patients with less intra-articular damage that have greater improvement in pain with operative than non-operative management of meniscal tear

Keywords

osteoarthritis; meniscus; meniscectomy; epidemiology

Introduction

Meniscal tears are common in patients with osteoarthritis (OA), with up to 91% of patients with symptomatic OA having meniscal tear identified on magnetic resonance imaging (MRI).² Of the nearly one million arthroscopic knee surgeries performed annually in the United States, approximately half are performed to treat meniscal tears.¹⁵ However, randomized trials have not demonstrated clear benefit of arthroscopic partial meniscectomy (APM) in the management of meniscal tears. Several studies of patients with mild to moderate OA did not document a statistically or clinically significant difference in pain relief between APM and physiotherapy (PT).^{6, 9, 16, 21} A trial comparing APM to sham surgery in patients with mild to moderate OA did not demonstrate statistically or clinically significant differences in pain relief at 12 months between the two groups.²⁰ However, a recent trial including patients with meniscal tear and a less than 50% reduction in joint space found that patients undergoing APM plus PT had a clinically and statistically significant improvement in knee pain compared to those receiving PT alone.⁵ Further, while the intention to treat analyses of several of the aforementioned trials did not document a clear benefit for APM, up to one third of subjects crossed over from PT to APM.^{9, 16} Thus, some of the benefit ascribed to PT in the intention to treat analyses may reflect the results of APM in participants who crossed over.¹⁷

These observations demonstrate uncertainty regarding whether APM is an effective treatment for meniscal damage in persons with concomitant cartilage damage. Given this uncertainty, there is considerable interest in whether particular patient subgroups may benefit more from APM than from PT. Since most patients undergo MRI prior to APM, it would be useful to know whether certain MRI features are associated with particularly favorable (or unfavorable) outcomes of surgery as compared with PT. The purpose of our study was to evaluate whether intra-articular damage, as quantified by MRI features of bone

marrow lesions (BMLs), articular cartilage damage, and meniscal damage, is associated with differential outcome from APM vs. PT. Specifically, we hypothesized that patients with less intra-articular damage as quantified by smaller or fewer BMLs, less extensive cartilage damage, and simple meniscal tears will have greater improvement in pain with APM and PT than with PT alone at 6 months.

Methods

Study Sample

We used data from subjects enrolled in the Meniscal Tear in Osteoarthritis Research (MeTeOR) randomized clinical trial.⁹ Details of this trial design have been published previously.¹⁰ Three hundred and fifty-one subjects were recruited from 7 academic referral centers between June 2008 and August 2011. Recruited males and females were 45 years or older and had at least 4 weeks of knee pain and an MRI with evidence of meniscal tear extending to the meniscal surface. Included participants also had evidence of OA as determined by osteophyte or joint space narrowing on plain radiographs, or articular cartilage defect on at least one tibial or femoral surface on MRI. Exclusion criteria included a chronically locked knee, inflammatory arthritis, or prior surgery on the index knee. Participants with radiographic Kellgren-Lawrence (KL) grade 4 OA (greater than 50% loss of tibiofemoral joint space) were excluded.¹³ Participants were randomized to APM with PT or PT alone. Participants randomized to APM were scheduled through the study site. The aim was to have participants proceeded to APM within 2-weeks of randomization, after which participants received postoperative PT. All participants randomized to APM underwent the procedure as outpatients. During the surgery meniscal tears were resected back to a stable margin. Debridement of large articular flap tears and loose bodies were permitted if these were felt to be symptomatic, since failure to do so was considered unethical. Abrasion arthroplasty, subchondral microfracture, and synovectomy were not permitted. Participants in the APM and PT arms followed the same PT protocol though could progress through the phases at different rates. Participants had PT sessions twice per week for 6–8 weeks. The PT protocol is outlined in appendix 1. Randomization was performed using blocks of varying size within each site. Participants were stratified by KL grade on baseline radiograph, grade 0–2 vs grade 3. During the course of the trial participants in both arms were able to use acetaminophen, non-steroidal anti-inflammatory agents, narcotic pain medication, or knee braces. Intra-articular injections were discouraged but permitted in both arms.

For this analysis, we included only participants with baseline MRIs that were available to be re-read centrally. All participating centers used cartilage sensitive sequences in MRI acquisition. There were no statistically significant differences in age or KL grade between those with and without available MRIs. We excluded three participants without baseline Knee injury and Osteoarthritis Outcome Scale (KOOS) pain scores and 12 without 6-month KOOS pain scores.¹⁹ Participants with missing KOOS Pain scores did not differ from those included with regards to age, gender, or KL grade. The 12 participants with missing 6-month KOOS scores did have statistically greater mean pain scores at baseline (60 points vs 45 points). As our aim was to assess the treatment-specific effect of APM and PT on 6-month

outcomes, participants randomized to APM who did not have surgery within 6 months were excluded. Participants randomized to PT who crossed over to the APM arm prior to 6 months were excluded from the primary analysis. We excluded this subset as they received APM at a variety of time points, and thus were in various stages of post-operative recovery by the 6-month pain assessment. Participants randomized to PT who crossed over to the APM arm after 6 months were included in the PT arm (Figure 1). We conducted two sensitivity analyses. First we included the 41 participants who crossed over from PT to APM prior to 6 months and analyzed them under the APM arm in an as treated analysis. Secondly we used an intention to treat approach, including all patients in the arm to which they were randomized. All participants provided consent and the study was approved by the (removed for blinding), and by the IRBs at the 6 additional participating sites. This trial is registered at clinicaltrials.gov (removed for blinding).

Data Elements

Data on demographics and OA severity were collected at baseline. In addition to age and sex, we collected data on body mass index (BMI, kg/m²) and KL radiographic grade, categorized as 0) normal; 1) questionable osteophyte; 2) definite osteophyte; and 3) <50% joint space narrowing.¹³ Subjects with KL 4 (> 50% narrowing) were excluded.

MRI Imaging Features

As part of the MeTeOR trial the MRIs performed at study entry were re-read centrally by a single experienced musculoskeletal radiologist and scored according to the previously established MRI OA Knee Score (MOAKS) criteria⁷. This reader had an interclass correlation of 0.98 when compared to a musculoskeletal radiologist with 19 years of experience in reading knee MRI using semiquantitative scoring systems for the total OA score according to MOAKS. All MRIs were performed with cartilage sensitive sequences (SPGR, FLASH, DESS, 3 point DIXON) as well as water sensitive sequences (e.g. proton density-, T2-, Intermediate- weighted sequences with fat suppression) enabling accurate assessment of cartilage and BMLs. We used MOAKS-based evidence of BMLs (number and size), cartilage damage (size and depth), meniscal extrusion, and meniscal damage. MOAKS divides the articular and subspinous region of the knee into subregions to grade BML and cartilage (15 subregions for BML and 14 for cartilage). For this analysis, we computed the number of subregions with BML (size >0) and maximum BML size score. The number of subregions with any BML (possible range from 0–15 subregions) was categorized as none, 1, 2, 3, or 4 and further dichotomized to none vs. any. BML size is categorized as 0) no BML; 1) < 33%; 2) 33–66%; and 3) >66% of a subregion occupied. Maximum BML size score was dichotomized as <33% and ≥33% (MOAKS 0–1 vs. 2–3). Cartilage damage is quantified in two ways: size of any cartilage loss (% of surface area in subregion); and depth of cartilage damage (% of full thickness loss in subregion). For each subregion, both cartilage damage size and depth are categorized as encompassing 0) none; 1) <10%; 2) 10–75%; and 3) >75% of a subregion. For this analysis, we used the maximum size and depth of cartilage across the 14 regions for analysis. We further dichotomized maximum cartilage damage size to <75% and ≥75% (MOAKS <3 vs. 3) and cartilage damage depth to <10% vs. ≥10% (MOAKS 0–1 vs. 2–3). Extruded menisci are categorized as 1) any extrusion <2mm; 2) any extrusion 2–2.9mm; and 3) any extrusion ≥3mm. Extrusion was dichotomized at

2.9mm and 3mm (MOAKS <3 vs. 3). Meniscal tears types are marked yes or no according to MOAKS. We regarded meniscal damage as binary – those with only simple tears (comprised of vertical and radial tears) versus all other damage morphologies (root tears, maceration, horizontal and complex tears). As root tears, maceration, horizontal, and complex tears are more often associated with older age and degeneration of the meniscus and intra-articular structures, simple tears reflect the least amount damage on the meniscal damage spectrum.^{1, 3, 4, 7}

Outcome and Assessment

The outcome of interest was change in patient reported pain from baseline to 6-month follow-up. The KOOS pain scale was used to assess overall patient reported knee pain in the last week and was transformed to a 0–100 scale with 0 being least amount of pain and 100 greatest amount of pain¹⁹. The 6-month time point was chosen as it gave sufficient recovery time from APM, but was soon enough after treatment that other competing causes of knee pain aside from meniscal tear would be less likely to arise. The 6-month time point was also used for the primary outcome assessment in the parent MeTeOR trial.⁹

Statistical Analysis and Creation of a Damage Score

The developers of MOAKS did not provide a rubric for a summed or composite MOAKS score across domains. Since, we were particularly interested in investigating whether a combination of features aided in identifying participants in which the response to APM or PT would be more favorable, we created a ‘Damage Score. We described baseline characteristics of the study sample using means and percentages. First, for each binary intra-articular feature (BML size, number of subregions with BML, cartilage damage size, cartilage damage depth, meniscal extrusion, and meniscal tear type) we calculated the change in KOOS pain from baseline to 6 months separately for each treatment. Second, we assessed the differential impact of each intra-articular feature on the change in KOOS over 6 months between treatments using linear regression with the interaction term treatment*intra-articular feature. If the interaction term exhibited a p-value < 0.2 we advanced it for inclusion in the Damage Score.

Finally, we created the Damage Score to quantify as a summary measure of intra-articular deficiency. To do this, we created an indicator variable by assigning the lower category a damage score of 0, and the higher category with a score of 1 for each candidate feature advanced. For example, in cartilage damage size those with maximum damage <75% were scored as 0, while those with ≥75% were scored as 1. We calculated a Damage Score as the sum of these indicators. The Damage Score included BML number (none=0, any=1) and cartilage damage size (<75% =0, ≥75%=1) with possible values of 0 (least damage), 1 and 2 (greatest damage). BML size, maximum cartilage damage depth, meniscal extrusion, and meniscal damage did not meet the pre-specified threshold and thus were not included in the Damage Score. We used this Damage Score in multivariable linear regression to assess whether the Damage Score modified the effect of treatment on change in KOOS Pain over 6 months, considering age, sex, body mass index (BMI, kg/m²), KL grade, and baseline KOOS pain as potential covariates.

Results

Baseline Characteristics

The sample consisted of 220 persons (one affected knee per person), with 121 randomized to APM followed by PT and 99 to PT alone. The mean age was 59 (SD 7) years, mean BMI was 30 (SD 6), and 54% were female. Subjects were evenly distributed among the KL grades with 23% to 27% of participants falling in each grade category. The overall average baseline KOOS Pain score was 45 (SD 16). Sixteen percent of subjects had no BML, 48% had maximum BML size <33%, 63% had maximum cartilage damage size < 75%, 55% had maximum cartilage damage depth <10%, 58% had meniscal extrusion < 2.9mm, and 16% had simple meniscal tears (Table 1). Tear type and location as identified on MRI are outlined in appendix 2. Medial tears were seen in 202 participants, lateral tears in 77 participants, and 60 participants had both medial and lateral tears identified. On average participants undergoing APM completed the 6-month questionnaire 166 days after surgery.

Development of a Damage Score

In linear regressions, the number of subregions with BML ($p=0.17$) and maximum cartilage damage size ($p=0.05$) achieved the pre-specified screening p value of <0.2 for interaction between the intra-articular feature and treatment type on change in KOOS Pain score at 6 months. Neither maximum BML size, maximum cartilage damage depth, meniscal extrusion, nor meniscal damage met the pre-specified threshold (Table 2). Those with no BML undergoing APM and PT had a 13-point greater improvement than those undergoing PT alone ($p=0.05$), while subjects with any BML undergoing APM and PT had only a 3-point greater improvement when compared to PT alone ($p=0.2$). Among those with less cartilage damage (<75%), subjects undergoing APM and PT improved in KOOS Pain score by 8 points more than subjects undergoing PT alone ($p=0.01$). In comparison, those with greater cartilage damage ($\geq 75\%$) undergoing APM and PT improved 2 points less than those undergoing PT alone ($p=0.6$).

Thirteen percent of participants had a Damage Score of 0 (least damage), 52% a Damage Score of 1 (moderate damage), and 34% a Damage Score of 2 (greatest damage). At baseline, the mean age of participants with a Damage Score of 0 (least damage) was 56 (SD 8) years, 58 (7) years for those with a Damage Score of 1, and 60 (7) years for those with a Damage score of 2. Those with Damage Score of 0 were also more likely to have KL grade 0 disease-38% versus 29% and 9% for those with Damage Score 1 and 2, respectively. The mean baseline KOOS pain score did not vary significantly between the damage categories (43–46) (Table 3). Because age and KL grade varied among the different Damage Score categories they were included as covariates in the final model.

In the multivariable model the difference in 6-month change in KOOS Pain scores between APM and PT and PT alone were statistically significant for participants with the least and moderate damage. Participants with the least damage had a 15-point greater improvement in KOOS Pain score following APM and PT than PT alone; and those with a Damage Score of 1 had, on average, a 7-point greater improvement with APM ($p=0.03$ for both). However, those with Damage Score of 2 had similar improvement in KOOS Pain score between APM

and PT and PT alone. The interaction of damage score and treatment type on change in KOOS Pain at 6 months was not statistically significant (p interaction=0.13). (Table 4 and Figure 2).

In a sensitivity analysis examining the 40 patients (1 excluded for missing change in pain at 6-months) crossing over from PT to APM prior to 6mo, we found similar levels of intra-articular damage at baseline. Thirty-five percent of subjects had no BML, 60% had maximum BML size <33%, 53% had maximum cartilage damage size < 75%, 65% had maximum cartilage damage depth <10, 60% had meniscal extrusion < 2.9mm, and 15% had simple meniscal tears. The mean baseline KOOS Pain scores were higher (51 points). Inclusion of these patients who crossed over from PT to APM in the APM arm did not change the results of the primary analysis- with APM leading to greater pain relief than PT at six months among those with the least damage, and little difference between APM and PT and PT alone in those with the greatest damage (appendix 3). Using an intention to treat approach again yielded similar results to the main analysis, though the interaction of damage score and treatment type on change in KOOS Pain at 6 months was statistically significant (p interaction=0.03) (appendix 4).

Discussion

In this longitudinal study of patients with meniscal damage and various degrees of osteoarthritic change, we found that patients with fewer BMLs and smaller areas of cartilage damage had greater improvement in pain at 6 months when treated with APM and PT than with PT alone. Similarly, using BML and cartilage damage size to create a summed Damage Score, we demonstrated that those with less severe intra-articular damage had greater pain relief with APM and PT as compared to PT alone, though the overall interaction did not achieve statistical significance.

We acknowledge that our study was a post-hoc exploratory analysis of clinical trial data and we lacked power to evaluate the interaction definitively. The effect of the Damage Score on 6-month pain score outcomes was not statistically significantly modified by treatment type (p interaction= 0.13). Thus, we regard these findings as hypothesis generating. Of note, while all groups improved over 6 months in both the operative and non-operative arms, the 15 point greater improvement in KOOS Pain score among patients with a Damage Score of 0 who underwent an APM and PT, as compared with those who had PT alone, exceeded the KOOS minimal clinically important difference of 8–10.¹⁸ In knees with less intra-articular damage, meniscal tear may be the etiology of pain and thus amenable to APM, in comparison to knees with greater osteoarthritic findings, where pain may be more multifactorial with variable or little contribution from meniscal tear.

In the MeTeOR trial, functional improvement did not significantly differ between APM and PT and PT alone after stratification by KL grade (0–2 vs. 3).⁹ Similar findings were demonstrated in the study by Sihvonen et al, where stratification by KL grade (0 vs. 1) yielded no significant between group differences or interaction between APM and sham surgery on pain outcomes.²⁰ Our study builds on these prior analyses in that we used MRI assessment to categorize intra-articular damage, which may offer a more detailed portrayal

of joint damage than plain radiographs. Furthermore, Sihvonen et al compared APM to sham surgery and, not to PT.⁸ Our study adjusted for KL grade, further suggesting that more granular imaging features, such as BMLs and cartilage damage, may associated with differentially greater pain relief following APM and PT than PT alone independent of severity on plain radiographs.

Prior research has investigated predictors of poor outcome after APM. In a prospective study of patients undergoing APM, those with more severe MRI-defined cartilage damage and bone marrow lesions had less clinical improvement based on pre and post-operative International Knee Documentation Committee (IKDC) knee evaluation questionnaires.¹⁴ This study also found that patients with root tears on MRI had a statistically significant increased risk of not improving postoperatively.¹⁴ This was in agreement with two retrospective studies by Katz et al that found worse functional outcomes post APM in those with more extensive cartilage damage documented on MRI or arthroscopic visualization.^{11, 12} These prior studies focused exclusively on surgically treated subjects. Our analyses took advantage of the randomized trial design of MeTeOR, which permitted us to focus on the differential effect of PT and APM on pain in the context of select MRI findings. Therefore, our findings are germane to the decision of whether to recommend APM or PT. The ability of a priori imaging to assist in predicting differential outcomes between surgical and non-operative therapy suggests imaging may guide treatment decision-making.

Our study has several limitations in addition to its hypothesis-generating nature as a post-hoc analysis of a trial that was not designed to address the interaction between treatment and MRI features. The Damage Score is a novel summed assessment of intra-articular damage and has not been validated. The least Damage Score category yielded the largest difference in outcomes after APM versus PT, but had the fewest participants. As many of the included participants had advanced osteoarthritic changes further studies should include samples enriched for patients with mild intra-articular damage. We are only able to analyze participants who had MRI available for central re-reading, which opens the possibility of selection bias, though age and KL grade did not differ between those with and without MRI. Furthermore, MRIs were obtained at different enrolling centers and therefore did not adhere to a single, study-wide protocol. However, all centers included cartilage sensitive sequences, permitting valid application of MOAKS scoring. We excluded participants crossing over from PT to APM prior to 6 months, as these participants received an APM procedure at varying time points prior to the 6-month pain analysis. This cohort may be unique in that perhaps participants were 'not responding' adequately to PT and thus opted to pursue APM, however, a sensitivity analysis that included patients who crossed over from PT to APM within 6 months in the APM arm and an intention to treat strategy yielded similar results. The primary outcome was assessed at 6-months and does not speak to long-term or durable response. However, we chose the 6-month time point as it allowed for surgical recovery yet would avoid additional competing risks for knee pain. Patient-reported physical activity was not ascertained during the MeTeOR trial and reflects a limitation as this may influence outcomes. The average participant in this trial was considered obese by BMI. Obesity is a likely contributor to pain in knee OA which was not addressed as part of the MeTeOR treatment regimen. While the trial enrolled in seven centers across the US, the great majority of participants were white, limiting generalizability.

In summary, in exploratory analysis we demonstrated that in patients with meniscal damage and knee OA, those with less severe intra-articular damage identified on MRI, including BMLs and cartilage damage, had greater pain relief with APM and PT than with PT alone. This suggests that intra-articular damage on MRI may be useful to guide the initial decision of surgical versus non-surgical management for meniscus tears in patients with OA. As the interactions we observed were not statistically significant, these findings should be interpreted cautiously. Further studies should be conducted on a larger cohort to evaluate more definitively the effect of the severity of intra-articular damage on outcomes after surgical versus non-surgical management in this patient population.

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Appendix

Appendix 1:

Physical therapy protocol for physical therapy and arthroscopic partial meniscectomy participants.

Phase	Goals and Criteria for Advancement to next phase	Interventions
Phase I	<u>Goals:</u> --Reduce inflammation, swelling --Restore passive/active ROM --Reestablish quads muscle activity <u>Advance to Phase II when....</u> --ROM > 115 deg flexion, 0 deg extension --Moderate to minimal effusion --Mild to moderate knee pain --Good muscle strength	-- <u>Stretching</u> (hams, quads, psoas, gastrocsoleus) -- <u>Strengthening- Open chain</u> Quads sets, SRL, Hip adduction, abduction Knee extension, active assisted ROM stretching -- <u>Strengthening - Closed chain</u> Weight bearing quad sets with theraband Standing hamstring curls, toe raises, ½ squats Stationary bicycle, no resistance --Balance proprioceptive drills. gait training Modalities: Cryotherapy, ultrasound, electric stim, compression
Phase II	<u>Goals:</u> --Restore strength, endurance --Full, pain free active ROM --Return to functional activities --Minimize gait deviations <u>Advance when...</u> --ROM > 135 deg flexion, 0 deg extension --No pain, tenderness --Minimal effusion --Grossly normal strength	--Cryotherapy --Stretching (hams, quads, psoas, gastrocsoleus) -- <u>Strengthening - closed chain</u> Bicycle for motion, strength, endurance Lateral lunges, front lunges, ½ squats Lateral step-ups, toe raises --Proprioceptive balance training
Phase III	<u>Goals:</u> Enhance strength and endurance Maintain full ROM Return to sport, recreation, functional activities	<u>Exercises:</u> --Open chain Continue PRE exercise program, LE stretches --Closed chain e.g. leg press, partial squats, total gym

Phase	Goals and Criteria for Advancement to next phase	Interventions
		--Proprioceptive (jump, hop, figure eights, etc)

Appendix 2:

Number of patients with each type and location of meniscal tears identified on MRI

	Anterior Medial	Body Medial	Posterior Medial	Anterior Lateral	Body Lateral	Posterior Lateral
Signal Abnormality	17	59	37	10	17	17
Radial tear	-	2	20	-	-	1
Horizontal tear	4	36	70	19	23	15
Vertical tear	1	4	19	5	4	1
Complex tear	1	12	28	5	3	10
Maceration	1	14	11	10	12	9
Root tear	-	-	33	1	-	3

Appendix 3.

Adjusted Mean Change in 6-month KOOS pain scores after APM or PT by Damage Score (Damage Score compiled from binary measure of cartilage damage size and number of BML) using an as treated analysis.

Damage Score	KOOS Pain (95% CI) at 6 months*		
	APM and PT	PT alone	P interaction
Least: 0	-26 (-32, -19)	-14 (-25, -3)	
Moderate: 1	-28 (-32, -24)	-20 (-25, -15)	0.31
Greatest: 2	-22 (-26, -17)	-20 (-26, -14)	

KOOS; Knee injury and Osteoarthritis Outcome Score; APM; arthroscopic partial meniscectomy, PT; physical therapy

* Adjusted for age and Kellgren Lawrence grade.

Appendix 4.

Adjusted Mean Change in 6-month KOOS pain scores after APM or PT by Damage Score (Damage Score compiled from binary measure of cartilage damage size and number of BML) using an intention to treat analysis.

Damage Score	KOOS Pain (95% CI) at 6 months*		
	APM and PT	PT alone	P interaction
Least: 0	-29 (-37, -21)	-16 (-24, -8)	
Moderate: 1	-28 (-32, -23)	-23 (-27, -19)	0.03
Greatest: 2	-18 (-24, -13)	-23 (-28, -17)	

KOOS; Knee injury and Osteoarthritis Outcome Score; APM; arthroscopic partial meniscectomy, PT; physical therapy

* Adjusted for age and Kellgren Lawrence grade.

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Figure 1:
Diagram of included participants and reason for exclusion

Figure 2:

Difference in mean change in KOOS pain at 6-month between APM and PT for each Damage Score category (Damage Score compiled from binary measure of number of bone marrow lesions and cartilage damage size).

Table 1.

Baseline characteristics of entire cohort

Baseline Characteristics N=220				
	Overall	APM	PT	
Age	59 (7)	59 (8)	58 (6)	
Female, n (%)	118 (54)	65 (54)	53 (54)	
BMI	30 (6)	30 (6)	30 (6)	
KL grade, n (%)				
0	51 (23)	29 (24)	22 (22)	
1	56 (25)	30 (25)	26 (26)	
2	54 (25)	28 (23)	26 (26)	
3	59 (27)	34 (28)	25 (25)	
Baseline KOOS pain score	45 (16)	45 (15)	45 (17)	
Baseline MRI features, n (%) N=220				
	Overall	APM	PT	
BML number *				
None	34 (16)	21 (18)	13 (13)	
Any	184 (84)	99 (83)	85 (87)	
BML size *				
<30%	104 (48)	58 (48)	48 (48)	
33%,	114 (52)	63 (52)	51 (52)	
Cartilage damage size				
<75%	138 (63)	77 (64)	61 (62)	
75%	82 (37)	44 (36)	38 (38)	
Cartilage damage depth				
<10%	122 (55)	66 (55)	56 (57)	
10%	98 (45)	55 (45)	43 (43)	
Meniscal extrusion				
2.9mm	127 (58)	69 (57)	58 (59)	
3mm	93 (42)	52 (43)	41 (41)	
Meniscal damage				
Simple tear	36 (16)	17 (14)	19 (19)	
Other meniscal damage	184 (84)	104 (86)	80 (81)	

Mean (standard deviation) unless otherwise noted

APM; arthroscopic partial meniscectomy, PT; physical therapy, BMI; body mass index kg/m², KL grade; Kellgren-Lawrence grade, KOOS; Knee Injury and Osteoarthritis Outcome Score

* missing=2

Table 2:

Change in 6-month KOOS pain scores after APM or PT for each intra-articular feature

		6-month KOOS Pain Score (mean, SD)	KOOS Pain (95% CI)		
			APM	PT	P value for interaction
BML number *					
	None (MOAKS 0)	22 (16)	-29 (-37, -21)	-16 (-26, -6)	0.17
	Any (MOAKS 1-15)	22 (18)	-24 (-28, -20)	-21 (-25, -17)	
BML size *					
	<33% (MOAKS 0-1)	20 (17)	-28 (-33, -23)	-21 (-27, -16)	0.44
	33% (MOAKS 2-3)	24 (18)	-22 (-26, -17)	-19 (-24, -14)	
Cartilage damage size					
	< 75% (MOAKS 0-2)	21 (18)	-28 (-32, -24)	-20 (-24, -15)	0.05
	75% (MOAKS 3)	23 (16)	-19 (-25, -14)	-21 (-27, -16)	
Cartilage damage depth					
	< 10% (MOAKS 0-1)	21 (17)	-27 (-31, -22)	-20 (-25, -15)	0.38
	10% (MOAKS 2-3)	24 (17)	-22 (-27, -18)	-20 (-26, -15)	
Meniscal extrusion					
	2.9mm (MOAKS 0-1)	20 (17)	-27 (-31, -23)	-21 (-25, -16)	0.38
	3mm (MOAKS 2-3)	24 (17)	-22 (-27, -17)	-20 (-25, -14)	
Meniscal damage					
	Simple tear (MOAKS yes)	19 (19)	-32 (-41, -24)	-23 (-32, -15)	0.48
	Other meniscal damage (MOAKS yes)	23 (17)	-24 (-27, -20)	-19 (-23, -15)	

SD; standard deviation, KOOS; Knee Injury and Osteoarthritis Outcome Score, CI; confidence interval, BML; bone marrow lesion, APM; arthroscopic partial meniscectomy, PT; physical therapy

* missing=2

Table 3.

Baseline Characteristics by Damage Score. (Damage Score compiled from binary measure of cartilage damage size and number of BML).

	Damage Score		
	Least Damage: 0	Moderate Damage: 1	Greatest Damage: 2
N [*] (%)	29 (13)	114 (52)	75 (34)
Age	56 (8)	58 (7)	60 (7)
Female, n (%)	16 (55)	58 (51)	43 (57)
BMI	30 (6)	29 (6)	30 (6)
KL Grade, n (%)			
0	11 (38)	33 (29)	7 (9)
1	8 (28)	29 (25)	19 (25)
2	6 (21)	33 (29)	13 (17)
3	4 (14)	19 (17)	36 (48)
Baseline KOOS Pain Score	45 (13)	46 (16)	43 (17)

Damage score; sum of the binary intra-articular features cartilage damage size and BML number

Mean (standard deviation) unless otherwise noted

BMI; body mass index kg/m², KL grade; Kellgren Lawrence grade, KOOS; Knee injury and Osteoarthritis Outcome Score

* missing=2

Table 4.

Adjusted Mean Change in 6-month KOOS pain scores after APM or PT by Damage Score (Damage Score compiled from binary measure of cartilage damage size and number of BML).

Damage Score	KOOS Pain (95% CI) at 6 months *		
	APM and PT	PT alone	P interaction
Least: 0	-29 (-37, -21)	-14 (-25, -3)	
Moderate: 1	-27 (-32, -23)	-20 (-25, -15)	0.13
Greatest: 2	-20 (-25, -14)	-20 (-26, -14)	

KOOS; Knee injury and Osteoarthritis Outcome Score; APM; arthroscopic partial meniscectomy, PT; physical therapy

Missing=3

* Adjusted for age and Kellgren Lawrence grade.