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# The METEOR trial: No rush to repair a torn meniscus

## ABSTRACT

It is uncertain whether arthroscopic partial meniscectomy is better than physical therapy in patients who have a symptomatic torn meniscus on top of osteoarthritis of the knee. The Meniscal Repair in Osteoarthritis Research (METEOR) trial concluded that physical therapy is acceptable at first, and that surgery is not routinely needed. In patients assigned to physical therapy who eventually needed surgery, the delay resulting from a trial of conservative management did not impair outcomes at 12 months from the initial presentation. Here, we analyze the background, design, findings, and clinical implications of the METEOR trial.

## KEY POINTS

METEOR trial was a randomized controlled trial comparing the short-term and long-term efficacy of arthroscopic partial meniscectomy vs physical therapy in patients with a symptomatic meniscal tear and knee osteoarthritis.

Both treatment groups in the METEOR trial received physical therapy in order to determine the incremental benefit of surgery and physical therapy compared with physical therapy alone.

The trial investigators used specific definitions of osteoarthritis and symptoms of meniscal tear.

Meniscectomy is often performed for patients with symptoms consistent with a meniscal tear and evidence of a meniscal tear on magnetic resonance imaging, but the benefits of this procedure are unclear.

doi:10.3949/ccjm.81a.13075

Many patients who have osteoarthritis of the knee and a torn meniscus can defer having the meniscus repaired and undergo physical therapy instead. If a trial of physical therapy does not help, they can opt for surgery later.

This seems to be the take-home message from the recent Meniscal Tear in Osteoarthritis Research (METEOR) trial,[1] which compared the efficacy of arthroscopic partial meniscectomy plus physical therapy vs physical therapy alone for patients with knee symptoms, a meniscal tear, and mild to moderate osteoarthritis of the knee.[1]

In brief, patients improved to a roughly similar degree with either approach, and although many patients assigned to physical therapy eventually underwent surgery anyway by 6 months, the delay did not adversely affect outcomes.

In this article, we review the background, design, and findings of the METEOR trial, and their implications for clinical practice.

## SURGERY: HIGH VOLUME, BUT LITTLE EVIDENCE

Magnetic resonance imaging (MRI) often incidentally reveals meniscal lesions in middle-aged and older patients who have osteoarthritis and knee pain.[2] Should these patients undergo arthroscopic meniscal repair? The decision is difficult, since it is hard to distinguish the symptoms of a meniscal tear from those of osteoarthritis.[3]

Current evidence suggests that, for symptomatic knee osteoarthritis by itself, arthroscopic surgery is no more effective than conservative management.[4,5] But what about surgery for a torn meniscus in addition to osteoarthritis?

Osteoarthritis is the most common joint disease, accounting for many physician visits.[6] More than 26 million Americans over age 25 have some form of it, and the prevalence of symptomatic, radiographically confirmed osteoarthritis of the knee was 12.1% in the third National Health and Nutrition Examination Survey.[7]

We used to consider osteoarthritis a "wear-and-tear" disease—thus the term "degenerative joint disease." But today, we know that it is an active response to injury, involving inflammatory and metabolic pathways.[8] Moreover, the risk of osteoarthritis and its progression seems to be higher in those who have had meniscal injury and total or arthroscopic partial meniscectomy.[9,10]

MRI is not commonly used in managing knee osteoarthritis, but it has been used diagnostically in patients with symptoms of a meniscal tear, such as clicking, locking, popping, giving way, and pain with pivoting or twisting. Traumatic meniscal tears (a longitudinal or radial tear pattern) most often occur in active younger people and often lead to meniscal surgery.[11,12] In contrast, degenerative meniscal tears (horizontal, oblique, or complex tear pattern or meniscal maceration) tend to occur in older people,[11,12] but how to manage them is not widely agreed upon.

Of note, most patients with osteoarthritis of the knee have torn, macerated, or heavily damaged menisci.[13,14] Meniscal lesions are also common in middle-aged people in the general population, with a higher prevalence in people who are older, heavier, or female, or who have a family history of osteoarthritis.[15]

These abnormalities are only weakly associated with symptoms.[2] However, when a patient has knee symptoms and a torn meniscus is detected on MRI, the tear is often assumed to be the source of the symptoms, and meniscal tears are the most common reason for arthroscopy.[16]

Since we have no way to prevent the progression of joint damage from osteoarthritis with drugs or by any other means, the goal is to alleviate the symptoms. Many patients report pain relief or functional improvement after arthroscopic surgery. But arthroscopic lavage or debridement for osteoarthritis has not been found to be better than conservative treatment or placebo in randomized controlled trials.[4,5]

In contrast, the current standard treatment for a symptomatic degenerative meniscal tear is arthroscopic partial meniscectomy. Nearly 500,000 of these procedures are performed annually in the United States.[16] But based on the best evidence, arthroscopic partial meniscectomy does not result in better pain relief and functional improvement than does physical therapy alone in patients who have a torn meniscus and knee osteoarthritis.[17,18]

## OVERVIEW OF THE METEOR TRIAL

The METEOR trial was a randomized controlled trial conducted at seven US tertiary referral centers. Its aim was to compare the short-term (6-month) and long-term (12-month) efficacy of arthroscopic partial meniscectomy and physical therapy in patients with symptomatic meniscal tear and osteoarthritis of the knee.[19] It was supported by the National Institute of Arthritis and Musculoskeletal and Skin Diseases.[1]

### Patients were age 45 and older

METEOR patients had to be at least 45 years old and have symptomatic meniscal tears and knee osteoarthritis detected on MRI or radiography.[1]

**It may be hard to distinguish symptoms consistent with a meniscal tear**

Osteoarthritis was defined broadly, given that it begins well before the appearance of radiographic evidence such as an osteophyte or joint-space narrowing.[19] Patients with cartilage defects on MRI were also enrolled, as were patients with radiographically documented osteoarthritis.[19]

Patients were considered to have a symptomatic meniscal tear if they had had at least 4 weeks of symptoms (such as episodic pain and pain that was acute and localized to one spot on the knee, as well as typical mechanical pain suggesting a meniscal tear, such as clicking, catching, popping, giving way, or pain with pivoting or twisting) in addition to evidence of a meniscal tear on MRI.[19]

Patients were excluded if they had a chronically locked knee (a clear-cut indication for arthroscopic partial meniscectomy), advanced osteoarthritis (Kellgren-Lawrence grade 4), inflammatory arthritis, clinically symptomatic chondrocalcinosis, or bilateral symptomatic

meniscal tears.[19] Patients who had undergone surgery or injection of a viscosupplement in the index knee during the past 4 weeks were also excluded.[19]

Of 1,330 eligible patients, 351 (26.4%) were enrolled and randomly assigned in a 1:1 ratio to a treatment group by means of a secure program on the trial website.[1,19] Of those who were eligible but did not enroll, 195 (14.6%) were not referred and 784 (58.9%) declined to participate. Of those who declined, more preferred surgery than physical therapy (36.1% vs 21%). No information is available on any differences in baseline characteristics between the enrolled patients and the eligible patients who declined.

Randomization was done in blocks of varying size within each site, stratified according to sex and the extent of osteoarthritis on baseline radiography. The extent of osteoarthritis was categorized either as Kellgren-Lawrence grade 0 (normal, no features of osteoarthritis) to grade 2 (definite osteoarthritis, a definite osteophyte without joint-space narrowing) or as Kellgren-Lawrence grade 3 (moderate osteoarthritis, < 50% joint-space narrowing).[1,19] The two treatment groups were similar with respect to age, sex, race or ethnicity, baseline Kellgren-Lawrence grade, and baseline Western Ontario and McMaster Universities Arthritis Index (WOMAC) physical function score.[1]

The mean age of the participants was 58, and 85% were white. Sixty-three percent had Kellgren-Lawrence grade 0 to 2 osteoarthritis, and 27% had grade 3.[1]

**When a torn meniscus is detected on MRI, it is often assumed to be the source of the symptoms**

### Surgery plus physical therapy vs physical therapy alone

The surgery group underwent arthroscopic partial meniscectomy, which involved trimming the damaged meniscus back to a stable rim[1,19] and trimming loose fragments of cartilage and bone.

After the procedure, patients were scheduled for physical therapy. Although there is no consensus on the need for or the effectiveness of postoperative physical therapy in this setting, the investigators believed that including it in both study groups would help to isolate the independent effects of surgery. The physical therapy regimen after surgery was similar to that provided in the nonoperative group.[1,19]

Physical therapy was designed to address inflammation, range of motion, muscle strength, muscle-length restriction, functional mobility, and proprioception and balance.[1,19] There were three stages; criteria for advancing from one phase to the next included the level of self-reported pain, observed strength, range of knee motion, knee effusion, and functional mobility.[1,18]

The duration of participation varied depending on the pace of improvement. Generally, the program lasted about 6 weeks.[1,19]

### Crossover and other therapies were allowed

Crossover from physical therapy alone to surgery was allowed during the trial if the patient and surgeon thought it was clinically indicated.

Participants in both groups were permitted to take acetaminophen and nonsteroidal anti-inflammatory drugs as needed. Intra-articular injections of glucocorticoids were also allowed during the trial.

## OUTCOMES MEASURED

### WOMAC physical function score

The primary outcome of the METEOR trial was the difference between the study groups in the change in WOMAC physical function score from baseline to 6 months, at which point participants were expected to have achieved maximum improvement.[1,19] Questionnaires were also administered at 3 months to assess the early response to surgery or physical therapy and again at 12 months.

The complete WOMAC also measures pain and stiffness in addition to physical function, with separate subscales for each. The change in WOMAC score is one of the most widely endorsed outcome measures in assessing interventions in osteoarthritis or other conditions of the lower extremities.[20] The METEOR trial authors considered the WOMAC scale to be highly valid and reliable, with a Cronbach alpha value of 0.97 (maximum value = 1; the higher the better).

No ceiling or floor effects were observed in the WOMAC physical function score in patients with osteoarthritis and a meniscal tear in a pilot study for METEOR.[19]

In the main METEOR study, WOMAC physical function was scored on a scale of 0 to 100, with a higher score indicating worse physical function.[1] Changes in the score were also measured as a yes-or-no question, defined a priori as whether the score declined by at least 8 points, which is considered the minimal clinically important difference in osteoarthritis patients.[1,19]

### KOOS and MOS SF-36 scores

Secondary outcomes were measured in several domains, including pain, generic functional status, quality of life, and health care utilization.[1,19]

The KOOS (Knee Injury and OA Outcome Scale) is specific for knee pain, being designed to evaluate short-term and long-term symptoms and function in patients with knee injury and associated problems.[21] It has five subscales, which are scored separately: pain, other symptoms, activities of daily living, sport and recreation, and knee-related quality of life.[21] Since the WOMAC pain scale showed a ceiling effect in the pilot study in patients undergoing surgery, the authors chose the KOOS pain scale as a pain measure.[19] Scores were transformed to a 0–100 scale, with a higher score indicating more pain.[1]

The MOS SF-36 (Medical Outcomes Study 36-item short form) was used to measure general health status and function.[1,19]

## STATISTICAL ANALYSIS: INTENTION-TO-TREAT AND AS-TREATED

The study was powered to detect a 10-point difference in WOMAC physical function scores at 6 months of follow-up between the operative and nonoperative groups, anticipating losses to follow-up and crossover, with preplanned subgroup (Kellgren–Lawrence grade 0–2 vs grade 3) analysis.[1,19]

The primary analysis used a modified intention-to-treat approach and was implemented with an analysis of covariance with changes in the WOMAC score from baseline to 6 months as the dependent variable, treatment as the independent variable of interest, and study site as a covariate. Other covariates, such as age, sex, and baseline Kellgren-Lawrence grade, were balanced across groups and were therefore not included in the analysis.[1,19]

Secondary analyses used an "as-treated" approach, ie, according to the treatment actually received.[1,19] Secondary intention-to-treat analysis—using binary outcome measures in which treatment failure was defined as improvement in the WOMAC score of less than 8 points or crossing over to the other treatment—was also performed to estimate efficacy at the level of the patient rather than at the group level.[1,19]

## BOTH GROUPS IMPROVED

In the intention-to-treat analyses at 6 months and 12 months after randomization, both groups improved, with no clinically important or statistically significant differences between the groups in functional status (WOMAC score, MOS SF-36 score) or pain (KOOS score).[1] The mean improvement (decline) in the WOMAC score from baseline to 6 months was 20.9 points in the surgery group vs 18.5 points in the physical therapy group, a difference of 2.4 points (95% confidence interval [CI], −1.8 to 6.5).[1]

### 35% of physical therapy patients underwent surgery by 12 months

Of the 177 patients randomized to physical therapy alone, by 6 months 1 had died, 1 had undergone total knee replacement, 4 had withdrawn, and 2 were lost to follow-up. Of the 169 remaining, 51 (30%) had undergone arthroscopic partial meniscectomy. An additional 8 patients who were assigned to physical therapy crossed over to surgery between 6 and 12 months.[1,19]

Of the 174 patients randomized to surgery, by 6 months 1 had died, 3 had undergone total knee replacement, 7 had withdrawn, and 2 were ineligible. Of the 161 remaining, 9 (6%) had not undergone the procedure.

**Nearly 500,000 meniscectomies are performed annually in the United States**

### Other outcomes

Subgroup analysis based on the baseline radiographic grade (Kellgren-Lawrence grade 0 to 2 vs grade 3) did not show a difference between groups in functional improvement at 6 months ($P = .13$ for interaction).[1]

No statistically significant difference was noted in rates of overall or specific adverse events between the two groups over the first 12 months.[1] Adverse events rated as mild or moderate in severity occurred in 15 partici-

pants in the surgery group and 13 participants in the physical therapy group.[1] Long-term risks associated with these interventions are being assessed, and longitudinal assessment of imaging studies is planned to address this question but is not yet available.[1,18]

In the physical therapy group, 21 patients (12%) received intra-articular glucocorticoid injections, as did 9 patients (6%) in the surgery group.[1,19]

## TRANSLATING THE METEOR RESULTS TO EVERYDAY PRACTICE

There are many challenges in designing surgical trials. Indeed, by one estimate,[22] only about 40% of treatment questions involving surgical procedures can be evaluated by a randomized controlled trial.

Although the METEOR trial was not blinded, it was the first large, multicenter, randomized controlled trial to compare arthroscopic partial meniscectomy vs standardized physical therapy by using high-quality methodology such as careful sample-size calculation, balancing the groups according to known prognostic factors with block randomization, and intention-to-treat analysis. Moreover, the outcome measures were obtained from validated self-reporting questionnaires (WOMAC for function and KOOS for pain), reducing the possibility of observer bias.[19] In addition, analyses were performed with the analysts blinded to the randomization assignment.

**Of 1,330 eligible patients, 351 (26.4%) were enrolled and randomized**

### Limitations of the trial

A few limitations of the study are worth noting.

Patients age 45 or older with both symptomatic meniscal tear and osteoarthritis were the target population of this study. However, it is important to distinguish between the study population and the target population in a physician's practice.

The investigators adopted broad definitions of osteoarthritis and symptoms of meniscal tear. Twenty-one percent of participants had normal findings on plain radiography, with cartilage defects visible only on MRI. Further, episodic pain or acute pain localized to a joint line was regarded as a symptom consistent with a torn meniscus.

In practice, arthroscopic partial meniscectomy is usually considered when a patient with a long history of tolerable osteoarthritis presents with a sudden onset of intolerable pain after a squatting or twisting injury.

In addition, the study population was predominantly white (85%), and the study was performed in tertiary referral academic medical centers. Therefore, the outcomes achieved with surgery or physical therapy may not translate to the community setting. Clinicians must be careful to account for these types of differences in extrapolating to patients in their own practice.

### Potential enrollment bias

Although randomization is a rigorous method that eliminates selection bias in assigning individuals to study and control groups, selective enrollment could have created bias.[1] As the authors mentioned, only 26% of eligible patients were enrolled, possibly reflecting patients' or surgeons' strong preferences for one treatment or the other. Because the study and control groups were hardly random samples of eligible populations, we must be careful in generalizing the efficacy of physical therapy.[1]

### Crossover may have obscured the benefit of surgery

During the first 6 months, 30% of patients crossed over from physical therapy to surgery. High crossover rates in surgical trials are common, especially when comparing surgery with medical therapy.[23] Given that most of the patients assigned to only physical therapy who crossed over to surgery did not have substantial improvement in functional status, it seems that crossover occurred by nonrandom factors, potentially biasing the study results. With the high degree of crossover from the nonoperative group to the surgical group, intention-to-treat analysis may have given an inflated estimate of the effect of physical therapy.

To account for crossovers, researchers defined a binary outcome a priori: patients were considered to have had a successful treatment response if they improved by at least 8 points on the WOMAC scale (a clinically important difference) and did not cross over from their assigned treatment. At 6 months, 67.1% of patients assigned to surgery showed a successful treatment response, compared with 43.8% of patients assigned to physical therapy alone ($P = .001$).[1]

In patients who crossed over, the last scores before crossover were carried over, and primary analysis of the WOMAC score at 6 months was repeated to estimate the effect of crossovers from the nonoperative to the surgery group. This exploratory analysis showed a 13.0-point improvement in WOMAC score at 6 months with physical therapy alone vs a 20.9-point improvement with surgery, suggesting that the similarity in outcomes between the two groups may be explained in part by additional improvements from surgery for those who crossed over from physical therapy alone.[1]

### Implications for functional improvement

Lacking a comparison group that underwent a sham surgical procedure, one cannot conclude that surgery after crossover improved functional status in those patients. However, there was no significant difference in WOMAC physical function scores at 12 months between the 30% of patients in the physical therapy group who crossed over and underwent surgery during the first 6 months and patients initially assigned to surgery. This finding suggests that physical therapy can be recommended as a first-line therapy, although we must be cautious, given that the physical therapy group required more background therapy (eg, intra-articular glucocorticoid injections), and that this study was not powered to detect such differences at 12 months.

Also, a patient may need to get better quickly, to get back to work, for example. Although the data were not definitive, at 3 months the patients in the surgery group seemed to have better pain control and function than those in the physical therapy group. A cost-benefit analysis of physical therapy compared with surgery for short-term outcomes may be helpful before generalizing these findings.

## SURGERY VS SHAM PROCEDURE: THE FIDELITY GROUP RESULTS

In a later publication from the Finnish Degenerative Meniscal Lesion Study (FIDELITY) Group,[24] 146 patients with symptoms consistent with degenerative meniscal tear but no knee osteoarthritis were randomized to undergo arthroscopic partial meniscectomy or a sham procedure. At 12 months, no differences were noted between the groups in terms of change of symptoms from baseline to 12 months.

The authors concluded that the outcomes with meniscectomy were no better than with a sham procedure.[24]

## SURGERY FIRST, OR PHYSICAL THERAPY FIRST?

The use of knee arthroscopy has increased sharply in middle-aged patients in recent years. Indeed, this demographic group accounts for nearly half of the knee arthroscopic procedures performed for meniscal tears, although the increase may be due in part to issues with surgeons' coding and insurance authorization.[16]

The METEOR trial showed that a structured physical therapy program can be as effective as surgery as a first-line therapy in many patients with symptomatic meniscal tears and mild to moderate osteoarthritis. These results should inform clinical practice in that most such patients need not be immediately referred for surgical intervention.

**Mean declines in WOMAC scores at 6 months: 20.9 points with surgery vs 18.5 with physical therapy**

However, a subset of these patients may benefit from surgery rather than nonoperative therapy. Given the potential risks and public health implications of arthroscopic surgery for meniscal tears, further study is needed to better characterize these patients. A randomized sham-controlled trial is under way[25] with the goal of assessing the efficacy of arthroscopic partial meniscectomy for medial meniscus tears in patients with or without knee osteoarthritis, and it is hoped this study will shed further light on this issue.

Based on the results of the METEOR trial, the physical therapy regimen that was used may be reasonable before referring patients with knee osteoarthritis and symptomatic meniscal tears for surgery.

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