Meniscus Root Repair vs Meniscectomy or Nonoperative Management to Prevent Knee Osteoarthritis After Medial Meniscus Root Tears

CME

Clinical and Economic Effectiveness

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Background: Medial meniscus root tears are a common knee injury and can lead to accelerated osteoarthritis, which might ultimately result in a total knee replacement.

Purpose: To compare meniscus repair, meniscectomy, and nonoperative treatment approaches among middle-aged patients in terms of osteoarthritis development, total knee replacement rates (clinical effectiveness), and cost-effectiveness.

Study Design: Meta-analysis and cost-effectiveness analysis.

Methods: A systematic literature search was conducted. Progression to osteoarthritis was pooled and meta-analyzed. A Markov model projected strategy-specific costs and disutilities in a cohort of 55-year-old patients presenting with a meniscus root tear without osteoarthritis at baseline. Failure rates of repair and meniscectomy procedures and disutilities associated with osteoarthritis, total knee replacement, and revision total knee replacement were accounted for. Utilities, costs, and event rates were based on literature and public databases. Analyses considered a time frame between 5 years and lifetime and explored the effects of parameter uncertainty.

Results: Over 10 years, meniscus repair, meniscectomy, and nonoperative treatment led to 53.0%, 99.3%, and 95.1% rates of osteoarthritis and 33.5%, 51.5%, and 45.5% rates of total knee replacement, respectively. Meta-analysis confirmed lower osteoarthritis and total knee replacement rates for meniscus repair versus meniscectomy and nonoperative treatment. Discounted 10-year costs were $22,590 for meniscus repair, as opposed to $31,528 and $25,006 for meniscectomy and nonoperative treatment, respectively; projected quality-adjusted life years were 6.892, 6.533, and 6.693, respectively, yielding meniscus repair to be an economically dominant strategy. Repair was either cost-effective or dominant when compared with meniscectomy and nonoperative treatment across a broad range of assumptions starting from 5 years after surgery.

Conclusion: Repair of medial meniscus root tears, as compared with total meniscectomy and nonsurgical treatment, leads to less osteoarthritis and is a cost-saving intervention. While small confirmatory randomized clinical head-to-head trials are warranted, the presented evidence seems to point relatively clearly toward adopting meniscus repair as the preferred initial intervention for medial meniscus root tears.

Keywords: knee; articular cartilage; economic and decision analysis; Markov model

Medial meniscus root tears are increasingly being recognized as a cause for pain and the early onset of knee osteoarthritis.[20] Medial meniscus root tears typically occur in older patients, often resulting from seemingly trivial trauma.[2] The tears commonly cause moderate to severe joint-line pain.[21] Since most medial meniscus root tears occur in patients in their fourth or fifth decade of life, surgeons were historically reluctant to repair these lesions and frequently elected to treat without surgery initially or perform a meniscectomy. Unfortunately, both approaches increase contact pressures in the knee, which can accelerate the degeneration of the cartilage.[1,18,24] In

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addition, clinical studies showed that patients receiving either a meniscectomy or nonoperative therapy have a very high clinical failure rate and subsequent conversion to total knee replacement.[8,14,15]

Biomechanical testing revealed that meniscus root repair restores normal joint kinematics and contact pressures, and clinical studies assessing patients with root repairs documented healing via second-look arthroscopy and magnetic resonance imaging.[1,3,13,18,19,23] Moreover, when compared with patients treated with meniscectomy, patients treated with meniscus root repairs demonstrated improved clinical outcomes and slowed progression of radiographic knee osteoarthritis.[8,13]

There is still uncertainty and controversy regarding the effectiveness of treatment strategies in clinical practice for medial meniscus root tears, their associated risks for subsequent procedures, and the associated costs over an extended period.[24] In consideration of one surgical procedure to prevent another condition or knee operation, long-term projections of clinical outcomes and costs may be helpful to make informed decisions or provide accurate recommendations. Therefore, the purpose of the present study was to evaluate the long-term clinical effectiveness and cost-effectiveness of 3 strategies in the management of medial meniscus posterior root tears among those without osteoarthritis: arthroscopic meniscus root repair, arthroscopic meniscectomy, and initial nonoperative management.

METHODS

Study Design

A systematic review of the literature was performed with a quantitative synthesis (meta-analysis) of the discovered results. A decision-analytic model projected failure/revision rates, progression to osteoarthritis, total knee replacement, mortality, and associated costs and quality-adjusted life years (QALYs). The study was conducted in accordance with the 2009 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) and the 2013 Consolidated Health Economic Evaluation Reporting Standards statements.[11,26]

Systematic Review of the Literature

A systematic review of the literature regarding the existing evidence for the outcomes and complications of meniscus repair, meniscectomy, and nonoperative treatment was performed with the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed (1990-2017), and EMBASE (1990-2017). The queries were performed in March 2017.

The search strategy included the keywords meniscus [meniscal] and posterior root (for details, see Appendix, available in the online version of this article). We included only studies that reported any osteoarthritis classification in their follow-up protocol, that had a follow-up of at least 12 months, and whose main manuscript language was English. Cadaveric studies, animal studies, basic science articles, editorial articles, and surveys were excluded.

Two investigators (B.P.G., J.C.) independently reviewed the abstracts from all identified articles. Full-text articles were obtained for review if necessary to allow further assessment of inclusion and exclusion criteria. Additionally, all references from the included studies were reviewed and reconciled to verify that no relevant articles were missing from the systematic review. Journal and year of publication, level of evidence, type of treatment, number of patients, mean age, sex distribution, follow-up time, osteoarthritis scale utilized, progression to osteoarthritis, and progression to total knee replacement, if available, were extracted and recorded.

Pooling of Clinical Outcomes and Meta-analysis

To compare the different treatments' clinical effectiveness in terms of progression to osteoarthritis, we pooled all studies by arm in random effects models and computed event rates with 95% CIs in a commercially available software package (Comprehensive Meta Analysis, v 3; Biostat). Importantly, since the studies had different follow-up time points, we used the median follow-up time as a moderate variable in the models. We compared the overlap of the 95% CIs of the event rates because none of the studies compared the 3 treatments of interest with one another.

For the economic model, we used the proportion of progression to osteoarthritis and median follow-up time to compute, via rates, annual and monthly proportions of progression to osteoarthritis; the studies were weighted by the sample size. A standard exponential model was used to plot Kaplan-Meier survival curves for development of osteoarthritis.

Decision-Analytic Model and Economic Evaluation

Markov models are decision-analytic models where various outcomes can occur over an extended period—in this case, an individual moving between mutually exclusive health states. Cost-effectiveness analysis is the preferred type of

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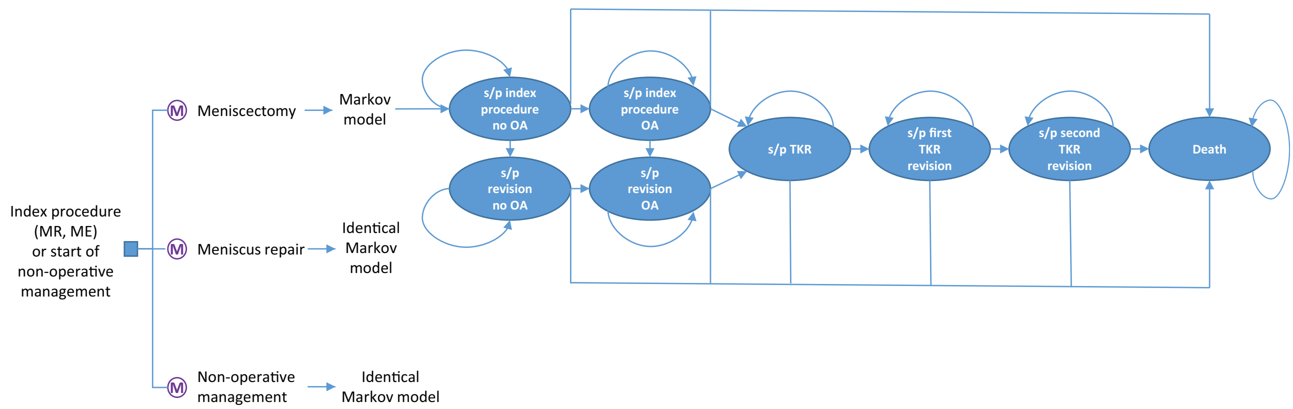

Figure 1. The model structure: a combination of a decision tree and a Markov model. In the base case, all patients start in the status post (s/p) index procedure state and can experience osteoarthritis (OA), a revision, or both. All patients with OA can progress to total knee replacement (TKR), and there are up to 2 TKR revisions possible. ME, meniscectomy; MR, meniscus.

health economic evaluation in medicine; it compares not just costs and health outcome but also types of interventions in a ratio: the incremental cost-effectiveness ratio ($/QALY). As a measure of health outcome, effectiveness is measured in QALYs ranging from 0 (death) to 1 (perfect health). In a Markov model, a cohort of simulated participants is initially allocated to each treatment strategy and subsequently assigned to mutually exclusive health states based on the estimated transition probabilities. During each cycle, participants accrue utilities according to their respective health states. At the end of each monthly cycle, individuals are reassigned between the states.

For this study, we adapted and expanded a previously developed Markov model to project strategy-specific progression to symptomatic osteoarthritis, total knee replacement, and revision total knee replacement in a cohort of 55-year-old patients presenting with medial meniscus root tears with no osteoarthritis at the time of treatment (Figure 1).[9] The setting was the United States, and all costs are presented in 2017 US dollars. Costs were estimated from the perspective of a US third-party payer perspective, with Medicare reimbursement as a proxy for cost.[28] In the base case, patients start in the nonosteoarthritis state status after the index procedure (if any) and have a strategy-specific probability to progress to osteoarthritis. Failure rates of repair procedures and progression to knee osteoarthritis for meniscectomy, meniscus repair, and nonoperative treatment were accounted for according to the meta-analysis findings. We assumed that any failure would require revision surgery and that meniscectomy would be performed in case meniscus repair failed. Patients with osteoarthritis have a certain sex-stratified probability to undergo total knee replacement. Status post–total knee replacement, there is a probability that a revision arthroplasty is necessary.

Utilities, costs, and event rates were based on literature and public databases; Table 1 summarizes the key input parameters (see online Appendix for additional detail). The original model publication provides further detail about failure rate assumptions.[9]

Analyses considered a 30-year time frame as a base case and explored the effects of parameter uncertainty and different analysis horizons. Other time frames were computed as scenario analyses. Costs and effects were discounted at 3% per annum, in line with health economic guidelines. Projected total knee replacement rates were compared with total knee replacement rates available from a subset of the studies to validate projections against real-world evidence.

RESULTS

Study Selection

The systematic search identified 13 independent cohorts from 9 studies, after removal of duplicates and application of exclusion criteria.[4,5,8,12,22,27,29] One data set was chosen when multiple studies reported on the same patients. Figure 2 shows the flow of studies. Following review of all references from the included studies, no additional studies met inclusion criteria.

Patient and Study Characteristics

A total of 355 patients were included in this review: 41 were treated nonoperatively; 229 underwent a root repair (n = 206 via a pullout technique [simple stitch or Mason Allen] and 23 via a suture anchor repair); and 74 patients had a medial meniscectomy.[8,12-15,22,23,27,29] The Kellgren-Lawrence grading scale evaluated progression to osteoarthritis in all but 3 studies reporting the presence of arthritis as the outcome criterion. The mean follow-up was 39.9 months (range, 13.4-67.5 months); the mean age at baseline was 55 years; and 22.6% were men. See Table 2 for the included studies.

Pooled Clinical Outcomes and Meta-analysis

Pooled probabilities of events via the meta-analytic approach, after adjustment for follow-up as a moderator

TABLE 1
Key Input Parameters for Decision-Analytic Model[a]

	Base Case	Minimum	Maximum
Age, y	55	20	80
Female, %	77	0	100
Proportion with osteoarthritis at baseline, %	0	0	100
Perioperative mortality from, %			
ME	0.3	0.25	0.35
MR	0.3	0.25	0.35
TKR	0.3	0.25	0.35
10-y probability of, %			
ME failure	6.4	3	10
MR failure	30.1	15	45
1-y MR failure at age, %			
40 y	10	0	30
80 y	75	0	80
Annual rate of OA from ME	0.38	0.19	0.57
Relative risk of developing OA from			
MR to ME	0.19	0.10	1.00
NO to ME	0.684	0.50	1.00
5-y probability of TKR given OA in, %			
Men	26	13	39
Women	50	25	75
Index procedure costs, $			
ME	2813	1969	3657
MR	2979	2085	3873
TKR costs (for index procedure and revisions), $	40,065	28,629	85,887
Annual nonoperative OA costs, $	2991	1495	4486
Annual discount rate for costs/effectiveness, %	3	0	10
Disutility with			
ME procedure	0.0077	0.0039	0.0116
MR procedure	0.0077	0.0039	0.0116
Revision TKR	0.05	0.025	0.075
Disutility for total knee replacement	0.025	0.0125	0.0375
Utility of patient in			
No-OA state	0.90	0.80	1.00
OA state	0.69	0.59	0.79
Post–revision TKR	0.785	0.60	0.85
After TKR	0.835	0.65	0.90

[a]ME, meniscectomy; MR, meniscus repair; NO, nonoperative; OA, osteoarthritis; TKR, total knee replacement/arthroplasty.

variable, were lower for meniscus repair (0.14; 95% CI, 0.10-0.19) than for meniscectomy (0.82; 95% CI, 0.72-0.90) and nonoperative treatment (0.79; 95% CI, 0.66-0.88), which were similar. The Appendix includes a forest plot with the pooled and adjusted event rates and 95% CIs. The approach via a conversion to rates of knee osteoarthritis progression resulted in weighted probabilities of 0.22, 0.81, and 0.63 for meniscus repair, meniscectomy, and nonoperative treatment, respectively. Figure 3A displays the pooled Kaplan-Meier survival curves for freedom from osteoarthritis.

Base Case Cost-effectiveness Analysis

Projected costs were lower for meniscus repair than for meniscectomy and the nonoperative treatment approach. Over 10 years, meniscectomy and nonoperative treatment incurred 40% and 11% higher discounted costs, respectively; over time, this difference shrunk to 13.5% and 1.3%. At the same time, patients treated with meniscus repair enjoyed slightly better quality of life (see Table 3 for details of the base case analysis across different time horizons).

Based on a conservative willingness-to-pay threshold of $50,000 per QALY gained, meniscus repair was cost-effective relative to meniscectomy and nonoperative treatment at time frames longer than 0.5 and 2.5 years from the index procedure date, respectively. Meniscus repair was cost-saving relative to meniscectomy and nonoperative treatment starting at 1.1 and 4.9 years from index procedure date, respectively. As QALY gains at these time points were already higher for meniscus repair than for meniscectomy and nonoperative treatment, meniscus repair was the dominant treatment strategy at time frames ≥4.9 years.

Sensitivity Analysis and Validation

To assess the effect of parameter uncertainty on the decision-analytic model, sensitivity analyses varying all input parameters were conducted. The Appendix contains

TABLE 2
Base Case Results of the Cost-effectiveness Analysis[a]

First Author (Year)	n	Mean Age, y	Male, %	Median Follow-up, mo	OA Criterion	Progression to OA, n (%)	Level of Evidence
Meniscus repair							
Lee (2009)[23]	21	51.2	N/A	31.8	+1 KL	1 (4.8)	4
Nha (2011)[27]	25	53	N/A	38.0	+2 KL	1 (4.0)	4
Kim (2011)[12,b]	22	53.2	31.8	25.9	≥1 KL	4 (18.2)	3
Kim (2011)[12,c]	23	52.8	39.1	26.8	≥1 KL	2 (8.7)	3
Seo (2011)[29]	21	55.4	9.1	13.4	MPFA	1 (4.8)	4
Lee (2014)[22,d]	25	56.6	8.0	25.9	≥1 KL	7 (28.0)	4
Lee (2014)[22,e]	25	55.7	8.0	24.1	≥1 KL	2 (8.0)	4
Chung (2015)[8]	37	55.5	10.8	72	≥2 KL	5 (13.5)	3
Kim (2011)[13]	30	55.2	16.7	48.5	≥1 KL	9 (30.0)	3
Meniscectomy							
Kim (2011)[13]	28	57.4	14.3	46.1	≥1 KL	21 (75.0)	3
Chung (2015)[8]	20	55	20.0	67.5	≥2 KL	16 (80.0)	3
Krych (2017)[14]	26	54.7	38.5	37.2	+ arthritis	24 (92.3)	4
Nonoperative: Krych (2017)[15]	41	58	40.4	62	≥2 arthritis	41 (78.8)	4

[a]KL, Kellgren and Lawrence system for classification of OA of knee; MPFA, mild patella-femoral arthrosis; N/A, not available; OA, osteoarthritis.
[b]Tibial pull through repair group.
[c]Suture anchor repair group.
[d]Modified mason allen repair group.
[e]Simple stitch repair group.

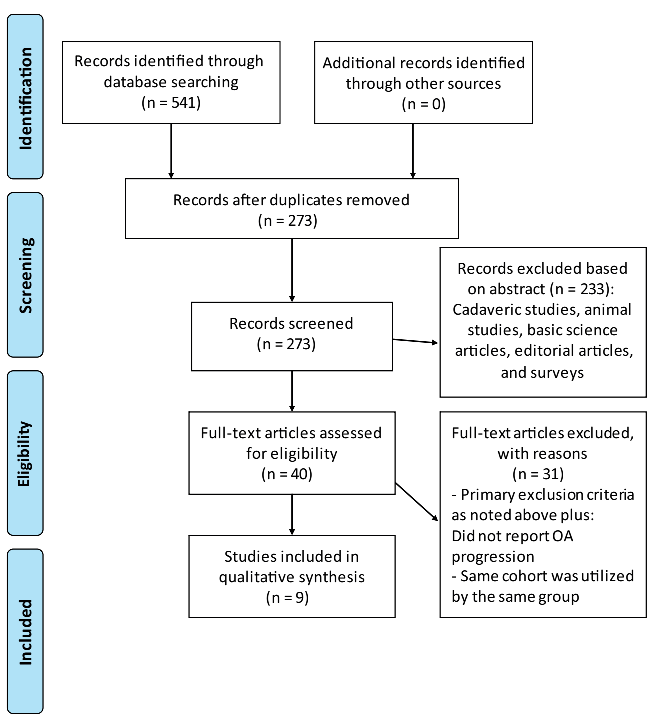

Figure 2. PRISMA-style flowchart of the included and excluded studies. OA, osteoarthritis.

a comprehensive table of 70 sensitivity analyses for all relevant parameters.

Figure 3b shows the comparison of our study-projected total knee replacement incidence versus reported total knee replacement event rates in a subset of the pooled studies. When compared with total knee replacement incidence documented in studies, this model overpredicts total knee replacement for patients treated with meniscus repair and underpredicts it for patients treated with meniscectomy and nonoperative treatment.

DISCUSSION

Our study, based on available clinical data, suggests that the 3 main treatment approaches of medial meniscus root tears (meniscus root repair, meniscectomy, and nonoperative treatment) are associated with very different rates (between 53% and 99%) of osteoarthritis development and the necessity to undergo a much more invasive and costly operation, such as a total knee replacement. Medial meniscus root tears are frequent in middle-aged patients and present a burden to patients not just after the initial meniscus injury but often for a prolonged time, putting them at risk of early-onset end-stage osteoarthritis. Likewise, downstream sequelae and interventions present an economic burden to the health care system. Overall, our study demonstrated that repair of medial meniscus root tears, as compared with total meniscectomy and conservative therapy, is a cost-saving intervention.

Given the recent recognition of medial meniscus root tears and their repairs, the body of evidence about long-term outcomes is still limited. We believe that our model can help with this dilemma in 2 ways. First, given the current available evidence, medial meniscus root tears should be repaired as the first-line therapy. Orthopaedic surgeons and sports medicine providers will find this information

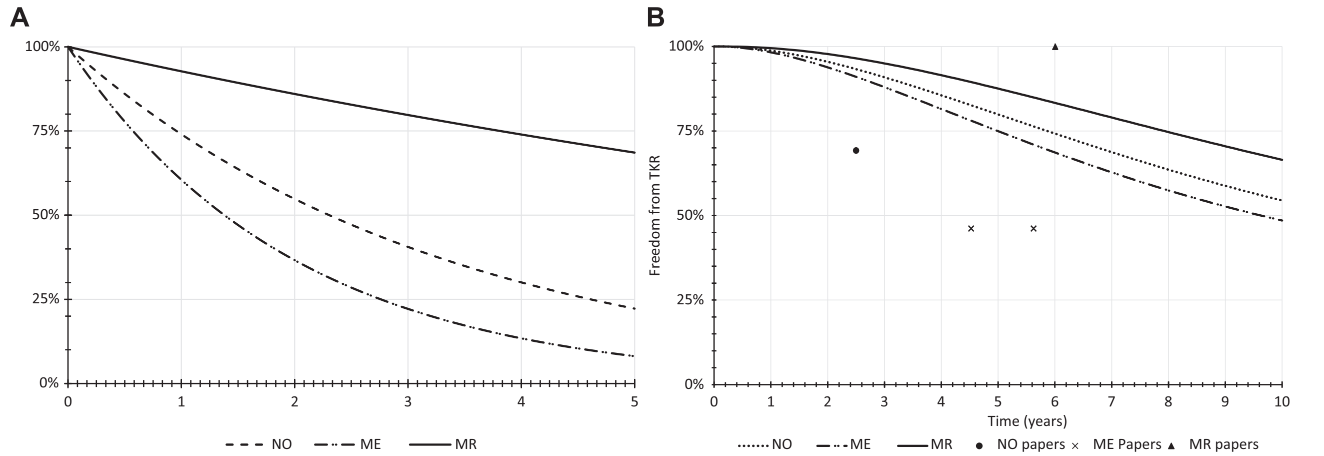

Figure 3. Kaplan-Meier survival curves for clinical outcome freedom from (A) OA and (B) TKR. ME, meniscectomy; MR, meniscus repair; NO, nonoperative; OA, osteoarthritis; TKR, total knee replacement.

TABLE 3
Base Case Results of the Cost-effectiveness Analysis for Different Time Horizons[a]

Time Horizon: Strategy	Costs, $	Incremental Costs, $	QALYs: Effectiveness	QALYs: Incremental Effectiveness	ICER[b]
5 y					
Meniscus repair	11,146		3.877		
Nonoperative	11,263	117	3.764	–0.113	Dominated
Meniscectomy	16,984	5837	3.652	–0.225	Dominated
10 y					
Meniscus repair	22,590		6.892		
Nonoperative	25,006	2415	6.693	–0.199	Dominated
Meniscectomy	31,528	8937	6.533	–0.358	Dominated
20 y					
Meniscus repair	36,384		11.234		
Nonoperative	38,056	1671	11.034	–0.200	Dominated
Meniscectomy	43,561	7177	10.873	–0.361	Dominated
30 y					
Meniscus repair	40,513		13.657		
Nonoperative	41,238	725	13.481	–0.175	Dominated
Meniscectomy	46,330	5816	13.319	–0.338	Dominated
Lifetime					
Meniscus repair	41,262		14.514		
Nonoperative	41,802	540	14.345	–0.168	Dominated
Meniscectomy	46,839	5577	14.181	–0.333	Dominated

[a]ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life year.

useful and take these systematically compiled clinical and economic effectiveness projections into account for their decision-making process and their recommendations to patients with medial meniscus root tears. Second, another clinical trial might be indicated comparing meniscus repair with nonoperative treatment or meniscus repair versus both treatments. Such a trial should be randomized and blinded, but it should also be limited to the smallest number of patients possible. In this regard, the results of our systematic review and meta-analysis might be useful for power calculations, to subject only the necessary number of patients to the confirming of our findings.

One of the main total cost variables is the progression to osteoarthritis necessitating total knee replacement. According to our validation, the present model overpredicted the incidence of total knee replacement for meniscus repair, which makes our analysis more conservative. To put this another way, if our estimate for meniscus repair were closer to the validation estimate, then the value of meniscus repair would be even greater. Similarly, the validation showed an underprediction of the total knee replacement incidence for meniscectomy and nonoperative treatment. Again, this is conservative and, if used, would make meniscus repair more valuable. In addition, we used a very conservative estimate (more likely) for medial meniscus root repair failure and progression of osteoarthritis.

This study validates the growing consensus that meniscus root repairs clinically outperform nonsurgical treatment and meniscectomy.[25] Nonsurgical treatment and meniscectomy biomechanically place stress on the compartment.[1,18] This results in further meniscus extrusion, increased contact forces with associated subchondral stress responses, and early-onset osteoarthritis.[17] The risk of osteoarthritis is increased with the occurrence of a meniscus root tear, but it does appear that the rate of knee osteoarthritis returns to the previous rate if a patient does not progress in the first year after repair.[7] Age at the time of meniscus root tear had the largest effect on the cost-effectiveness of meniscus repair. Patients who received this intervention at age 20 seemed to have the largest benefit. However, at no age in the sensitivity analysis did meniscectomy become cost-effective, and it was always dominated. This confirms the current consensus that the age of the patient at the time of the repair does not have a primary effect on the clinical prognosis for, or the cost-effectiveness of, repair in this population.[21] Based on previous literature, factors such as a high grade of knee osteoarthritis and varus alignment appear to be most predictive of meniscus repair failure.[6] Though not specifically addressed in our study, these factors need to be considered when determining a treatment plan for an individual with a meniscus root tear.

Our study is subject to some limitations. First, as discussed, the evidence for the treatment of medial meniscus root tears remains sparse. Hence, some uncertainty remains about the actual rates of progression of osteoarthritis across larger cohorts. However, we explored via sensitivity analyses the effect of variation in the pooled osteoarthritis rates, which confirmed the robustness of the finding that posterior root meniscus repair is the clinically and economically superior treatment approach.

Second, in the absence of robust clinical data about meniscus repair failure rates that require reoperation, we adopted the highly conservative meniscus repair failure rate assumptions used in the prior published analysis.[9] A potentially lower meniscus repair failure rate would have led to a higher economic benefit and further improved the clinical benefit of meniscus repair as compared with our base case.

Third, progression of osteoarthritis to total knee replacement relied on the assumptions of earlier studies, based on a systematic review of the published literature and confirmatory analyses. Comparison of the resulting total knee replacement rate projections in our analysis against the rates reported in a subset of medial meniscus root tear studies pooled in our analysis suggests that our projections might gradually overpredict total knee replacement incidence for patients undergoing meniscus repair and underpredict it for patients treated with meniscectomy or nonoperatively. If this were the case, our estimated clinical and economic benefit associated with meniscus repair, again, would be conservative. This implies that if the over- and underprediction in the present analysis are corrected, an even greater value of the meniscus repair could be demonstrated. The model accounted for the costs and utilities associated with total knee replacement only for patients who developed severe symptomatic osteoarthritis.

Fourth, similar to the earlier modeling study, we did not explicitly consider costs of physical therapy associated with the index procedure, as data are limited and no evidence was identified that would suggest significant differences among the treatment strategies. In addition, physical therapy is only partially covered by payers. Finally, the studies pooled in our analysis were conducted in different global geographies (United States and abroad), and international treatment preferences might differ from those in the United States.[10,16] However, incidence rates of total knee replacement, subsequent to osteoarthritis development, in our model projection are solely based on US data, alleviating most of the effects of these potential differences.

CONCLUSION

Repair of medial meniscus root tears, as compared with total meniscectomy and nonsurgical treatment, leads to less osteoarthritis and is a cost-saving intervention. While small confirmatory randomized clinical head-to-head trials are warranted, the presented evidence seems to point relatively clearly toward adopting meniscus repair as the preferred initial intervention for medial meniscus root tears.

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