Systematic Review

The Prevalence of Tibiofemoral Knee Osteoarthritis Following Arthroscopic Partial Meniscectomy Is Variably Reported in General, and Over Time: A Systematic Review With a Minimum of 5-Year Follow-Up

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Purpose: To assess the prevalence of tibiofemoral (TF) osteoarthritis (OA) following arthroscopic partial meniscectomy (APM) with a minimum follow-up of 5 years, to explore the prevalence of symptomatic TF OA, and to identify potential risk factors for the development of TF OA following APM. **Methods:** An electronic search was conducted using PubMed, CINAHL, Pedro, AMED, Embase, the Cochrane Library, and clinicaltrials.gov. Prospective/retrospective studies including participants with a mean age ≥18 years old, undergoing isolated APM, reported radiographic assessment of knee OA as an outcome, had at least 5-year follow-up, and were written in English were included. Two authors extracted relevant data. Four authors assessed methodologic quality using the Center of Reviews and Dissemination and the Downs and Black checklist. The prevalence of TF OA after APM was reported for each study, with the range provided across studies for each time period (5 years to <10 years, 10 years to <15 years, ≥15 years). **Results:** Twenty-two studies were included. Radiologic TF OA prevalence following APM ranged from 35% to 90%, 23% to 100%, and 52% to 57.7% at an average follow-up of 5 years to <10 years, 10 years to <15 years, and ≥15 years, respectively. Prevalence of symptomatic TF OA ranged from 24.1% to 67% according to individual operational definitions, with 2 studies reporting correlations between function and radiological findings. **Conclusions:** APM results in a prevalence of radiographic TF OA ranging from 23% to 100% across follow-up periods of 5 or more years with the lowest prevalence reported between 5 and <10 years and the highest prevalence reported between 10 and <15 years follow-up. Considerably less data was available to assess symptomatic TF OA or risk factors associated with TF OA. **Level of Evidence:** Level III, systematic review of Level II and III studies.

Arthroscopic partial meniscectomy (APM) is one of the most common orthopaedic procedures performed, with recent data suggesting that 500,000 surgeries are performed annually in the United States and 1 million performed in the United Kingdom between 1997 and 2017.[1,2] While the rate of knee arthroscopic surgery for osteoarthritis (OA) has decreased over the last 2 decades, the rate of APM continues to increase for individuals with meniscal tears who may or may not have radiographic evidence of OA.[1,3,4] Support for APM includes findings of decreased pain, and an improved quality of life.

A clinical practice guideline[5] based on 2 systematic reviews demonstrated strong evidence that APM provides small short- to medium-term benefit when compared with sham surgery or nonoperative management for degenerative knee disease. In addition, the frequent rate of APM has been challenged with the publication of clinical effectiveness studies, combined with research indicating that meniscectomy is not necessarily a risk-free procedure and can have rare,

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but serious, complications.[4,6] If APM is determined to be the choice of treatment, health care professionals should consider the long-term risk of developing OA following APM, given the important function of the meniscus in reducing compressive forces across the tibiofemoral (TF) joint. Another recent systematic review and meta-analysis assessed the benefits of APM in adults with a confirmed meniscal tear.[7] The results demonstrated that performing APM in all patients with meniscal tears is not recommended but may have a small-to-moderate benefit when compared with physiotherapy in individuals with meniscal tears and no OA at the time of surgery.[7] However, guidance on this topic from professional organizations is controversial.[8]

Previous systematic reviews have specifically addressed whether meniscectomy is a factor in the development of knee OA.[9,10] Petty et al.[10] conducted a review of 5 trials with a minimum of 8-year follow-up, which concluded that radiographic signs of OA were present following APM, but the clinical effect of such findings are not significant. Similarly, a review by Papalia et al.[9] included 32 published trials with a minimum of 5-year follow-up and concluded that minimally invasive procedures may reduce the long-term development of knee OA compared with more invasive open or total arthroscopic meniscectomy procedures.[9] These previous reviews are 10 years old, did not have well defined inclusion criteria,[10] and included studies that assessed open and total meniscectomy,[9] both of which are likely to further increase the risk of developing OA compared with APM. Furthermore, since the publication of these reviews, several additional trials have been conducted assessing radiologic and symptomatic TF OA after APM.[11-13] In an additional review, Poulsen et al.[14] assessed the risk of knee OA following meniscal tear, anterior cruciate ligament (ACL) tear, and combined ACL and meniscal tear. While a similar methodologic design was implemented, the current review aims to assess the risk of knee OA following APM for meniscal tears rather than in relation to knee injury with unknown treatment.

Given the increase in the number of individuals developing OA and the conflicting evidence for long-term outcomes following APM, an additional comprehensive systematic review that assesses the effects of APM on the development of TF OA is warranted. The purposes of this systematic review were to assess the prevalence of TF OA following APM with a minimum follow-up of 5 years, to explore the prevalence of symptomatic TF OA, and to identify potential risk factors for the development of TF OA following APM. We hypothesized that the prevalence of radiographic TF OA would be greater at later follow-up time periods.

Methods

This systematic review of prospective and retrospective studies was registered in the PROSPERO database (CRD42020214197) and conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[15] (Appendix Table 1, available at www.arthroscopyjournal.org).

Protocol Changes

Initially, the Modified Downs and Black Checklist was chosen to assess methodologic quality. However, in further assessing the studies, the scale would not accurately assess study quality for cohort studies dealing with prevalence. Therefore, quality was assessed using guidelines from the Center of Reviews and Dissemination, as well as questions from the Downs and Black Checklist similar to a previous review.[16] Second, the authors' goal was to conduct meta-analysis using odds ratios (ORs) to assess the prevalence of TF OA following APM with a minimum follow-up of 5 years. This was reconsidered due to the paucity of studies directly addressing this question. In contrast, all included studies had 1 cohort that received APM following a meniscal tear so they could provide information on the prevalence of TF OA after a meniscal tear and APM. However, for those studies with a comparison group, the comparison group consisted of either the healthy knee on the participant's other side, or individuals with no knee injuries, rather than a group with meniscal tears who did NOT receive APM. Given these considerations, ORs reflecting the appropriate comparison could not be derived from the included studies and therefore, forest plots and meta-analyses could not be developed. Furthermore, while it was the intention to provide one single calculated overall prevalence across studies, the vast differences in study designs and follow-up would have made such a summary more confusing than informative. Third, the original protocol allowed for inclusion of randomized clinical trials. Upon further consideration however, the authors decided to exclude randomized clinical trials as their controlled study protocols led to group comparisons that may not reflect the etiology and natural progression of typical individuals with APM. Finally, the heterogeneity in the patient-reported outcome measures resulted in the authors focusing on the general category of symptomatic TF OA rather than on specific patient-reported outcome measures, as a recent systematic review has done.[16]

Inclusion Criteria

Articles needed to meet the following inclusion criteria: (1) prospective cohort studies, case series, or retrospective cohort studies with no limits on date of publication; (2) include participants with a mean age of $\geq$18 years old at the time of surgery undergoing

isolated APM; (3) reported radiographic assessment of TF OA as one of the outcomes; (4) had a mean follow-up of a minimum of 5 years; and (5) written in English. Case reports, studies with fewer than 5 years of follow-up, or when the follow-up was not clearly described were excluded. In addition, studies that included patients with total and/or open meniscectomy, and studies that included patients with other knee pathologies (anterior/posterior cruciate ligament injuries, medial/lateral collateral ligament injuries, articular cartilage damage, fractures, dislocations, and a history of OA greater than grade 2 on any scale) were all excluded.

Outcomes

The primary outcome in this review was the development of radiographic TF OA following APM at a minimum of a 5-year follow-up, with a secondary outcome of the development of symptomatic TF OA.

Search Strategy

Two independent authors (P.L. and J.G.) conducted an electronic search in January 2021 using PubMed, CINAHL, Pedro, AMED, Embase, the Cochrane Library, and arthropscopyjournal.org. Key words were used independently and in combination including meniscectomy, meniscal repair, and knee OA. The complete search strategy used for each database is presented in Appendix Table 2, available at www.arthroscopyjournal.org.

Study Selection

Two separate authors (M.F.M. and K.K.) manually searched reference lists of all selected articles for any additional studies. Each author examined all titles and abstracts to determine initial eligibility and then re-evaluated full-text articles for specific inclusion criteria. A third author (R.S.) determined final eligibility when a discrepancy existed.

Data Extraction

Two independent authors (M.F.M. and K.K.) extracted data from included studies. Both authors reviewed the extracted data simultaneously for possible discrepancies and final decisions were reached via consensus. Data extracted included type of study, year of publication, number of participants, age at the time of surgery and follow-up (if available), sex, meniscectomy compartment, time of follow-up, radiologic classification system, radiologic views taken, pre-existing TF OA, symptomatic TF OA, and risk factors for TF OA.

Methodologic Quality Assessment

Four authors (M.F.M., K.K., P.L., and J.G.) independently assessed methodologic quality using the Center of Reviews and Dissemination,[17] as well as certain questions from the Downs and Black Checklist.[18] The checklist was modified for the purposes of this systematic review, given the fact that 2 previous reviews applied similar revisions during their methodologic quality assessments to enhance assessment of key design features of the included studies.[16,19] Each criterion was scored with yes (1 point), no (0 points), or unclear (0 points), for a total of 12 possible points. Studies scoring $\geq$8/12 (>60% of the maximum possible score) were classified as high quality based on a previous systematic review.[19] Before independent scoring occurred, the primary author educated other authors on the methodologic scoring for the criteria developed. The training resulted in a 75% agreement among authors before discussion and consensus. Following independent scoring, disagreements were decided by consensus. If consensus was not achieved, the primary author (M.F.M.) made the final judgment.

Data Synthesis

The large heterogeneity in the methodologic design of the included studies prevented meta-analysis. The authors presented the results using narrative synthesis to describe similarities, differences, and results between the included studies.[20,21] In addition, the prevalence of TF OA after APM was reported for each individual study; likewise, the range of prevalence rates was reported across the set of included studies. The authors delineated follow-up periods into 3 distinct categories to highlight studies with homogenous designs: studies with follow-up from 5 years to <10 years, studies with follow-up from 10 years to <15 years, and studies with follow-up $\geq$15 years.[22] When available, data regarding symptomatic TF OA and risk factors were reported descriptively.

Results

Study Selection

The search identified 8,050 articles with 4 additional papers identified through hand searching. After duplicates were removed, 5,056 articles were screened by title and abstract. A total of 155 studies were considered eligible and were read by 2 independent authors for potential inclusion. Any discrepancies were resolved through consensus or with the opinion of a third author. Of these 155 articles, 133 were excluded. A total of 22 studies were included in this systematic review (Fig 1). Of the included articles, 2 were prospective cohort studies,[12,23] and 20 were retrospective cohort studies.[11,13,24-44]

Forty-six studies were excluded because of surgical procedures other than APM, in which either a complete meniscectomy, an open partial meniscectomy, or a meniscal repair was performed. These types of surgical procedures can change the function of the meniscus postoperatively and therefore would increase the

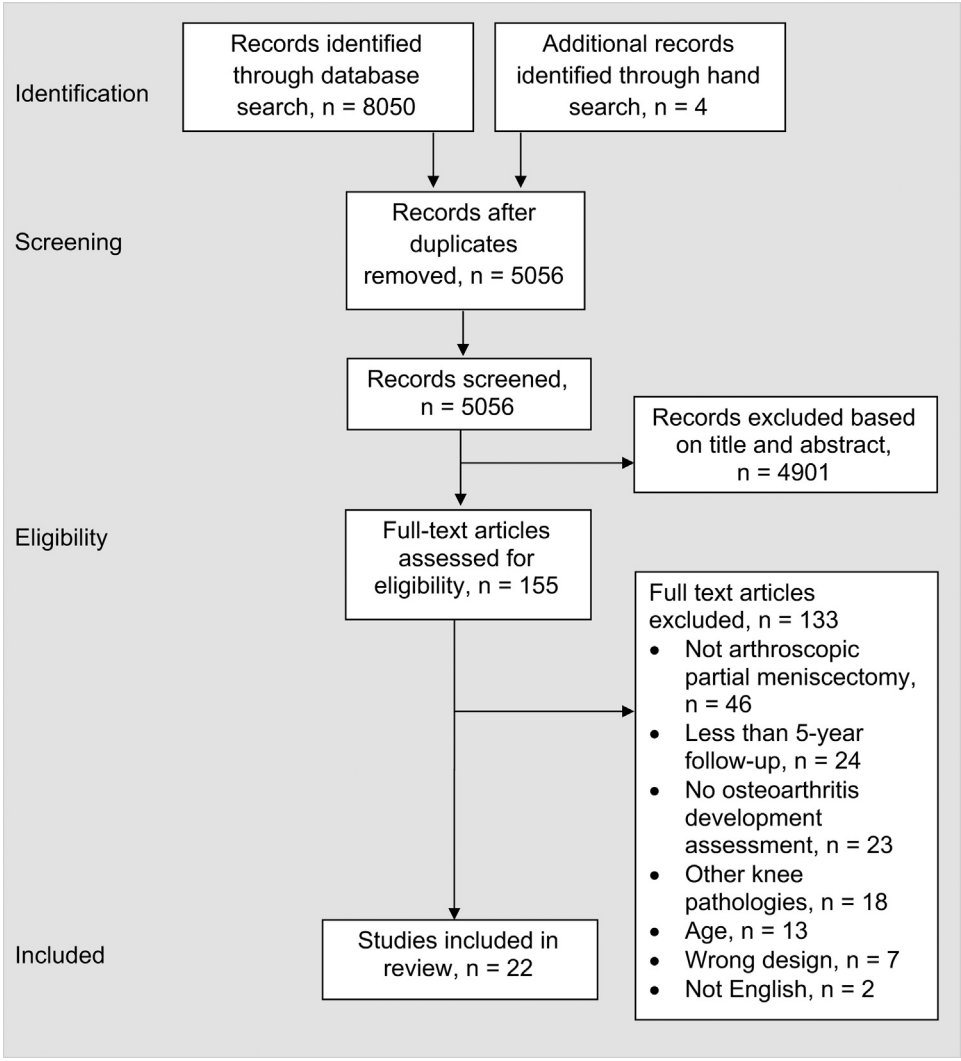

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

heterogeneity further of the included studies. Twenty-four studies had follow-up periods less than 5 years. This was an important exclusion criterion when assessing the prevalence of TF OA following APM. While functional outcomes can be assessed sooner after APM, the development of TF OA is a slower process and follow-ups of less than 5 years may provide incomplete data on the development of TF OA. Twenty-three studies did not perform any assessment of TF OA post APM. Eighteen studies had concomitant pathology at the time of APM, whereas 13 studies were excluded as the average age of participants was younger than 18 years old. Finally, 7 studies did not meet the appropriate methodologic design outlined in the inclusion criteria, and 2 studies were conducted in German.

Study Characteristics

The characteristics of included studies are presented in Table 1 and included 1,672 participants from 22 studies. Sample sizes ranged from 18 to 317, with male and female sample sizes ranging from 10 to 256 and 0 to 89, respectively. Of the 17 studies that reported the distribution of male and female patients, 68.4% were male. The age of participants at the time of surgery (19 studies) ranged from 8 to 85 years (mean 37.1 years). Twenty studies assessed surgically treated participants only,[11-13,23,25-29,31-33,36,37,39-44] whereas 2 studies assessed both surgically and nonsurgically treated participants.[24,30] Evidence of radiographic TF OA in the surgical knee was compared with the uninjured contralateral knee in 10 studies,[11,13,27,29,31,33,36,40-42] and to an uninjured control group in 2 studies.[24,30] Follow-up ranged from 5 to 22 years (mean 9.7 years) and included 2,306 knees. Thirteen studies had a mean follow-up between 5 and <10 years,[11-13,23,25-27,31,32,36,37,42,43] whereas 7 studies[24,28,29,33,39-41] had a mean follow-up between 10 and <15 years, and 2 studies[30,44] had a mean follow-up

Table 1. Description of Studies

Study	Patient Characteristics*	Meniscectomy Compartment	Follow-up†	Radiologic Classification System	Radiologic Views	Pre-existing TF OA Follow-up Symptomatic TF OA
Andersson-Molina et al., 2002,[24] retrospective, Level III	n = 18 0 F, 18 M Age at surgery: 29 y (16-38 y) Age at follow-up: 43 y (30-52 y)	Medial: 17 Lateral: 1	14y (12-15y)	Fairbank and Ahlbäck	WB flexion AP	No No
Benedetto and Rangger, 1993,[25] retrospective, Level III	n = 87 17 F, 70 M Age at surgery: 29.8 y Age at follow-up: NA	Medial: 70 Lateral: 17	6.3 y (5.8-7.2 y)	Fairbank	WB AP and lateral	No No
Bolano and Grana, 1993,[26] retrospective, Level III	n = 50 5 F, 45 M Age at surgery: 30 y Age at follow-up: NA	Medial: 33 Lateral: 13 Combined: 4	5.6 y	Fairbank	WB AP	Yes − grade 1 changes No
Bonneux and Vandekerckhove, 2002,[27] retrospective, Level III	n = 29 9 F, 20 M Age at surgery: 25 y Age at follow-up: NA	Lateral: 29	8 y (1.5 y)	Fairbank	WB 45° flexion PA	No No
Burks et al., 1997,[28] retrospective, Level III	n = 111 Sex: NA Age at surgery: NA Age at follow-up: NA	Medial: 114 Lateral: 27 Combined: 5	14.7 y (13.8-16.4 y)	Fairbank	WB AP and PA	No No
Chatain et al., 2001,[29] retrospective, Level III	n = 317 61 F, 256 M Age at surgery: 38 y (11 y) (11-66 y) Age at follow-up: NA	Medial: 317	11.5 y (10-15 y)	Radiological IKDC grade	WB 30° flexion AP and monopodal WB extension AP	No No
Englund and Lohmander, 2004,[30] retrospective, Level III	n = 48 Sex: NA Age at surgery: NA Age at follow-up: NA	Medial: NA Lateral: NA	(15-22 y)	Kellgren-Lawrence	WB 15° flexion AP	Yes − grade 1 and 2 Yes
Fauno and Nielsen, 1992,[31] retrospective, Level III	n = 136 35 F, 101 M Age at surgery: 33.4 y (8.5 y) Age at follow-up: NA	Medial: 117 Lateral: 19	8.5 y (7.9-11.6)	Fairbank	WB AP and lateral	No No
Han et al., 2010,[32] retrospective, Level III	n = 46 36 F, 10 M Age at surgery 59 y (48-85 y) Age at follow-up: NA	Medial: 46	6.5 y (5-8.6 y)	Outerbridge	WB 45° flexion PA WB AP and lateral	Yes − Grade 1 and 2 No
Higuchi et al., 2000,[33] retrospective, Level III	n = 67 34 F, 33 M Age at surgery: 26.7 y (8-52 y) Age at follow-up: NA	Medial: 37 Lateral: 30	12.2 y (10-16 y)	Fairbank	WB AP and lateral	Yes − Grade 1 and 2 No
Jaureguito et al., 1995,[36] retrospective, Level III	n = 31 Sex: NA Age at surgery: NA Age at follow-up: 38 y (22-65 y)	Lateral: 31	8 y (5.5-11.3 y)	Fairbank	WB AP and lateral	Yes − Grade 1 and 2 No
Kim et al., 2020,[37] retrospective, Level III	n = 114 89F, 25M Age at surgery: 56.3 y (6.5 y), (44-76 y) Age at follow-up: NA	Medial: 114	8.3 y (2.8 y), (5-15 y)	Kellgren-Lawrence	WB 45° of flexion PA and AP	Yes − Grade 1 and 2 No

(continued)

Table 1. Continued

Study	Patient Characteristics*	Meniscectomy Compartment	Follow-up†	Radiologic Classification System	Radiologic Views	Pre-existing TF OA Follow-up Symptomatic TF OA
Lamplot et al., 2019,[11] retrospective, Level III	n = 44 19 F, 25 M Age at surgery: 50.1 y (9.1 y) Age at follow-up: NA	Medial: 44	6.2 y (0.4 y), (5.6-8.0 y)	Kellgren-Lawrence	WB AP and lateral	Yes − Grade 1 and 2 Yes
Lizaur-Utrilla et al., 2019,[12] prospective, Level II	n = 258 73 F, 185 M Age at surgery: 55.7y (7.9y), (45-60y) Age at follow-up: NA	Medial: 210 Lateral: 48	5y	Kellgren-Lawrence	WB AP and lateral	Yes − Grade 1 Yes
Longo et al., 2019,[13] retrospective, Level III	n = 57 19 F, 38 M Age at surgery: 57.1 y (34-75 y) Age at follow-up: NA	Medial: 38 Lateral: 9 Combined: 10	8.1 y (5.1-12.1 y)	Kellgren-Lawrence	WB AP and lateral	Yes − Grade 1 No
Lutz et al., 2015,[39] retrospective, Level III	n = 22 Sex: NA Age at surgery: 38.9 y (8.1 y), (18-47 y) Age at follow-up: NA	Medial: NA Lateral: NA	10.6 y (10-13 y)	Kellgren-Lawrence	WB AP and lateral	Yes − Grade 1 and 2 Yes
Maletius et al., 1996,[40] retrospective, Level III	n = 40 8 F, 32 M Age at surgery: 29 y (18-40 y) Age at follow-up: 42 y (31-53)	Medial: 30 Lateral: 10	12-15 y	Fairbank and Ahlbäck	WB 30° flexion AP and lateral	Yes − Grade 1 and 2 No
Rockborn and Gillquist, 1995,[41] retrospective, Level III	n = 43 6 F, 37 M Age at surgery: 19 y (15-22 y) Age at follow-up: NA	Medial: 24 Lateral: 19	13 y (11-15 y)	Ahlbäck	WB slightly flexed AP Unloaded lateral	Yes − Grade 1 No
Scheller et al., 2001,[42] retrospective, Level III	n = 75 32 F, 43 M Age at surgery: 37.7 y Age at follow-up: NA	Lateral: 75	8.7 y (5-15 y)	Fairbank	WB AP and lateral	No No
Sommerlath, 1991,[23] prospective, Level II	n = 25 7 F, 18 M Age at surgery: 27 y (15-43 y) Age at follow-up: NA	Medial: 17 Lateral: 8	7 y (6-10 y)	Fairbank and Ahlbäck	WB 30° flexion	No No
Stein et al., 2010,[43] retrospective, Level III (	n = 20 Sex: NA Age at surgery: 30.4 y (9.6 y) Age at follow-up: NA	Medial: 20	9.2 y (2.6 y)	Fairbank	WB AP and lateral	Yes − Grade 1 and 2 No
Vautrin and Schwartz, 2016,[44] retrospective, Level III	n = 34 5 F, 29 M Age at surgery: 32.3 y (16-52 y) Age at follow-up: 54.3 y (36-76 y)	Medial: 23 Lateral: 11	22.6y	Ahlbäck	WB AP and lateral	No Yes

AP, anterior to posterior; F, female; M, male; NA, not available; OA, osteoarthritis; PA, posterior to anterior; TF, tibiofemoral; WB, weight-bearing.

*Age is reported as mean ± standard deviation and/or range across all study subjects who received arthroscopic partial meniscectomy unless otherwise indicated.

†Follow-up time periods are reported as the mean ± standard deviation and/or range after surgery unless otherwise indicated.

Table 2. Risk of Bias Assessment

	Question Number												
Study	1	2	3	4	5	6	7	8	9	10	11	12	Total
Andersson-Molina et al., 2002[24]	1	1	1	1	0	1	0	0	0	0	1	1	7
Benedetto and Rangger, 1993[25]	1	1	1	1	0	1	1	1	1	0	1	0	9
Bolano and Grana, 1993[26]	1	1	1	0	0	1	1	0	1	0	1	0	7
Bonneux and Vandekerckhove, 2002[27]	0	1	1	0	1	0	0	0	1	1	1	1	7
Burks et al., 1997[28]	0	1	0	1	0	1	1	1	1	0	1	0	7
Chatain et al., 2001[29]	1	1	1	0	1	1	1	1	1	1	1	0	10
Englund and Lohmander, 2004[30]	1	1	0	1	1	1	0	1	1	1	1	0	9
Fauno and Nielsen, 1992[31]	1	1	1	1	0	1	1	1	1	0	1	0	9
Han et al., 2010[32]	1	1	0	0	1	1	0	1	1	0	1	0	7
Higuchi et al., 2000[33]	1	1	1	1	0	1	1	1	1	0	1	1	10
Jaureguito et al., 1995[36]	1	1	1	0	0	1	1	0	1	0	1	1	7
Kim et al., 2020[37]	1	1	1	0	1	1	1	1	1	0	1	1	10
Lamplot et al., 2019[11]	1	1	1	0	0	1	0	1	1	1	1	1	9
Lizaur-Utrilla et al., 2019[12]	0	1	1	1	1	1	1	0	1	1	1	1	10
Longo et al., 2019[13]	1	1	1	1	1	1	0	0	1	1	1	0	9
Lutz et al., 2015[39]	1	1	1	1	1	1	0	1	1	1	1	0	10
Maletius et al., 1996[40]	1	1	1	1	1	1	1	0	1	0	1	0	9
Rockborn and Gillquist 1995[41]	1	1	0	0	0	1	0	1	1	1	1	0	7
Scheller et al., 2001[42]	1	1	1	0	0	0	1	1	1	0	1	0	7
Sommerlath, 1991[23]	0	1	1	1	1	0	0	0	1	1	1	0	7
Stein et al., 2010[43]	1	1	1	1	0	1	0	1	1	1	1	0	9
Vautrin and Schwartz, 2016[44]	0	1	1	1	0	1	0	1	1	0	1	0	7

Yes = 1; no = 0; unclear = 0.

1. Is the primary hypothesis/aim/objective of the study to evaluate the prevalence of radiographic and/or symptomatic knee osteoarthritis in people with meniscectomy?
2. Are the main outcomes to be measured clearly described in the introduction or methods section?
3. Are the characteristics of the patients included in the study clearly described?
4. Is the sample of interest clearly described?
5. Are the distributions of principal confounders in each group of subjects to be compared clearly described?
6. Are the main findings of the study clearly described?
7. Was the sample size included in the analysis adequate, and was the dropout rate okay?
8. Were the subjects asked to participate in the study representative of the entire population from which they were recruited?
9. Were the main outcome measures used accurate (valid and reliable)?
10. Was an acceptable case definition used in the study?
11. Was the same data collection used for all subjects?
12. Was the person(s) scoring the radiographs described and suitably qualified?

of ≥15 years. There were a total of 1,273 medial, 347 lateral, and 19 combined medial and lateral meniscectomies.

There was some variability across studies in the radiologic classification system used to assess the development of TF OA, as well as in the specific radiographic views taken. Fourteen studies[23-28,31,33,36,40-44] implemented the Fairbank, or the Ahlbäck classification system, 6 studies[11-13,30,37,39] assessed radiologic OA using the Kellgren-Lawrence scale, 1 study[29] implemented the radiologic international knee documentation committee grade, and 1 study[32] used the Outerbridge classification system. In terms of the radiographic views used to assess TF OA, while there was some inconsistency, all 22 studies implemented a weight-bearing anterior–posterior or posterior–anterior view with or without a lateral view. With this, 13 studies[11-13,26,30,32,33,36,37,39-41,43] included participants with pre-existing radiographic TF OA (grade I/II), whereas 9 studies[23-25,27-29,31,42,44] included those without radiographic TF OA, and 5 studies[11,12,30,39,44] assessed symptomatic TF OA at follow-up.

Methodologic Quality

Table 2 shows the methodologic quality assessments. The lowest score of all studies was 7, whereas the highest was 10. Twelve studies (54.5%) scored ≥8 and were considered high quality. The 2 prospective studies had an average score of 8.5. The 20 retrospective studies had an average score of 8.3, with the highest score being 10 and the lowest being seven. Consensus was reached in 100% of the questions. Five studies did not have a clear hypothesis or aim described, whereas 4 studies did not clearly describe the characteristics of the included participants. Nine studies did not clearly describe the sample of interest, whereas 8 studies did not clearly describe confounding factors. Eleven studies did not provide appropriate calculation of sample size or address dropout rates, 8 studies did not have

Table 3. Results of Radiographic Tibiofemoral Osteoarthritis

Study	Participants With APM (Analyzed)	Participants With OA Following APM	Prevalence of OA Following APM	Comparison Group	Participants in CG	Participants With OA in CG	Prevalence of OA in CG
5 y to <10 y							
Benedetto and Rangger, 1993[25]	87	20	23%	NA			
Bolano and Grana, 1993[26]	50 (29)	18	62%	NA			
Bonneux and Vandekerckhove, 2002[27]	29	26	90%	Contralateral knee	29	5	17.2%
Fauno and Nielsen, 1992[31]	136	72	53%	Contralateral knee	136	30	22.1%
Han et al., 2010[32]	46	16	35%	NA			
Jaureguito et al., 1995[36]	31	17	55%	Contralateral knee	31	14	44%
Kim et al., 2020[37]	114	69	60.5%	NA			
Lamplot et al., 2019[11]	44 (32)	16	50%	Contralateral knee	44 (32)	6	20%
Lizaur-Utrilla et al., 2019[12]	258	136	52.7%	NA			
Longo et al., 2019[13]	57	36	62.7%	Contralateral knee	57 (46)	13	28.3%
Scheller et al., 2001[42]	75 (58)	45	77.6%	Contralateral knee	75 (58)	42	72.4%
Sommerlath et al., 1991[23]	25	13	52%	NA			
Stein et al., 2010[43]	20	12	60%	NA			
10 y to <15 y							
Andersson-Molina et al., 2002[24]	18	5	28%	Uninjured match controls	36	4	11%
Burks et al., 1997[28]	111*	78	70.3%	NA			
Chatain et al., 2001[29]	317 (218)	102	46.8%	Contralateral knee	317 (218)	38	17.5%
Higuchi et al., 2000[33]	67	38	56.7%	Contralateral knee	67	24	35.8%
Lutz et al., 2015[39]	22 (21)	21	100%	NA			
Maletius et al., 1996[40]	40	28	70%	Contralateral knee	40	16	40%
Rockborn and Gillquist 1995[41]	43 (33)	20	60.6%	Contralateral knee	40 (33)	5	15.2%
≥15 years							
Englund and Lohmander 2004[30]	48	25	52%	Uninjured match controls	68	7	10%
Vautrin and Schwartz, 2016[44]	34	20	57.7%	NA			

ACL, anterior cruciate ligament; APM, arthroscopic partial meniscectomy; CG, comparison group; NA, not available; OA, osteoarthritis.
*Data are representative of ACL-normal knees.

participants that were representative of the entire population, 11 studies did not provide an adequate case definition, and 15 studies had no information on the qualifications of the individual interpreting the radiographs.

Prevalence of Radiographic OA

Five Years to <10 Years

For the 12 studies that had an average follow-up of 5 years to <10 years, the prevalence of radiographic TF OA ranged from 23% to 90% (Table 3, Fig 2). Seven of these[11-13,25,31,37,43] were high quality, ranging from 23% to 62.7%. Six studies[11,13,27,31,36,42] reported the prevalence of radiographic TF OA in the contralateral knee ranging from 17.2% to 72.4%. Five studies[23,25,27,31,42] included only participants without pre-existing radiographic TF OA with prevalence ranging from 23% to 90%.

Ten Years to <15 Years

For the 7 studies that had an average follow-up of 10 to <15 years, the prevalence of radiographic TF OA ranged from 28% to 100% (Table 3, Fig 2). Four of these studies[29,33,39,40] were high quality, with TF OA prevalence ranging from 46.8% to 100%. Four studies[29,33,40,41] reported the prevalence of radiographic TF OA in the contralateral knee ranging from 15.2% to 40%. One study[24] reported radiographic TF OA in uninjured matched controls with a prevalence of 11%. Three studies[24,28,29] included only participants without pre-existing radiographic TF OA, with prevalence ranging from 28% to 70.3%.

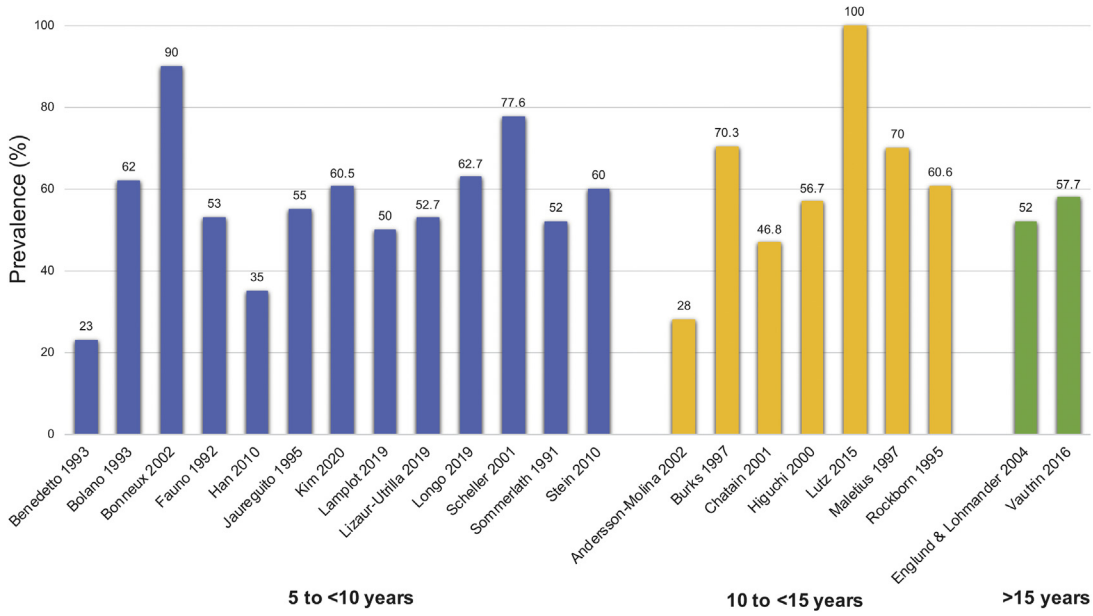

Fig 2. Prevalence of radiographic TF OA. (OA, osteoarthritis; TF, tibiofemoral.)

Greater Than or Equal to 15 Years

For the 2 studies that had an average follow-up of ≥15 years, the prevalence of radiographic TF OA ranged from 52% to 57.7% (Table 3, Fig 2). One study[30] was high quality, with a prevalence of 52%, and reported radiographic TF OA in uninjured matched controls with a prevalence of 10%. One study[44] included only participants without pre-existing radiographic TF OA, with prevalence of 57.7%.

Age

The authors further assessed the prevalence of radiographic TF OA by grouping studies into specific age groups regardless of length of follow-up. Of the 22 included studies, seven[23-25,27,33,40,41] had participants whose mean age was <30 at the time of surgery, demonstrating a prevalence of radiographic TF OA ranging from 23% to 90% at the time of follow-up. Seven studies[26,29,31,39,42-44] had participants with a mean age between 30 and <50 at the time of surgery, with final prevalence ranging from 46.8% to 100%. Five studies[11-13,32,37] had participants who had a mean age >50 years at the time of surgery, with final prevalence ranging from 35% to 62.7%.

Prevalence of Symptomatic TF OA

Five studies assessed the prevalence of symptomatic TF OA.[11,12,30,39,44] Of these, three[11,12,30] reported prevalence of symptomatic TF OA according to individual operational definitions (24.1%,[12] 27%,[30] 67%[11]) and 2 additional studies[39,44] correlated radiographic findings to functional outcome measures. Figure 3 illustrates the comparisons between radiographic and symptomatic TF OA for the 3 studies that reported both. In addition, Lutz et al.[39] demonstrated a significant linear correlation between functional and radiographic results, with functional scores inversely proportional to radiographic scores. Vautrin et al.[44] concluded there was a correlation between functional and radiographic findings, but the significance was unclear.

Risk Factors for the Development of TF OA

Four studies[11,12,29,30] reported risk factors for the development of TF OA using logistic regression to identify the factors. In addition, studies by Englund and Lohmander[30] and Lamplot et al.[11] reported risk factors for the development of symptomatic TF OA. The consistent risk factors for the development of radiographic TF OA across studies were age >35 years old, degenerative cartilage lesions, body mass index >30, and lateral or total meniscectomy. In terms of symptomatic TF OA, Englund and Lohmander[30] reported that female sex, body mass index ≥25, and a degenerative meniscal tear compared with a traumatic tear were risk factors for symptomatic TF OA development. Similarly, the study by Lamplot et al.[11] identified female sex as a significant factor for the development of symptomatic TF OA (OR 9.1).

Discussion

This review found that prevalence of radiologic TF OA following APM ranged from 23% to 90%, 28% to 100%, and 52% to 57.7% at follow-up of 5 years to <10 years, 10 years to <15 years, and ≥15 years, respectively. These findings do not support the authors' hypothesis that the prevalence of TF OA would be

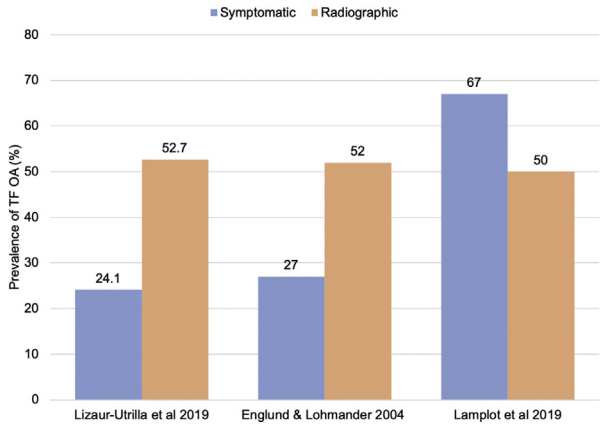

Fig 3. Prevalence of radiographic versus symptomatic TF OA. (OA, osteoarthritis; TF, tibiofemoral.)

greater at longer follow-up time periods. The authors identified 22 articles, with 11 studies not included in previous reviews,[9,10] investigating 1,672 participants following isolated APM and a mean follow-up of 9.5 years. This review also assessed the prevalence of symptomatic TF OA and found prevalence ranging from 24.1% to 67%. This review assesses the rate of TF OA only in participants with APM, rather than bundling them with participants with open and total meniscectomy, as previous reviews have done.[9,10] This is an important distinction as open and total meniscectomy may increase the likelihood of TF OA more than APM does. Other important strengths of this review include the assessment of methodologic quality, a detailed description of excluded articles, and analysis of long-term follow-up.

One of the keys of this systematic review is the categorization into different follow-up time periods. Across all time periods, the prevalence fell within 23% to 100%, with the lowest prevalence reported between 5 and <10 years and the highest prevalence reported between 10 and <15 years follow-up. Although it might be anticipated that longer follow-up assessment after APM would reveal greater prevalence of radiographic TF OA, the results of this review do no support this assumption. Surprisingly, the 2 studies with >15-year follow-up reported prevalence of 52% and 57.7%, despite higher and lower ranges of radiographic TF OA during shorter follow-up time periods. Given the variability in results, it is plausible that TF OA develops within the first 5 to 10 years following APM and then plateaus. If verified by further research, this finding may have important clinical implications for the management of individuals following APM. It may suggest a need to provide evidence-based education and exercise recommendations for the management of subsequent knee OA, for example.[45] Future trials should implement designs that incorporate multiple follow-up assessments within the same patient cohort to accurately assess progression of radiographic TF OA following APM and clarify the large range of reported prevalence. In addition, prospective cohort studies should be designed to compare the prevalence of TF OA following meniscal tear in participants with APM versus conservative management.

Since the results demonstrated variability in radiographic TF OA across follow-up periods, the development over time may be influenced by other factors. While, one consideration may be age at the time of surgery, the data collected do not support that view. The lowest prevalence was reported in participants <30 years of age (23%), but unexpectedly, participants >50 years did not demonstrate the greatest prevalence of radiographic TF OA (35%-62.7%). The greatest prevalence was instead found in participants aged 30 to 50 years (100%).

A second consideration in understanding the variability in reported prevalence across time periods is whether participants had pre-existing radiographic TF OA at the time of surgery. The results of this review do not support this consideration either, as large ranges of prevalence were observed regardless of whether studies did (35%-100%) or did not (23%-90%) include participants with pre-existing radiographic TF OA. Another consideration for the large range of TF OA within a specific follow-up period may be due to differences in the scale used to interpret the progression of radiographic TF OA. Again, the data collected here do not support that consideration. Of course, behavioral variables, systemic health, or other yet-unidentified factors also may contribute to the development of radiographic TF OA following APM. Given the relatively high prevalence seen here, it is plausible that all individuals will develop some grade of radiographic TF OA following APM due to the biomechanical challenges inherent in functioning with a compromised meniscus.[46]

Radiographic TF OA was assessed in the uninjured contralateral knee in 10 studies with prevalence ranging from 17.2% to 72.4% during follow-up of 5 to <10 years. While beyond the specific purpose of this review, data on the uninjured contralateral knee are interesting because they suggest that radiographic TF OA may develop over the first 5 to 10 years and plateau afterward. In addition, for both the injured and uninjured limbs of individuals undergoing APM, the lowest reported prevalence found in this review (15.2%)[41] is still greater than the reported global age-standardized prevalence of 3.8%.[47] Thus, a meniscal tear and subsequent APM may lead to bilateral maladaptive movement patterns potentially affecting the uninjured knee as well, and possibly explaining the development of TF OA in younger individuals. Comparison between the injured, surgically managed knee with the uninjured knee should be interpreted with caution, however,

given that the uninjured knee may be affected by the surgery and subsequent recovery experience.

Symptomatic TF OA prevalence was reported as 24.1%,[12] 27%,[30] and 67%[11] in 3 included studies. In these studies, at least one-half of those with radiographic TF OA were symptomatic. While previous research has identified a poor correlation between radiographic knee OA and pain,[48,49] very few studies have investigated the prevalence of symptomatic TF OA following APM. In a previous study, Suter et al.[50] reported the lifetime prevalence of symptomatic TF OA to be approximately 34% for both ACL and meniscal tears, which falls within the reported prevalence supported by this review. To date, the reasons for the poor correlation between radiographic findings and clinical symptoms have yet to be explained.[51]

While 22 studies were included in this systematic review, only 4 studies[11,12,29,30] performed an analysis of risk factors for the development of TF OA. However, none of the 4 considered confounding variables, which reduces the overall confidence in these results. Future studies should assess for confounding variables using multivariate regression analysis to avoid false positives or identifying risk factors by chance. In addition, future studies should clearly distinguish between radiologic and symptomatic TF OA.[16]

Methodologic Quality Assessment

This systematic review assessed methodologic quality using guidelines from the Center of Reviews and Dissemination,[17] as well as questions from the Downs and Black Checklist.[18] This approach was recently used in a similar systematic review that assessed the rate of knee OA following ACL injuries.[16] Low methodologic quality was present in 11 studies (45.5%). To date, there is still no current consensus in the literature regarding high- or low-quality studies, and determining quality from this perspective can be problematic.[17] However, the authors decided to distinguish study quality using a cut off score of $\geq$60% as high quality, consistent with 2 other systematic reviews.[16,19] That being said, the results of the quality assessment are only valid to this particular systematic review. Similar to the recent ACL systematic review, we did not distinguish the impact that particular questions may have on the overall study quality, therefore the results should be interpreted with caution.

Limitations

While this review had the benefits of focusing entirely on TF OA following isolated APM and examining long-term follow-up, it is not without limitations. One of the major limitations relates to limitations in the designs of the included studies. Many of the included studies were retrospective and none specifically compared prevalence of TF OA for individuals with meniscal tears who received APM versus individuals with meniscal tears who did not receive APM. Consequently, ORs and meta-analysis for that key comparison could not be determined, leaving a descriptive assessment of single-arm prevalence as the primary indicator of development of TF OA after isolated APM. This limitation highlights the critical need for more information about the potential risks of development of TF OA after meniscal tear with APM, especially given some of the results discussed above. Another limitation of this review relates to the heterogeneity of the included studies, which likely results from variation in protocols and duration of follow-up, ages at inception, mechanisms of injury, and injury status of the knees considered in the comparison condition. In addition, inconsistency in reporting of participant and study characteristics, including age at follow-up, degenerative versus traumatic meniscal tears, and the radiographic scale used to assess TF OA development, made interpretation of data more difficult. All of these factors may contribute to a lack of precision in the prevalence estimates obtained.

Furthermore, there is no current consensus for the definition of symptomatic TF OA, and only 3 studies assessed the prevalence of symptomatic TF OA, making overall clinical judgments elusive. Given the purpose of this review and the nature of cohort studies, it is not possible to assess preinjury function of participants and relate that to preoperative radiographic findings. This, in conjunction with the lack of data related to symptomatic TF OA, makes it difficult to discern whether preoperative function is a result of the meniscal tear or the pre-existing radiographic TF OA before APM. Other limitations are only including articles written in English, as well as the absence of a gold standard to assess methodologic quality. These limitations highlight the need for more rigorous prospective studies on the potential risks of developing TF OA after meniscal tear and APM.

Conclusions

APM results in a prevalence of radiographic TF OA ranging from 23% to 100% across follow-up time periods with the lowest prevalence reported between 5 and <10 years and the highest prevalence reported between 10 and <15 years' follow-up. Considerably less data was available to assess symptomatic TF OA or risk factors associated with TF OA.

Acknowledgments

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Appendix Table 1. PRISMA 2009 Checklist

Section/Topic	#	Checklist Item	Reported on Page #
Title			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title page
Abstract			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1-2
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3-5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
Methods			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	5-7
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	8
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	8 Appendix 2
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Fig 1 8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7-8 Tab 1
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	9 Table 2
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	5-7, 9-10
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	9-10
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA

(continued)

Appendix Table 1. Continued

Section/Topic	#	Checklist Item	Reported on Page #
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
Results			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Fig 1 10-11
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Tab 1 11-12
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	12-13 Tab 2
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	13-15 Fig 2, Fig 3 Tab 3
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	NA
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	NA
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
Discussion			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	16-20
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	20-22
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	22
Funding			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

NOTE. From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 2009;6:e1000097. https://doi.org/10.1371/journal.pmed1000097. For more information, visit: www.prisma-statement.org.

NA, not available; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Appendix Table 2. Search Strategy

PubMed	(("meniscal repair"[All Fields]) OR ("meniscectomy"[All Fields])) AND ("osteoarthritis"[All Fields])	1,148
Cochrane Library	"meniscectomy" in All Text OR "meniscal repair" in All Text AND "osteoarthritis" in All Text - (Word variations have been searched)	441
AMED (Ovid)	((meniscectomy or "meniscal repair") and Osteoarthritis).af.	386
CINHAL (Ebsco)	Osteoarthritis AND ("meniscal repair" OR meniscectomy)	2,523
Pedro	meniscal repair OR meniscectomy AND osteoarthritis	16
Embase	(meniscectomy [all fields] OR 'meniscal repair' [all fields]) AND osteoarthritis [all fields]	2,362
Arthroscopyjournal.org	meniscal repair OR meniscectomy AND osteoarthritis	1,174