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Meniscectomy as a risk factor for knee osteoarthritis: a systematic review

Rocco Papalia[†], Angelo Del Buono[†], Leonardo Osti[‡], Vincenzo Denaro[†], and **Nicola Maffulli[§*]**

[†]Department of Orthopaedic and Trauma Surgery, Campus Biomedico University of Rome, Via Alvaro del Portillo, Rome, Italy; [‡]Unit of Arthroscopy and Sports Trauma Surgery, Hesperia Hospital, Via Arquà 80/b, Modena, Italy, and [§]Centre for Sports and Exercise Medicine, Barts and The London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, UK

Introduction: This review defines the recognized risk factors responsible for the development of knee osteoarthritis after surgical management of meniscal tears.

Sources of data: We performed a literature search using Medline, Ovid, Cochrane and Google Scholar using the keywords: 'Meniscal tears', 'meniscectomy', 'osteoarthritis', 'complications' and 'risk factors'. Thirty-two published studies were identified.

Areas of agreement: In the long term, osteoarthritis develops in the knee of patients undergoing surgery for meniscal tears. The Coleman methodology score showed great heterogeneity in terms of patient characteristics and outcome assessment. Amount of meniscus removed, duration of pre-operative symptoms and lateral meniscectomy show strong statistical association to onset of knee osteoarthritis.

Areas of controversy: We did not find univocal findings defining the risk factors responsible for the development of post-operative knee osteoarthritis.

Growing points: There is a need for standardized clinical and imaging validated scale to improve definition of post-operative knee osteoarthritis to allow easier and more reliable comparison of outcomes in different studies.

Areas timely for developing research: Appropriately powered randomized controlled trials reporting clinical and imaging-related outcomes in patients undergoing arthroscopic minimally invasive procedures and meniscal suturing should be performed. Comparing imaging findings of patients undergoing arthroscopic partial and open meniscectomy, a lower incidence of knee osteoarthritic evolution was detected after arthroscopy. The amount of removed meniscus is the most important predictor factor for the development of osteoarthritis. Minimally invasive procedures seem to reduce the incidence of long-term osteoarthritic changes of the knee compared with more invasive open and or arthroscopic procedures.

**Correspondence address. Centre for Sports and Exercise Medicine, Barts and The London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, UK. E-mail: n.maffulli@qmul.ac.uk*

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Introduction

Surgical removal of a meniscus has been practiced since the second half of the 19th century, when open total meniscectomy was the recommended management of meniscal tears.[1] Following initial enthusiasm,[2–4] minimal meniscal resection, preserving a stable remnant, was advocated to prevent osteoarthritis.[5] Advances in technology have allowed arthroscopic partial meniscectomy to replace open total meniscectomy. Therefore, in the last two decades, this procedure has been considered as the gold standard for surgical management of torn menisci not suitable for suture repair, and has reduced hospitalization time, sick leave and costs of care.[5] A recent systematic review has reported on prognostic factors for progression of knee osteoarthritis.[6] To our knowledge, however, a systematic analysis of onset and progression determinants of knee osteoarthritis in patients undergoing meniscal surgery has not been performed. We describe the published evidence for functional results and post-operative osteoarthritis in patients undergoing open and arthroscopic, total and partial meniscectomy. We conducted a systematic literature review to evaluate: (1) the methodological quality of papers concerning long-term imaging diagnosis of Knee osteoarthritis, using a modified Coleman methodology score (CMS);[7,8] (2) to report on radiographic classification methods assessing post-operative osteoarthritis changes. Finally, we investigated the prognostic factors strongly associated with the development of osteoarthritic changes in patients who had undergone open and arthroscopic meniscectomy.

Methods

Study selection

We included randomized clinical trials, prospective or retrospective studies reporting a minimum of 5 years clinical and imaging outcomes of patients with an intact anterior cruciate ligament who had undergone a medial, lateral or combined medial and lateral meniscectomy. Given the linguistic capabilities of the research team, we considered only the publications published in English, Spanish, French and Italian.

Studies on patients with injuries other than their menisci, with $<$5-year follow-up, and no imaging assessment were excluded.

Search

We performed a search for relevant studies published up to December 2010 in Medline (http://www.ncbi.nlm.nih.gov/sites/entrez/); Ovid (http://www.ovid.com); Cochrane Reviews (http://www.cochrane.org/reviews/), Google Scholar. Keyword used were 'Meniscal tears', 'meniscectomy', 'osteoarthritis', 'complications' and 'risk factors', with no limit regarding the year of publication. We identified 1394 publications. Two authors (RP and ADB) reviewed the abstract of each publication. The papers were selected or excluded according to the abstract text, excluding the article if an abstract was not available. In addition, screening the reference lists of relevant studies, articles not identified at the first electronic search were included. All journals were considered and all relevant articles were retrieved.

Studies on animals, cadavers, *in vitro*, case reports, literature reviews, technical notes, letters to editors and instructional course were also excluded. To qualify, an article would have to have been published in peer-reviewed journals. We obtained full-text versions if the abstract did not permit to include or exclude the study. Fifty-two articles were thus identified and selected. To avoid bias, 52 full-text selected articles were reviewed and discussed by all the authors, and a fully trained orthopaedic surgeon with a special interest in knee surgery and sports medicine (LO) made the final decision if any doubt arose. After this further selection, finally, 32 publications relevant to the topic were included.

Quality assessment

To assess the methodological quality of each article twice, two investigators (RP and ADB) separately evaluated each study, using the CMS,[7] a 10 criteria scoring list assessing the methodological quality of the selected studies (CMS). Each study was assessed for each of the 10 criteria to give a final score ranging from 0 to 100 (Table 1). A perfect score of 100 would represent a study design that largely avoids the influence of chance, various biases and confounding factors. The two investigators discussed scores where more than a two-point difference was evident, until consensus was reached.

Data extraction

To assess the impact of methods on reported outcomes, the CMSs were correlated with reported success rates (in percent) and with publication year to examine trends in methods over time. The intra-class correlation coefficient score was calculated to assess the extent of agreement

Table 1 Coleman methodology scores and criteria.

Section score (maximum score)	Mean	Standard deviation	Range	Median
Part A				
Study size (10)	8.5	2.2	4–10	10
Mean duration of follow-up (10)	5.0	—	—	5
No. of surgical procedures (10)	6.9	4.8	0–10	10
Type of study (15)	1.3	3.9	0–15	0
Diagnostic certainty (5)	3.2	1.4	1–5	3
Description of surgical procedure (5)	0.3	1.1	0–5	0
Description of post-operative rehabilitation (10)	0.4	1.3	0–7	0
Part B				
Outcome measures (10)	6.4	2.7	2–10	8
Outcome assessment (15)	8.5	2.7	3–12	9
Selection process (15)	8.4	3.3	2–15	9
Total score (100)	49.1	11.5	26–69	51

between the Coleman scores of the two independent assessors. The Spearman correlation was used to assess correlation between the year of publication and the Coleman score. Analysis was performed using SPSS software (version 16.0, Chicago, IL, USA). Based on available data, type of surgery (open and arthroscopy), amount of removed meniscus (total, partial, subtotal), age at surgical timing, length of follow-up, sex, type of lesion and lesion site were correlated to the rate of post-operative knee osteoarthritis.

Evidence synthesis assessment

To determine predictive factors of post-operative osteoarthritis, regardless its grading, we synthesized extracted findings into four evidence levels: (I) no evidence: one or more study available; (II) weak evidence: significant association detected in four or more studies correlating two selected variables or five studies, of which four reported association and one no association; (III) strong evidence: significant association found in six or more studies, or in seven studies of which six detected association and one no association; (IV) inconsistent evidence: remaining instances. Finally, weak or strong evidence for 'no association' was provided when six or more studies are available, of which >60 and $>80\%$, respectively, reported no association.

Results

We identified 32 published studies from 1969 to 2006 which reported >5 years clinical and imaging outcomes in patients with meniscal tear history, who had undergone partial or total meniscectomy. Among

these, we found four studies describing long-term post-operative outcomes in paediatric patients.

Pre-operative features. The mean interval time from onset of symptoms to meniscectomy was 13.4 months (range from 0[9] to 39[9] months). The mean age of included patients at operation time and last follow-up were 30.9 years (range: 7[10]–71[11]) and 45.5 years, respectively (range from 15[12] to 86[13]).

Study size and follow up. The total number of patients included in the various studies was 4642, and varied from 24[12] to 577.[14] With regard to gender distribution, of 3504 assessed patients, 2799 (79.3%) were male and 733 (20.9%) were female. According to available data, 2929 tears (77.1%) regarded the medial side and 868 (22.9%) involved the lateral side. The mean follow-up time was 13.3 years, ranging from 5.5[15] to 39[16] years. The average modified CMS was 49.1 (range from 26.0[17] to 69.0[16,18]). The lowest scores were found within the categories (i) type of study, (ii) description of surgical technique, (iii) description of post-rehabilitation programme, (iv) description of subject selection process. The average total CMS and the average CMS for each criterion are given in Table 1.

Study type. We selected 1 randomized trial clinical study, 3 prospective cohort studies and 28 retrospective studies.

Type of management

Many procedures were performed. In 11 studies all patients underwent open total meniscectomy, in 2 studies all received open partial meniscectomy. In 3 studies, open total and partial meniscectomy had been performed. Arthroscopic partial or subtotal meniscectomy only was performed in 13 articles. Only one study investigated the long-term outcomes relative to patients undergoing arthroscopic partial meniscectomy or meniscal repair (Table 2). In this instance, we extracted the data relative to arthroscopic partial meniscectomy, and used them in our analysis.

Surgical description and post-operative rehabilitation. Concerning description of the surgical technique, 2[19,20] of 32 studies (6.25%) achieved a score ≥ 3, but the maximum score of 5 points was achieved in only one study.[19] The description of post-operative rehabilitation scored 7 in only one study,[19] and it was only mentioned in four studies.[4,11,20,21] Since 26 of 32 studies did not contain any referral to post-operative rehabilitation, they scored 0.

Subject selection, outcome criteria and outcome assessment. With regard to the description of subject selection criteria, 16 of the 32 selected (50%) studies reported a score ≥ 9. The articles showed a wide variation in outcome criteria used. In 20 of the 32 studies (62.5%),

Table 2 Sample data.

Author	Sample size	Sample mean age	Surgery	Length of follow-up (year)
Abdon *et al.*[10]	89	16.2	Open total meniscectomy	16.8
Allen *et al.*[3]	210	—	Open total meniscectomy	17
Andersson *et al.*[28]	72	28.5	Arthroscopic partial and total meniscectomy	14
Benedetto and Rangger[20]	295		Arthroscopic partial meniscectomy	6–6.7
Bolano and Grana[15]	50		Arthroscopic partial meniscectomy	5.5
Bonneux and Vandekerckhove[22]	29	25	Arthroscopic partial and subtotal meniscectomy	8
Burks *et al.*[32]	111	35.8	Arthroscopic partial meniscectomy	14.7
Chatain *et al.*[26]	317	38	Arthroscopic partial meniscectomy	11.5
Chatain *et al.*[27]	471	38.5–35	Arthroscopic partial meniscectomy	11
Dai *et al.*[12]	24	12.5	Open total meniscectomy	16.1
Englund *et al.*[1]	205		Arthroscopic and open total meniscectomy	14
Englund and Lohmander[34]	317		Open partial and total meniscectomy	18
Fauno[25]	136	35.2–31.6	Arthroscopic partial meniscectomy	8.5
Gonet and Raine[11]	244	36.3	Open total meniscectomy	
Hede *et al.*[18]	189		Open partial and total meniscectomy	7.8
Higuchi *et al.*[31]	67	26.7	Arthroscopic partial meniscectomy	12.2
Hulet *et al.*[29]	57	36	Arthroscopic partial and total meniscectomy	12
Jackson[14]	577		Open total meniscectomy	
Jaureguito *et al.*[23]	31		Arthroscopic partial meniscectomy	8
Johnson *et al.*[2]	99	27.1	Open total meniscectomy	17.5
Jorgensen *et al.*[4]	101		Open total meniscectomy	14.5
Kruger-Franke *et al.*[30]	100	30.3	Arthroscopic partial meniscectomy	7
McNicholas *et al.*[16]	63	16	Open total meniscectomy	30
Medlar *et al.*[33]	26	15	Open total meniscectomy	8.3
Neyret *et al.*[13]	91	35	Open partial meniscectomy	26
Rockborn and Gillquist[9]	43	19	Open partial and subtotal meniscectomy	13
Roos *et al.*[36]	107		Open total meniscectomy	21
Roos *et al.*[38]	159		Open total meniscectomy	19
Scheller *et al.*[24]	75		Arthroscopic partial meniscectomy	8.7
Shelbourne and Dickens[21]	49	28.9	Arthroscopic partial meniscectomy	11.8

Continued

Table 2 *Continued*

Author	Sample size	Sample mean age	Surgery	Length of follow-up (year)
Sommerlath[19]	25	27	Arthroscopic partial meniscectomy Meniscal repair	7
Tapper and Hoover[17]	213		Open total and partial meniscectomy	

validated scoring systems with good reliability and sensitivity were applied. The 'outcome assessment' section scored adequately ($\geq$9) in 21 of the 32 articles (65.6%). In the remainder of the published articles, this category scored low from the lack of one or more of the four criteria mentioned in the CMS.

Reported outcomes and complications. Almost all the articles used different methods of reporting their results. Hence, we could not summarize the post-operative success rates according to specific scores, but we limited to report results as described in each study, regardless of the classification system used. The Lysholm score and satisfactory subjective assessment were, respectively, administered in 7[15,18,19,22–25] and 7 articles[10,16,26–30]. In eight studies, outcomes were reported according to the Tapper and Hoover criteria[10,12,15,31] (Table 3) and International Knee Documentation Committee (IKDC) assessment[22,26,27,29]. The Marshall[30] and Johnson scoring system[10] were, respectively, used in only one study. In five studies,[2,3,13,32,33] outcomes were rated in form of excellent good results using unspecified scores. The reported percentage of good excellent outcome resulted in an average value of 73.7% (range from 42.5 to 100%).

With regard to post-operative complications, few data were extracted from the selected studies. However, further meniscectomy in the index knee to remove meniscal remnant is the most frequently complication.[23,28,33,34] Gonet[11] observed cases of recurrent effusion, frank sepsis and deep vein thrombosis.

CMSs and statistical results. The mean CMSs for each section is reported in Table 4 (range 25[14]–69[16,18]). The CMS of individual scientific articles are listed in Table 4.

The intra-class correlation coefficient gave a score of 0.75. This indicates a high correlation between the CMSs awarded to each scientific article by each independent marker. We found no statistically significant association between percentage of good or excellent results and CMS ($r = 0.28$, $P = 0.2$). A positive correlation was detected between CMS and the study level of evidence.

Table 3 Clinical and imaging outcomes.

Author	% of osteoarthrosis	Rate of success
Abdon *et al.*[10]	89	74% according to subjective satisfaction
Allen *et al.*[3]	18.3	61%
Andersson *et al.*[28]	20.8	94.4% according to subjective satisfaction
Benedetto and Rangger[20]	23	
Bolano and Grana[15]	62	82% according to Lysholm knee scale score and Tapper-Hoover criteria
Bonneux and Vandekerckhove[22]	92.9	64.5% according to Lysholm knee scale score and 48.4% acc to IKDC Subjective Knee score
Burks *et al.*[32]		88% in intact ACL group
Chatain *et al.*[26]	31.2	91.1% according to IKDC subjective form and 95.7% according to subjective satisfaction
Chatain *et al.*[27]	25.3	90.2% in medial meniscectomy group and 85.9 in lateral meniscectomy group according to IKDC subjective form
Dai *et al.*[12]	87.5	62.5% according to Tapper and Hoover criteria
Englund *et al.*[1]		
Englund and Lohmander[34]	48	
Fauno[25]	53	83% according to Lysholm knee scale score. No inter-groups difference between flap-tears and Bucket-handle tears
Gonet and Raine[11]		
Hede *et al.*[18]		62% of patients undergoing partial meniscectomy and 52% of patients undergoing total meniscectomy according to subjective satisfaction
Higuchi *et al.*[31]	57	79% according to Tapper and Hoover criteria
Hulet *et al.*[29]	16	100% according to IKDC objective form
Jackson[14]	23	
Jaureguito *et al.*[23]	62	62% according to Lysholm knee scale score
Johnson *et al.*[2]	74	42.5%
Jorgensen *et al.*[4]	89	
Kruger-Franke *et al.*[30]	32	99% according to modified Marshall score and 98% according to subjective satisfaction
McNicholas *et al.*[16]	36	71% according to subjective satisfaction; 60% according to Tapper and Hoover criteria
Medlar *et al.*[33]		42.3%
Neyret *et al.*[13]	35%	68% in intact ACL group
Rockborn and Gillquist[9]	60.6	
Roos *et al.*[36]	71	
Roos *et al.*[38]		
Scheller *et al.*[24]	77.3	66% according to Lysholm knee scale score
Shelbourne and Dickens[21]		
Sommerlath[19]	52	84% in excision group according to Lysholm knee scale score
Tapper and Hoover[17]		66% of total meniscectomy group and 68% of partial meniscectomized

IKDC, International Knee Documentation Committee.

Correlating the CMSs to year of publication we found that, although almost all the studies were retrospectives, the more recently published articles had significantly higher scores ($r = 0.52$; $P = 0.0025$) than the

Table 4 Coleman methodology scoring system.

Section	Number or factor	Score
Part A—only one score to be given for each of the seven sections		
Study size—number of subjects (*n*) (if multiple follow-up, multiply *n* by number of times subjects followed up)	>60	10
	41–60	7
	20–40	4
	<20, non-stated	0
Mean follow-up (months)	>24	5
	12–24	2
	<12, not stated, or unclear	0
Number of different surgical procedures included in each reported outcome. More than one surgical technique may be assessed but separate outcomes should be reported	One surgical procedure only More than one surgical procedure, but >90% of subjects undergoing the one procedure	10
		7
	Not stated, unclear, or <90% of subjects undergoing the one procedure	0
Type of study	Randomized control trial	15
	Prospective cohort study	10
	Retrospective cohort study	0
Diagnostic certainty (use of pre-operative ultrasound, MRI, or post-operative histopathology to confirm diagnosis)	In all	5
	In >80%	3
	In <80%, no, not stated, or unclear	0
Description of surgical procedure given	Adequate (technique stated and necessary detail s of that type of procedure given)	5
	Fair (technique only stated without elaboration)	3
	Inadequate, not stated, or unclear	0
Description of post-operative rehabilitation	Well described with >80% of patients complying	10
	Well described with 60–80% of patients Complying	5
	Protocol not reported or, 60–80% of patients complying	0
Part B—scores may be given for each option in each of the three sections if applicable		
Outcome criteria (if outcome criteria is vague and does not specify subjects' sporting capacity, score is automatically 0 for this section)	Outcome measures clearly defined	2
	Timing of outcome assessment clearly stated (e.g. at best outcome after surgery or at follow-up)	2
	Use of outcome criteria that has reported good reliability	3
	Use of outcome with good sensitivity	3
Procedure for assessing outcomes	Subjects recruited (results not taken from surgeons' files)	5
	Investigator independent of surgeon	4
	Written assessment	3
	Completion of assessment by subjects themselves with minimal investigator assistance	3
Description of subject selection process	Selection criteria reported and unbiased	5
	Recruitment rate reported >80 *or* <80%	5
	Eligible subjects not included in the study satisfactorily accounted for or 100% recruitment	5

Table 5 Coleman Score, type of study and level of evidence.

Author	Coleman score	Type of study	Level of evidence
Abdon *et al.*[10]	49	Retrospective	IV
Allen *et al.*[3]	50	Retrospective	IV
Andersson *et al.*[28]	41	Retrospective	IV
Benedetto and Rangger[20]	40	Retrospective	IV
Bolano and Grana[15]	53	Retrospective	IV
Bonneux and Vandekerckhove[22]	45	Retrospective	IV
Burks *et al.*[32]	54	Retrospective	IV
Chatain *et al.*[26]	61	Retrospective	IV
Chatain *et al.*[27]	50	Retrospective	III
Dai *et al.*[12]	37	Retrospective	IV
Englund *et al.*[1]	52	Retrospective	IV
Englund and Lohmander[34]	43	Retrospective	IV
Fauno[25]	40	Retrospective	IV
Gonet and Raine[11]	34	Retrospective	IV
Hede *et al.*[18]	69	Randomized clinical trial	I
Higuchi *et al.*[31]	61	Retrospective	IV
Hulet *et al.*[29]	52	Retrospective	IV
Jackson[14]	25	Retrospective	IV
Jaureguito *et al.*[23]	52	Retrospective	IV
Johnson *et al.*[2]	53	Retrospective	IV
Jorgensen *et al.*[4]	62	Prospective	II
Kruger-Franke *et al.*[30]	51	Retrospective	IV
McNicholas *et al.*[16]	69	Prospective	II
Medlar *et al.*[33]	30	Retrospective	IV
Neyret *et al.*[13]	51	Retrospective	III
Rockborn and Gillquist[9]	40	Retrospective	IV
Roos *et al.*[36]	46	Retrospective	IV
Roos *et al.*[38]	57	Retrospective	IV
Scheller *et al.*[24]	58	Retrospective	IV
Shelbourne and Dickens[21]	56	Retrospective	IV
Sommerlath[19]	66	Prospective	II
Tapper and Hoover[17]	26	Retrospective	IV

older studies. We found significant correlation between the Coleman methodology and level of evidence ($r = -0.57$; $P = 0.0006$) (Table 5).

Range of movement

Abdon[10] reported decreased range of motion in 32 of 89 patients (36%), all undergoing lateral meniscectomy. Another study[2] observed mean passive range of motion of 143° in excellently rated knees, 141° in fairly rated knees and 129° in poorly rated knees. Comparing 17 and 30 years outcomes, McNicholas[16] observed over time deterioration in terms of a progressively greater flexion contracture. Seven of thirty (23.3%) patients with a lateral meniscectomy exhibited a mean flexion contracture of 8° (from 5 to 15) at 17-year follow-up. At 30-year follow-up, a mean flexion contracture of 15° (from 5 to 25) was

measured in 9/63 (14.3%) contra-lateral non-operated knees and in 17/63 (27%) operated knees, with no difference between medial and lateral meniscectomy. Medlar,[33] comparing operated and non-operated knees, observed 4/26 (15.4%) ROM deficient operated knees (two full extension and two full flexion). Rockborn[9] found no difference between operated and non-operated knees (145.7° vs. 147.6°).

Radiographic classification

Many different radiographic classification methods were used in the 32 included studies. Fourteen of thirty-two (41.9%) studies used Fairbank's changes classification system,[35] 4/32 (12.5%) studies[2,9,10,28] used the method described by Ahlbach. Three of thirty-two (9.4%) studies[26,27,29] used the IKDC form classification, and 2/32 (6.25%) studies[34,36] the Kellgren Lawrence classification.[37] Holden grading system,[32] Appel classification,[12] Burnett classification,[16] Jager Wirth classification,[24] Rosenberg classification[21] were used in one study each (3.2%).

In most studies, weight bearing antero-posterior, postero-anterior and lateral radiographs were performed for both the operated and non-operated knees. At times, the Merchant patellar projection was taken.

Knee osteoarthritis

According to reported percentages, we calculated an overall mean prevalence of knee osteoarthritis in 53.5% (ranging from 16[29] to 92.9%[22] of the operated knees). The corresponding rate in the contralateral, non-operated knee, ranged from 0 to 44%.[24] Additionally, we identified the total number of patients undergoing imaging assessment at last follow-up. Of 3326 patients evaluated radiographically, 1317 (39.6%) received a diagnosis of osteoarthritis on the operated and 215 (6.46%) on the contralateral knee. Finally, we observed a higher incidence of osteoarthritis in children undergoing open total meniscectomy,[10,12] compared with adult patients undergoing arthroscopic partial meniscectomy[20,26–30]. Concerning partial arthroscopic procedures, there was a lower incidence of osteoarthritis following medial[26,29,30] than lateral meniscectomy.[23,24]

Predictive factors for the development of knee osteoarthritis (Table 6).

- Eight studies found positive association between lateral[3,4,18,20,25] and medial meniscectomy[3,20,25,31] and knee osteoarthritis, demonstrating strong evidence of association.
- Four studies[3,16,26,27] reported a positive association and seven studies[10,24,25,29–31,33] found no association between increasing age at

Table 6 Results of evidence synthesis.

Factors that mirror directly post-operative knee arthropathy	Studies	Association	Evidence (direction)
Medial and lateral meniscectomy	Allen *et al*. (1984), Benedetto and Rangger (1993), Hede *et al*. (1992), Higuchi *et al*. (2000), Jorgensen *et al*. (1987), Fauno and Nielsen (1992)	*Positive*	Strong (positive)
Age at surgery	Abdon *et al*. (1990), Allen *et al*. (1984), Chatain *et al*. (2001), Chatain *et al*. (2003), Higuchi *et al*. (2000), Hulet *et al*. (2001), Kruger-Franke *et al*. (1999), McNicholas *et al*. (2000), Medlar *et al*. (1980), Scheller *et al*. (2001), Fauno and Nielsen (1992)	*Positive*: Allen *et al*. (1984), Chatain *et al*. (2001), Chatain *et al*. (2003), McNicholas *et al*. (2000); *No*: Abdon *et al*. (1990), Higuchi *et al*. (2000), Hulet *et al*. (2001), Kruger-Franke *et al*. (1999), Medlar *et al*. (1980), Scheller *et al*. (2001), Fauno and Nielsen (1992)	Inconsistent
Extent of meniscectomy	Andersson Molina *et al*. (2002), Bolano and Grana (1993), Bonneux and Vandekerckhove (2002), Englund *et al*. (2001), Englund and Lohmander (2004), Rockborn and Gillquist (1995)	*Positive*: Andersson Molina *et al*. (2002), Bolano and Grana (1993), Bonneux and Vandekerckhove (2002), Englund *et al*. (2001), Englund and Lohmander (2004), Rockborn and Gillquist (1995)	Consistent
Sex	Allen *et al*. (1984), Burks *et al*. (1997), Chatain *et al*. (2001), Englund and Lohmander (2004), Hulet *et al*. (2001), Kruger-Franke *et al*. (1999), McNicholas *et al*. (2000), Medlar (1980), Fauno and Nielsen (1992)	*Positive for females*: Burks *et al*. (1997), Englund and Lohmander (2004), Hulet *et al*. (2001), Kruger-Franke *et al*. (1999), McNicholas *et al*. (2000); *No*: Allen *et al*. (1984), Chatain *et al*. (2001), Medlar (1980), Fauno and Nielsen (1992)	Inconsistent
Duration of follow-up	Abdon *et al*. (1990), Allen *et al*. (1984), Dai *et al*. (1997), Jackson (1968), Scheller *et al*. (2001)	*Positive*: Dai *et al*. (1997), Jackson (1968), Scheller *et al*. (2001); *No*: Abdon *et al*. (1990), Allen *et al*. (1984)	Inconsistent
Duration of pre-operative symptoms	Allen *et al*. (1984), Jackson (1968), Scheller *et al*. (2001)	*Positive*: Allen *et al*. (1984), Jackson (1968), Scheller *et al*. (2001)	Strong (positive)
Cartilage status	Chatain *et al.* (2003), Englund and Lohmander (2004), Higuchi *et al*. (2000), Hulet *et al*. (2001), Fauno and Nielsen (1992)	*Positive*: Chatain *et al.* (2003), Englund and Lohmander (2004); *No*: Higuchi *et al*. (2000), Hulet *et al*. (2001), Fauno and Nielsen (1992)	Inconsistent

Continued

Table 6 *Continued*

Factors that mirror directly post-operative knee arthropathy	Studies	Association	Evidence (direction)
BMI index (obesity)	Englund and Lohmander (2004), Hede *et al*. (1992), Scheller *et al*. (2001)	*Positive*: Englund and Lohmander (2004), Hede *et al*. (1992); *No*: Scheller *et al*. (2001)	Inconsistent
Functional results and objective symptoms	Andersson Molina *et al*. (2002), Hulet *et al*. (2001), Jaureguito *et al*. (1995), Johnson *et al*. (1974), Roos *et al*. (2001), Tapper and Hoover (1969)	*No*: Andersson Molina *et al*. (2002), Hulet *et al*. (2001), Jaureguito *et al*. (1995); *Positive*: Johnson *et al*. (1974), Roos *et al*. (2001), Tapper and Hoover (1969)	Inconsistent

surgery and development of knee arthrosis. Therefore, the evidence of association between the two variables was inconsistent.

- In seven studies,[1,9,15,22,25,28,34] the amount of meniscus removed was strongly associated with post-operative osteoarthritic changes. Comparing the different meniscectomy techniques, partial meniscectomy leads to significant higher good outcomes than subtotal and total meniscectomy.
- With regard to sex, females reported worst outcomes in five studies,[16,29,30,32,34] and no evidence of association was found in four included studies.[3,25,26,33] According to these results, an inconsistent evidence of association was found.
- Since post-operative osteoarthritic changes and duration of follow-up correlated positively in three studies[12,14,24] and did not correlate in two studies,[3,10] the evidence of synthesis was inconsistent.
- According to detection of positive association between duration of symptoms and post-operative osteoarthritis,[3,14,24] we found evidence of positive association between these variables.
- Two studies[27,34] reported a positive association and three studies[25,29,31] found no association between cartilage status at surgery and development of knee osteoarthritis. These variables were inconsistently associated.
- Two studies[1,15] reported higher evidence of knee osteoarthritis following excision of degenerated than traumatic meniscal tears.
- Since two studies[18,34] reported a positive association and one study[24] found no association, the association between high BMI index (obesity) and development of knee osteoarthritis was inconsistent.
- Given the discordant evidence regarding the relationship between functional results and objective symptoms and knee osteoarthritis throsis[2,17,23,28,29,38] the evidence of association was shown to be inconsistent.

Discussion

The main finding of the present study is that the amount of meniscal tissue removed remains the strongest predictor of long-term onset of osteoarthritis. This is a systematic review addressing whether meniscal excision procedures are associated with osteoarthritic changes of the knee or progression of pre-existing degenerative joint disease. A systematic review about partial meniscectomy and arthritis was recently published,[39] but the research strategy used was limited to Pubmed and English language, identifying less than half of the studies that we report.

We performed a comprehensive search, and, although we found a large number of studies, relatively few investigations could be included in the present investigation. In interpreting this review, readers should note that some articles may have escaped our search, and the literature may not provide important findings derived from negative studies. Further, when information is incomplete or vague, data extraction becomes difficult, as frequently occurring in our analysis. Specifically, in almost all the studies there is no adequate description of surgical technique, and the nature of the surgical meniscal procedures has been generally defined 'partial' or 'complete.' In addition, since the criteria evaluating long-term functional results were varied and heterogeneous, estimates of the good and excellent functional and clinical outcomes would be of limited importance. We performed this search with no attempt to describe long-term post-operative functional status, but we focused on aspects that would afford additional evaluable insights regarding osteoarthritis deterioration following meniscal excision. In this effort, we were limited by multiple imaging methods used to assess post-operative knee osteoarthritis. Without greater uniformity or standardization of such methodological issues, it is difficult to understand whether heterogeneity in study findings represent true differences in examined populations or simply artefact-related to measurement bias or other errors. We have attempted to minimize heterogeneity by grouping studies by source of case selection, according to strict inclusion and exclusion criteria. Many studies reporting short-term follow-up in older patients were excluded from the analysis. We report that 39.6% (1317/3326) of all patients undergoing imaging assessment develop osteoarthritis changes after meniscal surgical management. We recognize that this is an imprecise estimate because of potential missed or undiagnosed osteoarthritis, and the problematic assessment of these patients. In addition, these selected studies have reported wide variation in the incidence of post-operative arthrosis because of differences in study designs and patient characteristics, potentially reflecting selection bias towards the inclusion of patients with combined knee

instability,[10,13,18] pre-operative chondromalacia,[29,31] and altered alignment of lower limbs.[3,32] Our review, however, showed consistency in the overall frequency of knee osteoarthritis across the four different types of surgical management, suggesting that the lowest and highest incidence are, respectively, found among patients undergoing arthroscopic partial meniscectomy and open total meniscectomy. Intermediate incidence has been recorded following open partial and arthroscopic total or subtotal meniscectomy. Moreover, the highest percentage of osteoarthritic changes in the knee have been reported in long-term follow-up studies focusing on children.

The large quantity of poor quality studies and the lack of prospective long-term data limited our statistical analysis. Since reported synthesis data did not allow us to perform multivariate analysis, we were not able to calculate statistical associations. However, to define the risk factors responsible for the development of osteoarthritis following meniscectomy, we used the method of best evidence synthesis. We detected heterogeneous findings: amount of meniscus removed, site of lesion (either medial or lateral) and degenerative tears did show evidence of association with post-operative knee osteoarthritis. Age at surgery, sex, type of lesion, pre-operative cartilage status, time from injury to surgery, length of follow-up, BMI and simultaneous ACL deficiency were inconsistently associated with osteoarthritis.

Concerning imaging assessment, we met the same difficulties found in recently published systematic review,[40] since several different classification systems were used in the articles included. To standardize radiographic classification systems and minimize heterogeneity, we used Fairbank's classification, reported in 14 of 32 selected studies. This classification is simple, and allows surgeons to examine radiographs, optimizing the reliability of reported data. As there was no information on the cut-off set to define osteoarthritis, we limited ourselves to summarizing results as reported in each study, regardless of the classification system used. The reader could find a potential limitation depending on low-quality older studies and poor prospective long-term data. Using an extensive and in depth electronic search, we have tried to retrieve and identify all published data. We selected long-term follow-up studies to avoid bias. In fact, comparing long-term vs. short-intermediate follow-up, it becomes apparent that the prevalence of osteoarthritis continues to increase. No additional randomized controlled trials enrolling patients managed conservatively or using innovative meniscal procedures have been found. It seems very unlikely that studies reporting knee osteoarthritis-related data following procedures such as meniscal suture repair will have been published and not identified by our search.

Given these limitations, analytical statistical techniques could not be applied to establish cause–effect relationships, but our synthesis took into account only reported statistically significant associations. Imaging comparison between meniscectomized and control groups, operated and non-operated knees demonstrated whether minimally excised menisci may result or accelerate osteoarthritic changes. The timing of post-operative arthritis onset is of concern, as well as the role of post-operative rehabilitation. No significant correlation between outcome results and CMS was detected. This is in agreement with another review that used the CMS to assess methodological limitations of cartilage repair techniques.[8] Given the great number of retrospectives studies, the CMS did not correlate with the level-of-evidence rating. However, the methodological quality of published studies has improved over years, as demonstrated by positive correlation between the CMS and the year of publication.

Based on published reported data, the amount of removed meniscus is the most important predictor for the development of knee osteoarthritis. Several reasons may explain the finding that a more extensive meniscal resection may result in worse long-term outcomes. First, the resection of meniscal tears increases contact stress on cartilage surfaces, accelerating the development of osteoarthritis. Compared with patients undergoing partial resection, the patients with larger resections present at index surgery with more extensive meniscal degeneration and advanced cartilage degenerative changes. As longer-term follow-up study reported on patients undergoing subtotal or total open meniscectomy, it is difficult to establish whether increased rates of osteoarthritis are secondary to long-term degeneration or amount of meniscal tissue removed.

In conclusion, minimally invasive procedures seem to reduce the incidence of long-term osteoarthritic changes of the knee compared with more invasive open and or arthroscopic procedures.

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