Are Outcomes of Acute Meniscus Root Tear Repair Better Than Debridement or Nonoperative Management?

CME

A Systematic Review

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Background: Meniscus root tears (MRTs) are defined as radial tears within 1 cm of the meniscus root insertion or an avulsion of the meniscus root itself. They lead to altered joint loading because of the failure to convert axial (compressive) loads into hoop stresses. Untreated MRTs can result in altered joint biomechanics and accelerated articular cartilage degeneration and the development of osteoarthritis (OA), yet optimal management remains unclear.

Purpose: To review treatment outcomes after acute MRTs by surgical repair, debridement, meniscectomy, or nonoperative treatment.

Design: Systematic review; Level of evidence, 4.

Methods: A systematic review of the evidence from human clinical studies was conducted with electronic searches of the PUBMED, Medline, EMBASE, and the Cochrane Library databases. One reviewer extracted the data and 2 reviewers assessed the risk of bias and performed synthesis of the evidence.

Results: Eleven studies of low to moderate methodological quality were identified. All treatment options improved functional scores after >12 months. Arthroscopic repair may be associated with better functional outcomes when compared with partial meniscectomy and nonoperative management at 12-month follow-up. Radiographic progression of OA occurred in all treatment groups; there was some evidence that this was delayed after repair when compared with other treatments. Baseline severity of meniscal extrusion, varus malalignment, and pretreatment degeneration were predictors of poor functional outcomes. Age was not found to be an independent predictor of functional outcome.

Conclusion: The current level 3 and 4 evidence suggests that arthroscopic repair may result in slower progression of radiological deterioration compared with meniscectomy and nonoperative management. The current literature does not support the exclusion of patients from MRT repair on the basis of age. Patients undergoing acute MRT treatments (repair, debridement, or nonoperative) can be expected to experience improvement in functional outcomes after >12 months. The strength of conclusions are limited because of the paucity of high-quality studies on this subject. Further studies, preferably randomized sham controlled trials with function-oriented rehabilitation programs, are needed to compare treatment strategies and stratification of care based on the risk of meniscal extrusion.

Registration: CRD42018085092 (PROSPERO).

Keywords: knee; meniscus; rehabilitation; meniscus root tear

The menisci play an important role in normal biomechanics of the knee. Meniscal functions include load transmission, joint stability, and tibiofemoral congruency.[17] These actions are facilitated by "hoop stresses," contingent on circumferentially orientated collagen fibers and meniscus root attachment.[34]

Meniscus root tears (MRTs) are defined as radial tears within 1 cm of the meniscus root insertion[23,28] or an avulsion of the meniscus root itself. MRTs can be acute (excessive force on a normal meniscus) or degenerative (repetitive force on

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a worn meniscus) and can be associated with concomitant bony or ligamentous injuries.[25,35] However, there is no established consensus on the definition of "acute" injury in the literature, and these definitions exist on a continuum.

MRTs lead to altered joint loading because of the failure to convert axial (compressive) loads into hoop stresses. Biomechanically, posterior medial MRTs have been shown to "increase contact pressures and decrease contact areas of the medial compartment, similar to total medial meniscectomy."[3,16] Furthermore, meniscal extrusion (ME) from the joint space can lead to degeneration. Untreated MRTs have been reported to result in altered joint biomechanics and accelerated articular cartilage degeneration and the development of osteoarthritis (OA).[28] The current literature defines 3 groups according to the time after painful deterioration: the early period/acute injury (<1 month), subacute period (1-3 months), and chronic period (4-12 months).[18]

Optimal management remains unclear. Varied outcomes of treatment have been reported after operative repair,[19,29] nonoperative management, and debridement.[8,11] Reported outcomes after repair of acute MRTs are generally good.[2,27] However, some studies report incomplete or failed healing, ME, or progression of OA.[1] A recent systematic review and meta-analysis by Faucett et al[15] found that meniscal repair may be more cost-effective compared with meniscectomy and nonoperative management and may result in delayed progression to OA and total knee replacement. This review included studies recruiting a significant proportion of individuals managed "nonoperatively" with a moderate or advanced radiographic OA (Kellgren-Lawrence [K-L] $\geq$ grade 2) at the baseline and thus was not included in our series.

This systematic review aims to evaluate the reported outcomes of treatments for acute MRTs in the current literature comparing surgical repair against debridement/meniscectomy or nonoperative management. See Table 1 for a list of all abbreviations used in this article.

METHODS

Literature Search

For the purpose of this review, studies comparing primary operative repair versus arthroscopic debridement/partial meniscectomy (PM), or nonoperative management in populations with or without mild knee OA, and with an acute or subacute MRT were assessed. A systematic electronic literature search was performed on the PUBMED, Medline, EMBASE, and the Cochrane Library databases for all published and unpublished studies up until the first week of November 2019. This search identified studies on the outcome of operative or nonoperative management of meniscus root injury. The search methodology is presented in the Appendix (available in the online version of this article).

A total of 585 studies were identified from the initial search. A single reviewer (K.C.E.) screened all articles for relevance by title and abstract according to the inclusion and exclusion criteria (Table 2). The full-text article was assessed if no abstract was available. A total of 438 papers were excluded after manual review of their study titles for relevance. Also, 104 further papers were excluded after detailed abstract review. Of the remaining 43 studies, 32 were excluded after full-text review, and 11 studies were included for the systematic review.

Data Extraction

Each study that met the inclusion criteria was abstracted and the following data were collected:

- Authorship/ publication year
- Methodology
- Patient characteristics
- Surgical technique
- Radiographic finding (K-L grade, joint space narrowing)
- Magnetic resonance imaging (MRI), ME, and healing
- Arthroscopic findings (Outerbridge classification)
- Outcome scores (patient-reported outcome measures functional scores/failure rates)
- Length of follow-up

Given the heterogeneity of patient selection, outcome measures, and variety of nonoperative protocols between studies, a meta-analysis was not performed.

Quality Assessment

The methodologic quality of the included studies was analyzed using the Coleman Methodology Score and is presented in Appendix Table A1 (available online).[13] This score assessed study methodology using 10 specific quantitative and qualitative criteria, producing a score out of 100.

RESULTS

The literature search yielded 147 potentially relevant articles and studies. After the application of exclusion

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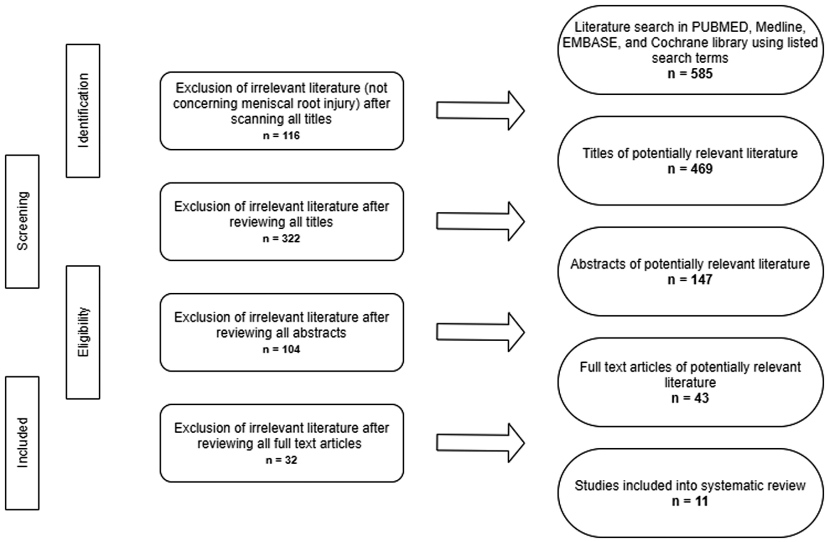

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram details the search and selection process applied during our systematic literature search and critical review.

criteria and removal of duplicate articles, 11 papers[¶] were selected for the final review. Five were level 3,[1,6,12,22,24] and 6 were level 4 evidence[9,19,21,23,31,33] (Figure 1 and Table 3). A total of 504 patients were included; 157 patients were managed nonoperatively, 176 with an arthroscopic PM, and 171 with a meniscus root repair (158 patients by "pull-out" repair and 13 by "all-inside" repair). The mean modified Coleman Methodology Score[13] for all studies was 44.4 (range, 34-49 scores) out of 100.

Randomization was not included in the methodology of any studies reviewed and only 2 articles included blinding in their methodology.[6,12] Ten of 11 studies used functional outcome scores, 2 the Lysholm score alone,[19,33] 3 the Lysholm and the International Knee Documentation Committee (IKDC) score,[1,12,22] 2 the Lysholm and Tegner scores,[21,31] one used the Lysholm and Hospital for Special Surgery knee scores (HSS),[9] and another 2 used the IKDC and Tegner scores.[6,23]

Change in Lysholm Score Measurement Over Time and Technique of MRT Management

All treatment options were found to significantly improve functional scores after 12 months' follow-up (Figure 2). Two studies showed a better functional improvement from repair compared with meniscectomy[6,12]; however, baseline functional scores were lower in the nonrepair group in 1 study,[12] while patient allocation across the nonoperative, repair, and meniscectomy cohorts was blinded in another study.[6] One rehabilitation (nonoperative)-based study showed results comparable with meniscal repair by 12-month follow-up.[31]

Two studies[19,33] reported outcomes after meniscectomy, 2 reported outcomes after nonoperative management,[23,31] and 2 were retrospective noncomparative series after a surgical repair.[9,21] Five papers compared meniscal repair with "nonrepair" treatment (2 compared repair vs PM [mean follow up, 49 and 60 months],[12,22] 2 compared repair vs nonoperative management [mean follow-up, 18 and 3 months],[1,24] and 1 compared repair vs PM vs nonoperative [mean follow-up, 74 months]).[6] Of the 7 studies that included a surgical repair group, 6 used the "transtibial pull-out" method,[1,6,9,12,22,24] and 1 used an "all-inside suture anchor" method[21] (Table 3).

TABLE 1
List of Abbreviations

BMI: body mass index
HSS: Hospital for Special Surgery knee score
IKDC: International Knee Documentation Committee score
JSN: joint space narrowing
K-L: Kellgren-Lawrence
MRI: magnetic resonance imaging
MFC: medial femoral condyle
ME: meniscal extrusion
MRT: meniscal root tear
OA: osteoarthritis
PM: partial meniscectomy
TAS: Tegner score
VAS: visual analog score

The management protocol was not consistent across the studies. One study[24] treated all patients nonoperatively for 3 months. Those failing nonoperative management were then treated with an operative repair. These "crossover" patients were included in the operative repair group; however, because these patients previously had failed a trial of nonoperative management, they were not directly comparable with those who underwent operative repair immediately.[1]

All 5 comparative studies were single-center, single-surgeon series[1,6,12,22,24] using the Lysholm or the IKDC

[¶]References 1, 6, 9, 12, 19, 21-24, 31, 33.

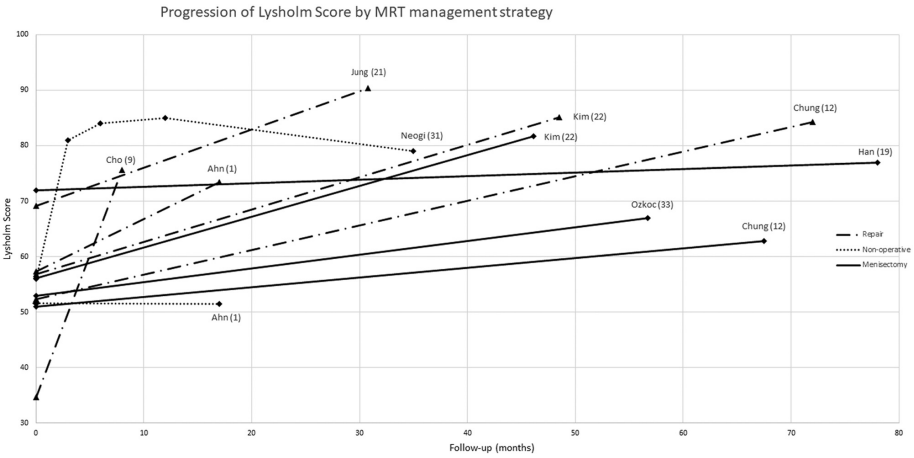

Figure 2. The effect of meniscus root tear management strategy (repair, hashed line; meniscectomy, plain line; and nonoperative, dotted line) on the progression of the Lysholm score, showing a mean score over time for each trial.

TABLE 2
Selection Criteria for Systematic Literature Review[a]

Inclusion Criteria	Exclusion Criteria
- Studies primarily investigating the outcome of operative or nonoperative management of MRT - Acute and subacute MRT (<3/52) - Confirmed diagnosis on imaging and/or intraoperatively - >10 participants - English text - Follow-up >12 months - At least 1 primary outcome measures reported both pre- and postoperatively - No date restrictions	- Animal, cadaveric, or in vitro studies - Review articles - Expert opinion, case reports, and technical notes - Studies on only degenerative MRT - K-L grade 3-4 (moderate/severe) OA or cartilage degeneration Outerbridge Class[39] > 2 at time of injury - Recent knee operation or injection - Concomitant ligamentous tear or other meniscal injury - Results of operative and nonoperative management reported separately

[a]K-L, Kellgren-Lawrence; MRT, meniscus root tear; OA, osteoarthritis.

scoring scale[7] (Appendix Table A3, available online). Ahn et al[1] further subdivided the repair group according to the varus angulation and the Outerbridge classification. This subgroup analysis reported a worse Lysholm score after a pull-out repair with a severe varus malalignment (mechanical axis >5°) when compared with nonoperative management. This supports existing work suggesting that a high grade of knee OA and varus alignment appear to be among the most predictive variables for meniscal repair failure.[12] The other 6 papers in the series studied a single intervention. Two studies on arthroscopic repair[9,21] reported an improvement in the Lysholm score by 118% and 31%, respectively, at 7 and 30 months, respectively. Two retrospective series reported outcomes after PM; and at 56.7- (4 years and 9 months) and 77-month (6 years and 4 months) follow-up, they reported an improvement in the Lysholm score from 26% to 7% respectively.[19,33]

Krych et al[23] retrospectively reviewed 41 patients who had undergone nonoperative management. The nonoperative protocol was not standardized and included knee cortisone injections, the use of an unloader knee brace, formal physical therapy, use of a gait aid (cane or crutch), and orthotic use. There was no evidence that this was in line with the best practice in all cases (only 52% of patients received physical therapy). Neogi et al[31] reported a standardized nonoperative protocol of a short course of analgesia and a 3-month supervised exercise program, followed by a home-based exercise regimen. A 50% mean improvement in the Lysholm score at 35-month follow-up was reported and an interesting sequential analysis of the temporal changes of the Lysholm knee score, the Tegner score, and the visual analog scale (VAS) pain score over time was performed (Appendix 3, available online). Their series (N = 37) showed a maximal improvement in the Lysholm score, the Tegner score, and the VAS score at 6 months before a functional decline. However, scores at the final follow-up remained significantly better than the pretherapy scores.[31]

Ahn et al[1] and Kwak et al[24] compared the nonoperative management of MRTs versus pull-out repair. Ahn et al[1] treated 25 patients with pull-out repair, and patients who either refused the repair procedure or had complex MRTs were treated nonoperatively. Conversely, Kwak et al initially trialed nonoperative management on 88 patients. This entailed activity modification that prohibited patients from

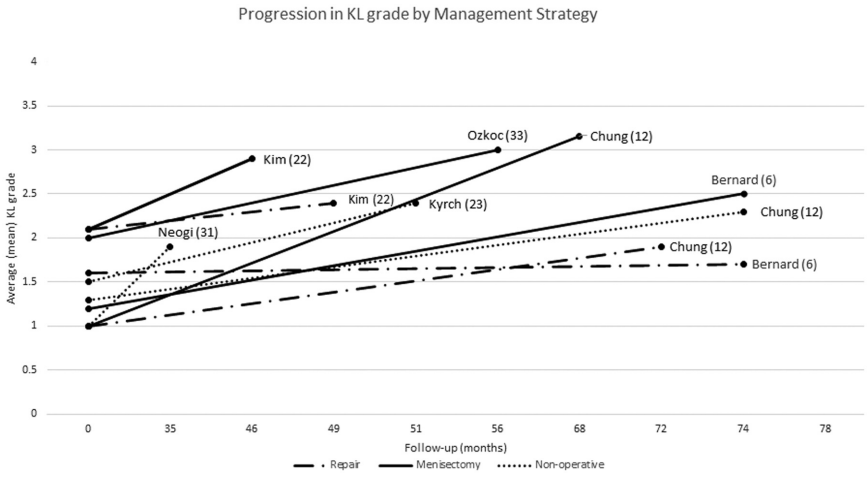

Figure 3. The effect of meniscus root tear management strategy (repair, hashed line; meniscectomy, plain line; and nonoperative, dotted line) on the progression of the Kellgren-Lawrence (KL) grade, showing a mean score over time for each trial.

squatting or going up the stairs, but allowed ice pack application, prescription of anti-inflammatory or analgesic medications, and weight control. Patients underwent surgical repair if they had persistent pain and/or functional impairment after 3 months of a nonoperative management trial.

Of the 5 comparative studies (Appendix Table A3, available online), 4 reported functional outcomes.[1,6,12,22] One study[1] reported a significant functional improvement with repair compared with nonoperative management, 1 showed no significant difference in the functional outcome score between PM and repair,[22] and 1 of the 4 studies showed better functional improvement from repair compared with PM by the final follow up.[12] The findings of the nonoperative arm in the study by Ahn et al[1] contrasted significantly with the nonoperative arm in the paper by Neogi et al,[31] with a greater increase in the Lysholm score seen after nonoperative management in the paper by Neogi et al than in the comparative review by Ahn et al.[1] The only study to compare repair, nonoperative management, and meniscectomy did not find a significant difference in the functional outcome among those patients who did not progress to arthroplasty and were excluded from further functional scoring, but it showed a significant association between meniscectomy and progression to arthroplasty when compared with both nonoperative management and meniscal repair (PM: 60%; nonoperative: 27%; meniscal repair: 0%).[6]

Radiological Analysis

Eight studies reported radiological outcomes (Figure 3).[6,12,19,21-23,31,33] All studies showed some degree of radiographic progression by the final follow-up, regardless of treatment type. Both of the comparative studies that reported radiological progression showed a faster rate of degeneration after meniscectomy and nonoperative management compared with repair.[6,12]

Two case series reported K-L scoring after PM[19,33] and 2 reported outcomes after nonoperative management.[23,31] Chung et al[12] compared the K-L score after meniscectomy against pull-out repair. They reported a more rapid OA progression (K-L score: 1 at baseline to 3.15 by the final follow-up) in the PM group compared with K-L score change (from 1 to 1.19) in the pull-out repair group.

Krych et al[23] and Neogi et al[31] reported a 0.9 and 1 point worsening in the K-L score at 62- and 35-month follow-up, respectively (after nonoperative management), while Ozkoc et al[33] reported a 1-point worsening in the K-L score after 57- and 77-month follow-up (after PM).

Han et al[19] reported a 35% progression of radiographic OA from the K-L grades 1 to 2 to grades 3 to 4 at 77-month follow up. They specified a tailored radiographic examination for their study, as follows:

1. standing posteroanterior view with 45° of knee flexion
2. standing anteroposterior and lateral views
3. skyline Merchant view (superoinferior projection of patella)

No other paper specified the method of radiographic examination. It is possible that such a tailored protocol for radiographic investigation would be more sensitive at identifying degenerative change. Failure to specify the radiological protocol in the other studies could affect reproducibility and be a significant source of bias in nonblinded studies.

Han et al[19] did not outline the mean progression of the K-L score in the group but retrospectively compared characteristics of those whose K-L score worsened by the final follow-up. When adjusting for age, sex, and body mass index (BMI), the severity of OA (K-L score $\geq$2) was the largest predictor of rate of radiological OA progression. There was also a significant negative correlation between the K-L score at time of surgery (PM) and the Lysholm score at the final follow-up.

The 2 series on nonoperative management showed the K-L change from 1.5 to 2.4 and 1 to 1.8 by the final follow-up (62- and 35-month, respectively).[23,31]

Chung et al[12] (Table 3) reported outcomes for patients with a mean age of 55 years who underwent posterior medial root meniscectomy versus root repair. They report

TABLE 3
Studies/Articles Accepted for Literature Review[a]

Authorship (Year)	Study Type (Level of Evidence)	Mean Age, y	Summary	No. of patients	Length of follow up, mo
Ahn et al[1] (2015)	Retrospective comparative (3)	Repair: 55.5 Nonop: 62	Pull-out repair (R) vs nonop (C)	R: 25 C: 13	R: 17.4 C: 18.4
Kwak et al[24] (2018)	Retrospective comparative (3)	R: 60 C: 60	Pull-out repair vs nonop	R: 31 C: 57	NR NR
Kim et al[22] (2011)	Retrospective comparative (3)	R: 55.2 C: 57.4	Pull-out repair vs PM	R: 30 M: 28	R: 48.5 M: 46
Chung et al[12] (2015)	Retrospective comparative (3)	R: 55.5 M: 55	Pull-out repair vs PM	R: 37 M: 20	60
Jung et al[21] (2012)	Retrospective case series (4)	53.2	All-inside suture repair	13	30.8
Cho and Song[9] (2014)	Retrospective case series (4)	50.3	Pull-out repair	20	7.1
Krych et al[23] (2017)	Retrospective case series (4)	58	Nonop management	52	62
Neogi et al[31] (2013)	Retrospective case series (4)	55.8	Nonop management	20	35
Ozkoc et al[33] (2008)	Retrospective case series (4)	NR	PM	67	56.7
Han et al[19] (2010)	Retrospective case series (4)	59	PM	46	77
Bernard et al[6] (2020)	Retrospective comparative (3)	R: 46.1 C: 47.3 M: 48.4	R vs PM vs C	R: 15 C: 15 M: 15	R: 40 C: 53 M: 58

[a]C, conservative (nonoperative) management; M, meniscectomy; NR, not reported; PM, partial meniscectomy; R, pull-out repair.

a 32-point improvement in the Lysholm score after repair, versus a 12-point improvement after PM. Our review found no evidence supporting management strategy being dictated by age alone.

In the only comparative study to include meniscectomy, repair, and nonoperative management, the meniscus root repair group had significantly less arthritic progression, as measured by change in the K-L grade from pre- to postoperatively (nonoperative, 1; PM, 1.3; meniscal repair, 0.1; $P = .01$), despite a higher grade of baseline K-L grading in the repair cohort.[6]

The Effect of Other Variables on Outcomes

Sex. Two papers in this review correlated sex with functional or radiographic outcomes.[1,23] Ahn et al[1] found no association between sex and functional outcome, while Krych et al[23] reported an association between female sex and more frequent progression to joint arthroplasty at longer follow-up.

Body Mass Index. Three papers explored the association between BMI and outcomes after MRT. Two papers[9,34] found no statistically significant relationship between BMI and functional outcome. One study[31] suggested an association between poor outcomes and BMI (Appendix Table A5).

MRI Analysis (Meniscal Extrusion and Healing Rates). Preintervention MRI findings were reported in 5 studies[6,9,12,24,33]; and preintervention and final follow-up MRI findings were reported in a further 4 studies.[1,21-23]

Ahn et al[1] reported that 36% of patients treated with arthroscopic repair had a modified Outerbridge grade 3 or 4 damage, compared with 69% in the meniscectomy group. The repair group reported superior functional outcomes (Appendix A3), but there was no control analysis to determine whether this was because of differences in preinjury degeneration.

Kwak et al[24] reported on 88 patients (Table 3). ME was calculated as a ratio of the amount of extrusion to the size of the medial femoral condyle (ME/MFC) based on a nonstanding MRI investigation. Those with a "poor" response to the trial of nonoperative therapy were found to have significantly greater ME (0.1 vs 0.09; $P < .01$) compared with those with a "good" response. This study found the ME/MFC ratio and the ME/medial tibial plateau diameter ratio to be major predictors of poor response to nonoperative management. This study suggested an ME/MFC ratio of 0.08 as a possible threshold for operative management.

Kim et al[22] reported MRI findings in a review of 30 patients after repair. They reported 56% "complete" meniscal healing, 36.7% "partial" healing, and a 6.7% retear rate at 49 months and found that ME had decreased in 87% of patients (mean, 3.13 mm-2.94 mm). MRI follow-up was not performed on the nonoperative group in the same study; thus, direct comparison of ME was not possible. Second-look knee arthroscopy was performed on 14 of these 30 patients based on the following criteria: 1) patients who were not satisfied with the results, and 2) patients who needed removal of a screw and a plate after a high tibial

osteotomy. The authors reported a "good correlation" between postoperative MRI assessments of meniscal repair with intraoperative assessment of repair quality but gave no quantitative substantiation of this.

Jung et al[21] performed postoperative MRI on 10 patients (of 13) after suture anchor repair. Five (50%) patients showed complete healing–2 of these 5 patients showed complete healing with isointense signal of a normal meniscus; and 3 showed intermediate signal tissue at the previous tear site without any high signal cleft or ghost sign; 4 (40%) patients showed partial healing; and 1 (10%) showed no healing.

Krych et al[23] reported a rate of "significant ME" (>3 mm from the superomedial edge of the tibial plateau) in 79% of their cohort at baseline (52 MRTs with nonoperative management). This series reported a "failure" rate of 87% of nonoperative management (defined as progression to arthroplasty or a severely abnormal IKDC score), with 31% of patients undergoing subsequent total knee arthroplasty after medial meniscus posterior root tears at 30 ± 35 months (range, 3-119 months) after diagnosis.

When assessing variables other than the primary outcome measures in such studies, there are challenges of insufficient sample size and statistical power that should be considered. While insufficiently described in the papers included in our study, the lack of statistical power in the analysis of secondary outcome measures is a potential source of bias.

DISCUSSION

The Lysholm knee scoring scale and the IKDC, HSS, and VAS pain scores have been validated to measure function in patients with a variety of knee injuries, including acute anterior cruciate ligament (ACL) and meniscal injuries.[30,37] The IKDC score is highly correlated with the VAS pain and Lysholm scores. After acute meniscal injury, the IKDC shows large effect sizes in patients at 1 year.[30] Its minimum clinically important difference has been reported to be 11.5 at 6 months and 20.5 at 28 months in those undergoing treatment for acute meniscal injury.[20]

The Lysholm score was originally intended for in-person clinician administration, in contrast to the IKDC score, which was not intended as an interview tool, but to be patient administered. Clinician administration introduces the possibility of selection bias. Its minimal detectable change has been reported as between 8.9 and 10.1, with a standard error of the measure reported to range from 3.2 to 3.6 for acute knee injuries.

The functional outcome after nonoperative management for MRT differed significantly between studies by Ahn et al[1] and Neogi et al.[31] We suggest a number of possible reasons for this. The latter study included a well-defined and detailed supervised and then home-based rehabilitation protocol, whereas the protocol in the study by Ahn et al[1] was nonspecific. This more "active" form of nonoperative management highlights the fact that the description of nonoperative management as "conservative" may underestimate the benefits and the role of structured physical therapy and rehabilitation in acute meniscal injury. Inclusion of detailed rehabilitation protocols would allow findings to be tested and reproduced in another settings. The principle findings from the Ahn et al[1] study were that (1) clinical results were superior in the repair group compared with the nonoperative group and that (2) severe varus alignment and severe pretreatment cartilage degeneration were predictive of poor outcomes. Han et al[19] reported a significant association between chondral wear identified on arthroscopy and poor clinical outcome after PM for MRT.

The comparative studies in this series suggested a positive association between repair and better functional outcome. However, the results did not allow definitive conclusions to be made regarding arthroscopic repair compared with meniscectomy.[8,12] One study[8] did show a statistically significant association, while 2 others[6,12] did not. The lack of randomization in all the studies in this review makes it difficult to exclude selection bias. The latter is supported by reported differences in terms of baseline Lysholm score between treatment arms reported in 1 of the studies[1] (Figure 2; Appendix Table A3, available online). In 1 study,[24] participants who had already failed nonoperative management were included in the surgical group and are not directly comparable with those who underwent immediate surgical management. Two retrospective series reported a significant functional improvement after meniscectomy followed by a slight deterioration. However, the Lysholm score remained above the baseline score in both studies by the final the follow-up.[19,33] All 4 retrospective reviews of nonrepair strategies (2 meniscectomy and 2 nonoperative management) were associated with a worsening of the K-L grade from presentation to final follow-up.[19,23,31,33] The 6 papers reporting radiographic degeneration highlighted the evidence of less severe radiographic degeneration after repair[6,12,21] compared with after meniscectomy[33] and nonoperative management (53% vs 67% vs 71%)[23,31] (Appendix Table A4, available online). This supports recent work showing a higher rate of conversion to arthroplasty after meniscectomy when compared with nonoperative management or repair.[15] All methods of management across the studies in our review showed progression of the K-L score from initial injury to final review, regardless of the method of management.

None of the studies discussed the reproducibility of the K-L scoring system as a method of reliably measuring knee OA radiographically. The multicenter anterior cruciate revision study group (MARS) conducted a multicenter, prospective longitudinal cohort of revision ACL reconstruction and reported a correlation coefficient of 0.38 (95% CI, 0.33-0.45), concluding moderate interobserver reliability for radiological classification of tibiofemoral arthritis of the knee. Other similar studies have shown a wide range of interobserver reliability (moderate to good, 0.51-0.89), with the level of interobserver reliability shown to be most significant for the K-L grade 1 compared with other K-L grades.[40]

There is a lack of high-quality level 1 and 2 evidence (randomized controlled or prospective trials) investigating outcomes after MRTs. Studies in our review lacked standardized treatment methodology, limiting meaningful comparisons, and this represents a significant limitation

of the review. While all the studies included reported the mean age of their study cohort, only 1 study[26] assessed it as a potential primary predictor of outcome. However, this study was excluded from the main review because of the existence of concomitant ligamentous injury in the cohort as per selection criteria (Table 2). None of the other studies identified age as a predictor of functional outcome.

The effect of the surgical technique/method on the functional outcome was poorly investigated. Surgeons in all 5 comparative studies[1,6,12,22,24] in Table 3 used the tibial pull-out method, while 1 retrospective series reviewed the all-inside suture anchor method.[21] While the methodology of studies assessing functional outcomes after nonoperative management needs refinement to allow robust comparison with repair, the evidence seems to suggest better functional outcomes and slower rates of degeneration after repair compared with PM and nonoperative management.

None of the studies included detailed the protocol of MRI performed. However, the standard protocol in the United Kingdom and the United States involves supine (nonloaded) MRI. The importance of ME has been reported in other studies outside the scope of this review.[10,14] Studies have suggested that ME is significantly greater on loaded MRI scans compared with the nonloaded, especially in those patients[36] with K-L scores <2. Dynamic ultrasound scanning has also been shown to have good ME measurement and intra- and interrater reliability in both supine and standing positions and may play a role in the more cost-effective identification of ME and a useful prognostic factor in MRT.[32,38] Certain MRI parameters show promise as predictors of the failure of nonoperative management; specifically, medial ME as a ratio of MFC or medial tibial plateau. The possibility of an ME/MFC ratio of 0.08 as a threshold for nonoperative versus operative management is a potential area for further work.

CONCLUSION

This review highlights the lack of good quality studies on this topic. The current level 3 and 4 evidence suggests that arthroscopic repair might result in slower progression of radiological degeneration compared with meniscectomy and nonoperative management. The lack of randomization in all the studies considered in this review means that selection bias is a significant weakness and limits conclusions that can be drawn. The current literature does not support the exclusion of patients from MRT repair on the basis of age.

Variability of reported outcomes for nonoperative studies suggests that reliable indicators for the likely failure of nonoperative management have not yet been established. Rates of complete healing of the repaired root and the importance of ME are yet to be well-defined. Differences in the length of follow-up in both the surgical and the nonoperative cohorts in the studies of this review mean that definitive comparisons of the efficacy of surgical versus nonsurgical management cannot yet be made. The retrospective nature of the studies on nonoperative management[23,31] meant that the nonoperative protocol was not standardized. It is essential that rehabilitation has clear objectives and milestones for pass/fail criteria to be established and to facilitate reliability and reproducibility. This was not found in the majority of the studies considered, and thus we find it difficult to robustly comment on the efficacy of meniscus root repair when compared with nonoperative management overall.

The theoretical aim of MRT refixation is to prevent the development of arthritis by restoring hoop tension and restoring biomechanical integrity of the meniscus root. However, most K-L grade 3 OA is asymptomatic.[9,15,33] The use of painful radiographic knee OA and progression to total knee arthroplasty was only used in 1 of the studies in our review[6] and would provide a more easily defined endpoint and should be considered for further work.

Randomized controlled trials are challenging, expensive, and time-consuming; however, at this stage, future studies should go in this direction, focusing on age and K-L grade as a determinant of outcomes after repair as well as the significance of surgical technique and the utility of ME as a possible predictor of failure of nonoperative management. Those will provide high-quality, unbiased evidence of treatment efficacy, cost-efficacy, or a favorable risk-to-benefit ratio. Previous experience with meniscal trials suggest a need for randomized sham controlled trials with function-oriented rehabilitation programs,[5] which would facilitate a meta-analysis and allow more definitive conclusions to be drawn.

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