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Clinical factors associated with successful meniscal root repairs: A systematic review☆,☆☆

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ABSTRACT

Purpose: To systematically review the literature to determine what clinical factors influence patient outcomes after meniscal root repairs.
Methods: A systematic review of multiple databases was performed. The inclusion criteria included English language, studies evaluating clinical and/or radiographic factors related to meniscal root repair outcomes, medial or lateral posterior root repairs, and human studies. The exclusion criteria included meniscectomy studies, meniscal body studies, technique descriptions, studies reporting only failure rate of meniscal repairs, multiligament repairs, abstracts, controlled laboratory studies, meta-analyses, and systematic reviews.
Results: Five studies were included for final analysis including four case series and one retrospective cohort study. A total of 178 patients in the five studies underwent posterior meniscal root repair (179 knees total). The mean age was 51.4 years. The mean duration of follow-up was 34.5 months. The mean Moga quality rating for case series studies was 15 points (83.3%) and NOS score for the retrospective comparative study was 8. Body mass index (BMI) was not associated with outcomes in 3/3 studies assessing BMI. Increased age was associated with worse outcome in 1/5 studies and had no association in 4/5 studies. Knee varus >5° was associated with worse outcomes in 3/3 studies.
Conclusions: Risk factors for poor clinical outcomes after posterior meniscal root repair include pre-existing high-grade (Outerbridge grade ≥ 3) chondral lesions and severe varus knee alignment (>5°) for medial root repairs.
Level of evidence: IV, systematic review.

☆ Declaration of interest: None.

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This project did not require the approval of the Biomedical Institutional Review Board of The Ohio State University.

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1. Introduction

Meniscal root tears (MRTs), first described in a 20-year-old football athlete by Pagnani et al., occur as avulsion injuries at the meniscal insertion site [1]. Since that time, several studies have demonstrated that MRTs result in abnormal knee motion and function, resulting in rapid progression to osteoarthritis [2–5]. Because of this debilitating outcome, there has been a shift toward surgical repair of MRTs, in an attempt to restore the meniscus' function [6]. The two most common methods of repair are transtibial pullout repair (TPR) and suture anchor repair (SAR) [7,8].

There have been several studies investigating the superiority of various types of repairs and repair techniques [9–14]. However, the success of a meniscal root repair is dependent not only on the repair itself, but also on clinical factors such as age, sex, body mass index (BMI), smoking status, presence of osteoarthritis, and cartilage lesions. Reports on the prognostic clinical utility of these types of repairs are limited in the literature.

The objective of this study is to systematically review the literature to evaluate what clinical factors lead to favorable patient outcomes after meniscal root repairs and what factors may lead to repair failure or progression of osteoarthritis [6]. We hypothesize that increasing age, increasing BMI, and pre-existing high grade chondral lesions (Outerbridge classification ≥3) will lead to lower patient subjective outcome scores and more rapid progression of osteoarthritis.

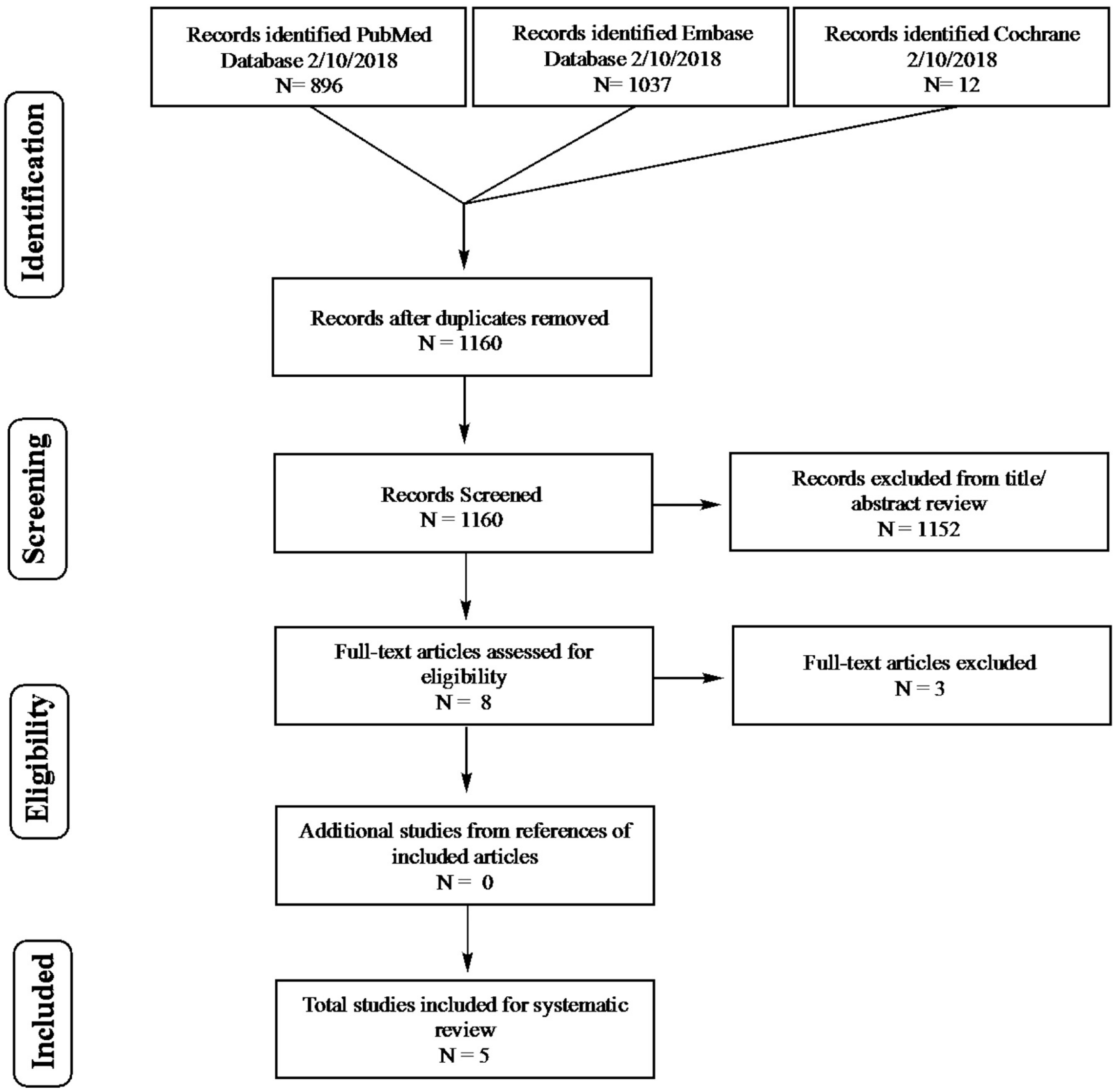

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [15]. Five studies were identified for inclusion.

Table 1
Quality of case series studies assessed by the quality assessment checklist by Moga et al. [17].

Authors (year)	Item number[a]; Item Criteria (0 = No, 1 = Yes; Maximum score of 18)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total	Percent
Chung et al. (2016) [23]	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	15	83.3%
Cho et al. (2014) [24]	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	15	83.3%
Moon et al. (2012) [25]	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	15	83.3%
Ahn et al. (2015) [26]	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	15	83.3%

[a] Item 1: Is the hypothesis/aim/objective of the study clearly stated in the abstract, introduction, or methods section?; Item 2: Are the characteristics of the participants included in the study described?; Item 3: Were the cases collected in more than one centre?; Item 4; Are the eligibility criteria (inclusion and exclusion criteria) to entry the study explicit and appropriate?; Item 5: Were participants recruited consecutively?; Item 6: Did participants enter the study at a similar point in the disease?; Item 7: Was the intervention clearly described in the study?; Item 8: Were additional interventions (co-interventions) clearly reported in the study?; Item 9: Are the outcome measures clearly defined in the introduction or methods section?; Item 10: Were relevant outcomes appropriately measured with objective and/or subjective methods?; Item 11: Were outcomes measured before and after intervention?; Item 12: Were the statistical tests used to assess the relevant outcomes appropriate?; Item 13: Was the length of follow-up reported?; Item 14: Was the loss to follow-up reported?; Item 15: Does the study provide estimates of the random variability in the data analysis of relevant outcomes?; Item 16: Are adverse events reported?; Item 17: Are the conclusions of the study supported by results?; Item 18: Are both competing interest and source of support for the study reported?

2. Methods

We conducted a systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [15]. Literature database searches were performed using PubMed, Embase, and Cochrane Central Register of Controlled Trials on February 10, 2018. The search terms included "(meniscus OR meniscal) AND (root OR horn) AND (repair OR fix OR surgery OR treatment)." All titles and abstracts were manually screened by two independent authors. No limits were placed on the date of publication. The full text of all studies with potential for final inclusion was evaluated for eligibility by two authors. References of included articles were reviewed for additional relevant studies missed by the initial search by the first author.

The inclusion criteria included English language, studies relevant to meniscal root repairs, studies evaluating clinical or radiographic factors related to meniscal root repair outcome, medial and lateral posterior root repairs, and human studies. The exclusion criteria included meniscectomy studies, meniscal body studies, technique descriptions, studies reporting only failure rate of repairs, multiligament repairs, abstracts, controlled laboratory studies, meta-analysis, and systematic reviews.

The quality of all included studies was independently evaluated by two authors (using the Quality Assessment Checklist by Moga et al. [16] (Appendix A) for case-series, and the Newcastle–Ottawa Quality Assessment Scale (NOS) [17] (Appendix B) for cohort studies. Discrepancies between raters were discussed and overcome by consensus.

The following data were collected from each included study: authorship, year of publication, mean age of patients, sex of patients, mean duration of follow-up, methods of initial study including post-operative rehabilitation protocol, results, and conclusions. Continuous variable data were reported as mean ± standard deviation, unless otherwise specified. Categorical variable data were reported as frequencies with percentages. A p-value < .05 was considered to be statistically significant, unless otherwise noted.

3. Results

Eight full text articles qualified for review after initial screening (Figure 1). Three full-text articles were excluded; two studies [18,19] were excluded because they were abstract-only articles and one study was excluded because the authors, Chung et al. [20], published two studies using the same population and reported similar data. The more complete article was selected and included in our study. References from full text articles were reviewed and no additional studies were eligible for our review. A total of five studies were included for final analysis in our systematic review (Figure 1).

The mean quality rating for case series studies was 15 points (83.3%) (Table 1). The most common causes of point deduction were Item 3 (Were the cases collected in more than one center?), Item 6 (Did participants enter the study at a similar point in the disease?), and Item 16 (Are adverse events reported?). All case series studies were done at a single center and therefore all studies received 0 points for Item 3. For Item 6, no studies commented on when the injury occurred and at what point in the disease course the surgery took place.

Table 2
Quality of included studies assessed by the Newcastle-Ottawa Scale (NOS) [18].

Authors (year)	Item number; Item criteria (Selection = maximum 4; Comparability = maximum 2; Outcome = maximum 3)		
	Selection	Comparability	Outcome
LaPrade et al. (2017) [22]	4	1	3

Table 3
Studies evaluating prognostic factors after meniscal root repair.

Authors (Year)	Total Number of Patients	Mean age	Sex	Mean duration of follow-up	Methods	Results
LaPrade et al. (2016) [21]	49 patients (50 knees)	38.3 years (18.2–65.7)	16 female, 33 male	30 months	Patients <50 and ≥50 years of age were analyzed for differences in subjective outcome scores. Medial and lateral repairs were analyzed for differences in subjective outcome scores. *Post-operative rehabilitation protocol*: Non-weightbearing with knee in full extension for 6 weeks; Passive range of motion beginning on postoperative day 1; partial weightbearing beginning week 7 increasing to full weightbearing as tolerated; strengthening exercises at 2 months postoperatively.	Cohort: <50 vs. ≥50 yo – All 3 failures were in patients younger than 50 years of age, though not significant ($p = .541$). – No difference in subjective Lysholm score, WOMAC score, SF-12 PCS, SF-12 MCS, Tegner activity scale, or patient satisfaction with outcome between the two groups. Cohort: medial vs lateral repair – All 3 failures were in patients who had a medial meniscal root repair, though not significant ($p = .544$). – No difference in subjective Lysholm score, WOMAC score, SF-12 PCS, SF-12 MCS, Tegner activity scale, or patient satisfaction with outcome between the two groups.
Chung et al. (2016) [22]	40 patients	55.5 years	36 female, 4 male	71.1 months	Prognostic factors included age, sex, body mass index, degree of varus alignment, K–L grade, medial joint space width, meniscal extrusion, and cartilage status busing the modified Outerbridge classification. Primary outcomes were Lysholm or IKDC scores, and progression of K–L grade. Postoperative outcomes were analyzed for correlations between prognostic factors using Pearson correlation analysis. *Post-operative rehabilitation protocol*: Partial weightbearing for 6 weeks; knee in full extension for first 3 weeks; full weight-bearing and strengthening exercises beginning after 6 weeks; return to sports at 6 months.	– Preoperative modified Outerbridge grade ≥ 3 chondral lesions and preoperative varus alignment were significant factors leading to unfavorable Lysholm scores. – Preoperative modified Outerbridge grade ≥ 3 chondral lesions and older age were significantly related to unfavorable IKDC scores. – Preoperative modified Outerbridge grade ≥ 3 chondral lesions increased the risk of K–L grade progression.
Cho et al. (2014) [23]	13 patients	50.3 years	12 female, 1 male	7.1 months (time between initial surgery and second-look arthroscopy)	Healing status seen on second-look arthroscopy was analyzed for correlations between prognostic factors (age, mechanical alignment (weight bearing line), symptom duration, meniscus subluxation on MRI). *Post-operative rehabilitation protocol*: knee in full extension for 2 weeks postoperatively; non-weightbearing for first 6 weeks; strengthening exercises beginning at 2 weeks; full weightbearing beginning at 8 weeks; return to sport 6 months postoperatively.	Healing status showed no relationship with age, pre-operative symptom duration, mechanical alignment (weight bearing line), nor the degree of medial meniscus subluxation ($p > .05$ for all variables).
Moon et al. (2012) [24]	51 patients	59 years	47 female, 4 male	33 months	Gender, age, BMI, meniscus extrusion, extrusion increase, subchondral edema in medial compartment, degree of varus alignment and cartilage status were analyzed as prognostic factors. Clinical outcomes: a visual analog scale (VAS) for pain and patient satisfaction scores, American Knee Society (AKS) scores, and Lysholm scores, and meniscus extrusion/-articular cartilage status on MRI. *Post-operative rehabilitation protocol*: knee in full extension for 2 weeks postoperatively; partial weightbearing beginning at 2 weeks;	Univariate analysis – Patients with varus alignment of >5° achieved poorer outcomes than those with varus alignment of <5° for VAS patient satisfaction scores and AKS function scores. – Patients with a cartilage status of Outerbridge grade ≥ 3 achieved lower AKS knee, AKS function, and Lysholm scores than grades 1 or 2. – Body mass index, pre-operative meniscus extrusion width, greater extrusion increase, and Outergridge grade ≥ 3 chondral lesions were found to be significantly and positively correlated with increased post-operative meniscus extrusion width.

Table 3 *(continued)*

Authors (Year)	Total Number of Patients	Mean age	Sex	Mean duration of follow-up	Methods	Results
					full weightbearing beginning at 6 weeks; 90° of flexion beginning at 2 weeks and full flexion at 12 weeks.	Multivariate analysis – Varus alignment of >5° was a poor prognostic factor in terms of patient satisfaction, AKS function, and Lysholm scores. – Outerbridge grade ≥ 3 chondral lesions were a poor prognostic factor in terms of AKS function and Lysholm scores. – Pre-operative meniscus extrusion width was correlated with increased post-operative meniscus extrusion width.
Ahn et al. (2015) [25]	25 patients	55.56 years	24 female, 1 male	17.43 months	Age, BMI, and gender, radiologic factors (mechanical axis angle, tibia vara angle, tibial slop angle and Kellgren-Lawrence grade) and MRI factors (medial meniscus extrusion width, subchondral edema, cartilage status in the medial compartment) were evaluated as prognostic factors of the pull-out repair. *Post-operative rehabilitation protocol*: not described.	Univariate analysis – Severe varus knee (>5°), increasing tibia vara angle, and Outerbridge grade ≥ 3 chondral lesions were significantly correlated with lower IKDC, Tegner and Lysholm scores after the PMMR repair. Multivariate analysis – Severe varus knee (> 5°) and Outerbridge grade ≥ 3 remained poor prognostic factors for IKDC, Tegner, and Lysholm scores.

WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; SF-12 PCS, 12-Item Short Form Health Survey Physical Component; SF-12 MCS; 12-Item Short Form Health Survey Mental Component Summary; K–L, Kellgren–Lawrence; IKDC, International Knee Documentation Committee; BMI, body mass index; VAS, visual analog scale; AKS, American Knee Society; PMMR, posterior medial meniscus root.

The quality rating score for the cohort study by LaPrade et al. [21] was 8 points (maximum, 9) (Table 2). The comparability section was only awarded 1 point (maximum, 2) as the study not controlling for additional factors; there was a significant difference in BMI between medial versus lateral meniscal repair groups ($p = .008$).

Study results and findings are reported in Table 3. Four studies [22–25] were case series (level IV evidence) and one study [21] was a retrospective cohort study (level III evidence). Of note, Ahn et al. [25] were considered to be a case series as only part of the study was relevant to this review; the relevant portion was conducted as a case series. A total of 178 patients in the five studies underwent posterior meniscal root repair (179 knees total). One hundred and thirty-five patients were female and 43 were male. The mean age was 51.4 years. The mean duration of follow-up was 34.5 ± 20.0 months.

LaPrade et al. [21] reported that age was not a significant predictor of repair failure or patient subjective outcome scores. In addition, the authors of this study found that the laterality of the repair (medial versus lateral meniscus) was not significantly correlated with repair failure or patient subjective outcomes scores (they had similar outcomes).

Chung et al. [22] found that preoperative modified Outerbridge grade chondral lesions greater than or equal to 3 resulted in statistically significant lower Lysholm and International Knee Documentation Committee (IKDC) scores as well as greater Kellgren–Lawrence (K–L) grade progression. In this study, increasing age was also significantly related to lower IKDC scores.

Cho et al. [23] conducted a second-look arthroscopy in patients undergoing posterior medial meniscus root (PMMR) repair to evaluate healing status (complete healing, lax healing, scar tissue healing, and failed healing). Healing status showed no correlation with age, BMI, pre-operative symptom duration, knee mechanical alignment nor the degree of preoperative medial meniscus subluxation (visualized on magnetic resonance imaging (MRI)) ($p > .05$ for all variables).

Moon et al. [24] examined clinical outcomes associated with posterior medial meniscal root repairs. Patients with varus alignment of >5° had higher pain scores and lower American Knee Society (AKS) scores than those with a knee varus alignment of <5°. Patients with cartilage defects (Outerbridge grade 3 or 4) achieved lower AKS and Lysholm scores than those with grade 1 or 2 lesions. Sex, age, BMI, pre-operative meniscus extrusion, extrusion increase, and subchondral edema were not significantly correlated with clinical outcome. However, pre-operative meniscus extrusion width was correlated with increased post-operative meniscus extrusion width.

Ahn et al. [25] followed 25 patients who underwent PMMR repair. Severe varus knee alignment (>5°) and Outerbridge grade ≥3 cartilage lesions were poor prognostic factors for IKDC, Tegner, and Lysholm scores after multivariate analysis.

4. Discussion

Based on this systematic review of the literature, there are several factors that may affect clinical outcome of PMMR repair. The main finding of this review was that three studies [22,24,25] all found significant correlation between high-grade cartilage lesions (Outerbridge grade ≥ 3) and worse clinical outcomes in patients undergoing PMMR. All three studies defined clinical outcomes using different subjective patient outcome forms (IKDC, Tegner, Lysholm, American Knee Society [AKS]). This association between cartilage degeneration and poor clinical outcomes is not surprising as pre-existing articular cartilage damage, possibly as a consequence of the root tear, can be a potential source of pain, even after the meniscus root is repaired and fixated. The findings in these studies are similar to that seen in a study by Han et al. [26] who noted a significant correlation between chondral wear and worsened clinical outcome after partial meniscectomy for an MRT. The study by Chung et al. [22] included in this review also demonstrated that high grade chondral lesions as a risk factor of K–L grade progression. This finding suggests that higher-grade lesions are more likely to rapidly progress, even after surgical repair of the meniscal root, likely leading to more rapid onset of osteoarthritis.

Severe varus alignment (>5°) was also found to be a significant factor for poor clinical outcomes in three studies [22,24,25]. Of note, in all three studies, the PMMR was repaired. Increased medial compartment pressures as a result of varus alignment could impart increased stress and pressures on the repair in the medial compartment of the knee, which may potentially explain the poor outcome of these patients. Knee malalignment in these patients may be the result of pre-existing osteoarthritis [27] caused by cartilage loss, which by itself is a predictor of poor clinical outcomes after meniscal root repair as described above.

Age was found to be a possible, but not definitive, risk factor for poor clinical outcomes in our review. Four studies [21,23–25] found no significant relationship between increasing age and the outcome of meniscal root repair; only Chung et al. [22] reported a significant correlation. It is important to note that in the Chung et al. study, the average follow-up time was 71.1 months where the mean follow-up period in the other four studies were significantly less (30.0 [21], 7.1 [24], 33.0 [24], 17.4 [25] months). This discrepancy suggests the possibility that age may be a poor predictor of outcome in the long term, rather than the short term. Ultimately, more studies with longer follow-up periods are needed to assess for long-term outcomes and whether age is truly a risk factor for poor outcomes after root repair.

Interestingly, increasing BMI was not found to be a significant predictor of poor outcomes after meniscal root repair in the three studies that evaluated it [22,24,25]. Although it is known that obesity is a significant risk factor for the development of cartilage degeneration and osteoarthritis [28], it is possible that the patients included in these three studies had BMIs that were not significantly high enough for the development of knee degeneration. In both Chung et al.'s [22] and Ahn et al.'s [25] study, the mean BMI of the patients undergoing meniscal root repair was around 25 kg/m^2. Of note, a BMI of 25 kg/m^2 in western pacific countries such as South Korea falls into the category of moderate obesity (a normal BMI is defined as 18.5–22.9 kg/m^2) [29]. Even so, a BMI 25 kg/m^2 may not be severe enough to result in cartilage degeneration that is significant enough to lead to poor clinical outcomes after surgical repair. Studies with patients with higher BMIs may be needed to determine if BMI is indeed a significant factor for poor outcomes, although this may prove difficult as patients with high BMIs are often not candidates for meniscal root repairs and are thus excluded in many studies [24].

4.1. Limitations

This systematic review is limited by the level of evidence and quality of the studies analyzed. This is a review of four case series and one cohort study and is therefore considered evidence level IV. Furthermore, all studies were retrospective in nature. The quality of the studies analyzed in this review was quite high with an average quality score of 15 (83.3%) for the case-series and an average NOS [17] score of 8 (88.8%) for the single cohort study. According to the original study by Moga et al. [16], a score of 14 or more (≥70%) was considered to be of acceptable quality; all case-series studies in our review scored above 14. The NOS score for LaPrade et al.'s [21] study was also quite high, percentage-wise. There is no scoring cut-off distinguishing high- or low-quality studies using the NOS scale as the authors of this quality assessment tool are currently studying its validity. We chose to use this tool for our cohort study based on a systematic review of methodological quality assessment tools by Zeng et al. [30] recommending the use of the NOS tool for cohort and case–control studies.

Another limitation of our study is that the data was not pooled for meta-analysis, however this would have been difficult to do. Firstly, this was a systematic review of the previously published studies in the literature for prognostic clinical factors that influenced how patients responded to meniscal root repairs. Each study included in our review evaluated different patient factors. The only consistent patient factor that was evaluated between all five studies was age. Even then, the analysis by LaPrade et al. evaluated age using a different methodology and statistical analysis than the other papers by grouping patients into two cohorts (>50 years of age and <50 years), whereas the other studies evaluated age as a continuous variable.

One extrinsic limitation to this study is the limited number of total studies included in this review as well as the total number of patients included in the studies (178 total patients). Another limitation is the limited follow-up time across all studies. The mean follow-up time across all patients was 34.5 months. Short-term follow-up periods could possibly miss the effect some factors, such as age, may have on patient outcome. Another limitation is that four studies were conducted in South Korea, with the overwhelming majority of these patients in these studies being female. Therefore, the results of this study may not be generalizable to other countries or to male patients.

5. Conclusions

Risk factors for poor clinical outcomes after posterior meniscal repair include pre-existing high-grade (Outerbridge grade ≥ 3) chondral lesions and severe varus knee alignment (>5°) for medial root repairs.

Ethical review statement

This study was exempt from approval by the Biomedical Institutional Review Board of The Ohio State University.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.knee.2019.01.005.

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