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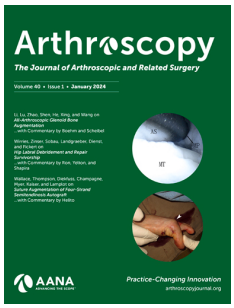

Osteochondral Allograft (OCA) Transplantation with Concomitant Meniscus Allograft Transplantation (MAT) Improves Clinical Outcomes and Yields High Patient Satisfaction: A Systematic Review

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Osteochondral Allograft (OCA) Transplantation with Concomitant Meniscus Allograft Transplantation (MAT) Improves Clinical Outcomes and Yields High Patient Satisfaction: A Systematic Review

Running Title: OCA with MAT : A Systematic Review

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ABSTRACT

Purpose: To conduct a systematic review evaluating subjective patient reported outcomes (PROs), reoperations, and graft failure after concomitant osteochondral allograft (OCA) transplantation and meniscal allograft transplantation (MAT).

Methods: A literature search was performed by querying MEDLINE, Embase, and PubMed according to the 2020 PRISMA statement. Inclusion criteria were limited to peer-reviewed English level I-IV studies with at least 10 patients reporting clinical outcomes and complications following OCA transplantation with concomitant MAT for osteochondral defects and meniscal deficiency with a minimum of 2-years follow up. For a majority of the included studies, failure was defined as conversion to arthroplasty, revision OCA, or graft failure on postoperative imaging.

Results: Six studies with a total of 188 patients met inclusion/exclusion criteria. The mean patient age was 32.4 years (Range 15 to 66 years). Improvement in the following outcome scores was observed across all included studies from pre- to postoperative status: Lysholm Knee Score (+21 to +26.69), International Knee Documentation Committee (IKDC) Subjective Knee Form

(+19 to +26.55), Knee Injury and Osteoarthritis Outcome Score (KOOS) Pain Score (+17.91 to +26), KOOS Symptom Score (+9 to +18.16), KOOS Activities of Daily Living (ADL) Score (+11.91 to +23.4), KOOS Sport Score (+19 to +26.04), KOOS Quality of Life Score (+22 to +35.01), 12-Item Short Form Survey (SF-12) Physical Score (+5 to +12.26), and SF-12 Mental Score (+1.8 to +4) ($P < 0.05$ for all). Reoperation rate was found to be between 6.7% and 54%. Failure rate was found to be between 13% and 22.9%. Although patient satisfaction data was only available in 2 studies, 82% - 90% of patients would choose to undergo OCA transplantation with MAT again.

Conclusion: OCA transplantation with concomitant MAT for the treatment of focal chondral defects in the presence of meniscus deficiency results in improved patient-reported outcome measures with high patient satisfaction rates. Reoperation rates and failure rates at a mean follow up time of 4.7 years (Range 1.7 to 17.1 years) are 37.3% and 17.1%, respectively, which are expected and consistent with the existing literature in isolated procedures.

Level of Evidence: Level IV; Systematic Review of Level III-IV Studies

Keywords: meniscal, osteochondral, allograft, knee

INTRODUCTION

Chondral or osteochondral defects are a common cause of knee pain, swelling, and dysfunction with a reported incidence of 61% in patients undergoing knee arthroscopy [1]. These lesions have limited healing potential and may eventually progress to osteoarthritis if left untreated [2-4]. Osteochondral allograft (OCA) transplantation is an effective single-staged procedure used to resurface large defects > 2 cm^2 with mature hyaline articular cartilage, while simultaneously addressing underlying subchondral bone deficits. In isolation, OCA transplantation has been reported to be a reliable treatment option resulting in significant improvements in pain and function, with long-term graft survival rates ranging from 70% to 91% over ten years [5-7].

Previous studies have demonstrated inferior outcomes following OCA transplantation performed in the presence of meniscal deficiency [8]. Meniscal deficiency results in loss of chondral protection due to the interrupted continuity of meniscus hoop stresses, which leads to accelerated cartilage wear and a shortened survival time of OCAs [9-11]. Nevertheless, it is not uncommon to find co-occurrence of meniscal and chondral lesions within the same compartment. Previous studies have identified concomitant meniscal injuries in 42% of patients with osteochondral defects of the knee [1].

In the setting of symptomatic meniscal deficiency, meniscal allograft transplantation (MAT) is a viable treatment option [12-14]. This procedure involves the replacement of the

damaged or absent meniscus in the knee with donor meniscal tissue. Outcomes with MAT have demonstrated significant improvements in pain, function, and activity level. [15, 16] Previously published long-term survival rates of MAT range from 73.5% to 81.8% at 10 years [17, 18]. OCA transplantation with concomitant MAT aims to address both articular cartilage defects and meniscal deficiency. The literature to date consists largely of small case-series from single institutions, limiting the ability to summate clinical outcomes. The purpose of this study was to conduct a systematic review evaluating subjective patient reported outcomes (PROs), reoperations, and graft failure after concomitant osteochondral allograft (OCA) transplantation and meniscal allograft transplantation (MAT). We hypothesized that combined OCA transplantation and MAT will result in an improvement in patient clinical outcomes.

METHODS

Search Strategy and Study Selection

In June 2024, a systematic review of the MEDLINE, Embase, and PubMed databases was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [19] in search of clinical studies analyzing OCA transplantation with concomitant MAT. The search included the following terms combined with Boolean operators: [("osteochondral allograft" OR "osteochondral allograft transplantation") AND ("meniscus transplantation" OR "meniscal allograft" OR "meniscus allograft transplantation")].

The inclusion criteria included level I-IV clinical studies with at least 10 patients, reporting outcomes following OCA transplantation with concomitant MAT for treatment of osteochondral defects involving either the medial femoral condyle (MFC) or lateral femoral condyle (LFC) with concurrent meniscal deficiency. 10 patients were used as a threshold to

ensure a basic level of statistical power and reliability Only studies published in a peer reviewed journal written in English with a minimum follow-up of 2 years were included. Non-English language studies, abstracts, technical notes, systematic reviews, meta-analyses, expert opinions, unpublished data, biomechanical, basic-science, cadaveric and animal studies were excluded from analysis. Eligibility assessment of title, abstract and full-text screening of all retrieved articles were screened by two independent reviewers (JBV, CG) by applying the inclusion and exclusion criteria. A third reviewer who is an orthopedic surgeon, (FG) was consulted to arbitrate any discrepancies that arose.

Data Extraction

Data was extracted from the included studies and entered into a predetermined Microsoft Excel Spreadsheet (Version 16, Microsoft, Redmond, WA). Extracted study characteristics and demographic variables included authors, year of publication, level of evidence, etiology, number of patients, sex, age, BMI, follow up time, location of osteochondral defect (MFC vs LFC), surgical technique, and defect size. Furthermore, failure rate, reoperation rate, and preoperative and postoperative clinical outcomes including Lysholm Knee Score, International Knee Documentation Committee (IKDC) Subjective Knee Form, Knee Injury and Osteoarthritis Outcome Score (KOOS) Pain Score, KOOS Symptom Score, KOOS Activities of Daily Living (ADL) Score, KOOS Sport Score, KOOS Quality of Life Score, 12-Item Short Form Survey (SF-12) Physical Score, and SF-12 Mental Score were extracted for inclusion in a quantitative analysis. For continuous variables (such as age, follow-up, and outcome scores), the mean, standard deviation, and range were collected if reported.

Quality and Risk of Bias Assessment

The methodological quality of clinical evidence and risk of bias for the included non-randomized studies was performed using the Methodological Index for Non-Randomized Studies (MINORS) criteria [20]. This tool is designed to evaluate the internal validity of non-randomized studies by systematically identifying potential sources of bias across 8 items specifically tailored for non-comparative studies: a clearly stated aim, inclusion of consecutive patients, prospective collection of data, endpoints appropriate to the aim of the study, unbiased assessment of the study endpoint, follow-up period appropriate to the aim of the study, loss to follow-up less than 5%, and prospective calculation of the study size. For comparative studies, 4 additional items are evaluated: an adequate control group, contemporary groups, baseline equivalence of groups, and adequate statistical analyses. Each item is scored 0 to 2, where 0 indicates that the item is not reported, 1 indicates that the item is reported but inadequate, and 2 indicates that the item is reported and adequate.

Statistical Analysis

Continuous variables were described using mean and 95% confidence intervals, whereas dichotomous variables were reported using proportions with 95% confidence intervals. Open Meta-Analyst [21], an open source software available through Brown University, was utilized to create single-leg forest plots for reporting clinical outcomes and complication rates. Due to the heterogeneity of outcomes and the small number of studies per single outcome, no formal meta-analysis could be performed and data is reported with ranges.

RESULTS

Demographics and Study Characteristics

The initial search of databases revealed 2309 studies (Figure 1). Upon duplicate removal, 1086 studies were screened for eligibility. Following title and abstract screening, 13 studies qualified for full-text review. A total of 6 studies were found to meet eligibility criteria and were included in this review. Of these studies, 4 were non-comparative and 2 were comparative. No critical concerns were identified during risk of bias assessment using the MINORS criteria (Figure 2).

Of the 6 studies meeting inclusion criteria, there were four Level IV studies and two Level III studies with mean follow-up time ranging from 2.9- 6.8 years. A total of 188 patients were identified with a weighted mean patient age of 32.4. Importantly, 4 studies reported the number of previous surgeries; the mean was found to be between 1.9-3.3 surgeries prior to undergoing OCA transplantation with concomitant MAT. Patient demographics and indications for OCA transplantation with MAT are described in Table 1. Details regarding concomitant procedures, location of the allograft transplant, lesion size, and prior surgical treatment are outlined in Table 2.

Outcome Scores

All six studies reported PROs and a summary of these scores is included in Table 3 and Figures 3-6. 14 different outcome measures were recorded across the 6 included studies. The IKDC score was the most frequently used PRO and was reported in all 6 studies. The reported mean preoperative IKDC scores ranged from 31.4 - 48.74, and the mean postoperative score ranged from 55 - 74.47 with all 6 studies reporting an improvement from baseline to postoperative follow-up (Figure 4). The Lysholm Knee Scoring Scale was also frequently

utilized (5 studies), along with KOOS Pain (4 studies), KOOS Symptom (4 studies), KOOS ADL (4 studies), KOOS Sport (4 studies), KOOS QOL (4 studies), SF-12 Physical (3 studies), and SF-12 Mental (3 studies). The mean preoperative Lysholm Score ranged from 41.9 – 49.56, and the mean postoperative score ranged from 63.6 – 76.25 (Figure 3). The mean preoperative KOOS Pain, KOOS Symptom, KOOS ADL, KOOS Sport, and KOOS QOL scores ranged from 47.3 – 68.29, 49.2 – 59.38, 60.9 – 78.33, 20 – 40.13, and 13.9 – 29.22 while the postoperative scores ranged from 73.1 – 86. 2, 63 – 76.62, 84.3 – 91.92, 39 – 66.13, and 41 – 64.1 respectively (Figure 5). The mean preoperative SF-12 Mental ranged from 52.6 - 53, and the postoperative score ranged from 54.64 – 57 (Figure 6). The mean preoperative SF-12 Physical ranged from 33.94 - 37, and the postoperative score ranged from 42 – 46.2 (Figure 6). All other patient reported outcomes are outlined in Table 3.

Satisfaction

Two studies reported patient satisfaction as an outcome (Table 3). Abrams et al [22] utilized a point scale from 1 to 10, with 10 representing complete satisfaction. From this, the mean patient satisfaction rating was found to be 6.9 ± 2.8. They also assessed satisfaction by asking patients if they would undergo the procedure again. 28 of the 32 total patients in the study responded to this question, of which 23 (82%) stated that they were satisfied with the outcome and would undergo the procedure again. Getgood et al [23] captured patient satisfaction by asking a similar series of questions. Patients were asked if they would opt to have the surgery again and if surgery improved their function and pain. Of the patients who responded to these questions, 91% reported experiencing less pain and 90% reported having better function and would choose to undergo surgery again. Getgood et al also assessed patient satisfaction with a 4-

point scale (extremely satisfied, satisfied, somewhat satisfied, somewhat dissatisfied). 60% of patients reported they were extremely satisfied, 19% reported they were satisfied, 11% reported they were somewhat satisfied, and 3% reported they were somewhat dissatisfied.

Reoperation and Failure Rates

Failure rates were reported for 4 of the 6 studies (Table 2). The reported failure rate ranged from 13%-22.9%. It is important to note that different definitions of failure were used across studies. Frank et al [24]defined failure as revision OCA transplantation, conversion to arthroplasty, or the appearance of poorly incorporated osteochondral allograft at second-look arthroscopy. Husen et al [25] defined failure based on the need for further surgical management including graft fragment excision, conversion to total knee arthroplasty, and cartilage procedures such as chondroplasty. Rue et al [26] did not provide a clear definition for failure, but reported two cases of patients that were considered to have failed results. The first patient had a new twisting injury resulting in a bucket handle tear of the allograft meniscus which required revision lateral MAT. The second patient underwent complete meniscectomy and was found to have tricompartmental degenerative changes. Lastly, Getgood et al [23] defined failure as removal or revision of the graft(s). The time to failure across the 4 studies that reported failure rate was an average of 3.84 years [range 2.7-5.42 (3 studies)].

Given the heterogenous definition of failure across the included studies, we independently investigated the rate of OCA failure, MAT failure, revision OCA, revision MAT, and conversion to arthroplasty to obtain a cohesive understanding of failure associated with the grafts. Using this definition of failure, the failure rate remained the same in 3 of the 4 studies that provided data on failure. However, this decreased the failure rate that Husen et al [25] reported

by excluding 2 patients who underwent chondroplasty. With this, the failure rate was found to be 15.7%

Five of the 6 included studies reported reoperation rate after OCA transplantation with concomitant MAT. Across these 5 studies, 65 out of 178 patients underwent reoperation with an average reoperation rate of 37.3% (range 6.7%-54%) (Table 2). Reoperations reported in these studies included arthroscopic debridement to smooth any incongruent but nondegenerative chondral surfaces in and around the graft, resection of partial tears of the MAT, loose body removal, chondroplasty, lateral release, and synovectomy.

DISCUSSION

The main findings of this study were that OCA transplantation with concomitant MAT yielded improved postoperative outcomes with high patient satisfaction and acceptable revision and failure rates at short- to medium-term follow-up for the vast majority of patients with focal chondral defects of the MFC or LFC and concurrent meniscal deficiency. For the 2 studies that reported patient satisfaction, >80% of patients across series reported being satisfied with the outcome of the operation. Reoperation rates were seen in approximately a third of patients across all studies with the majority of reoperations being simple debridements with a nearly intact graft. The findings in our study may be utilized to guide preoperative patient counseling regarding the relatively high reoperation rate as well as expectations for clinical outcomes and satisfaction for this salvage knee joint preservation operation.

There is extensive literature available regarding OCA transplantation and MAT as independent procedures. The standards are also well established for assessing clinical efficacy in terms of the minimal clinically important difference (MCID) in these procedures. However, to

date there is a lack of literature reporting clinically significant outcomes for OCA and MAT in the combined setting. Ogura et al [27] determined the MCID in several patient reported outcome measures of patients undergoing isolated OCA transplantation in the knee at a minimum of 1 year postoperatively. The authors determined that the MCID was 16.7 for KOOS pain, 25 for KOOS sports/recreation, and 9.8 for IKDC. Similarly, Liu et al [28] established the MCID for patients undergoing MAT with respect to several patient reported outcome measures including the Lysholm score (12.3), IKDC (9.9), and the KOOS Pain (9.9), Symptoms (9.7), Activities of Daily Living (9.5), Sport (13.3), and Quality of Life (14.6). Despite the inability of this review to comment on clinically significant PRO changes due to lack of individual patient-level data in the included studies, there was marked improvement in every reported PRO. Importantly, given this lack of reported clinically significant outcomes in the included studies, future investigations that provide patient level metrics will permit calculation of MCID for OCA transplantation with concomitant MAT while anchor based questions will provide information on Patient Acceptable Symptom State (PASS) and Substantial Clinical Benefit (SCB). These findings will provide more insight on individual patient experiences. Nonetheless, in every study that evaluated these outcomes, the change between preoperative and postoperative outcomes surpassed the established MCID for both OCA transplantation and MAT with respect to IDKC and KOOS Pain. The previously established OCA transplantation and MAT MCID for KOOS Sport was also exceeded in 2 out of the 4 studies that evaluated this outcome. While there is no existing MCID for the Lysholm score, KOOS ADL, or KOOS QOL for OCA transplantation, the established values for MAT were surpassed in all the included studies that evaluated these measures. The established MAT MCID for KOOS Symptoms was also exceeded in 3 out of the 4 studies that investigated this outcome. In a recent systematic review, Su et al [29] demonstrated

that evaluating postoperative PROs with respect to the MCID is crucial to evaluate the effect of MAT on functional improvement. Although this may suggest that the observed postoperative improvements after concomitant OCA transplantation and MAT are clinically meaningful, it is necessary to implement clinically beneficial measures in future studies to further contextualize the relevance of these observed postoperative PRO increases.

Despite the differences in definition for failure among the included studies, the overall mean failure rate was 17.1% with a range of 13% to 22.9%, which is comparable to the reported rate of various other biologic cartilage restoration procedures at the tibio-femoral compartments [30, 31]. However, it is important to note that differences in technique within and across studies may ultimately impact the differences in observed failure rates. The highest observed failure rate of the included studies was 22.9% [23]. In this study, Getgood et al [23] performed the OCA transplant before the MAT. OCA transplantation was performed using commercially available instrumentation for dowel implantation if the defect was small. If more extensive femoral reconstruction was required, the femoral condyle defect was resected freehand then replaced en-bloc as a shell allograft and secured using lag screws. The MAT was subsequently implanted using a slot technique. When considering the cases in this study that utilized a freehand technique to resect the femoral condyle defect before replacing en-bloc as a shell allograft, it is possible the size matching of the allograft was inferior given the level of technical difficulty. Moreover, the study by Getgood et al[23] included bipolar lesions which were present in 50% of the cases. This may have ultimately contributed to the increase in failure rate observed in this study. Another consideration is the effect of defect size on failure rate. Of the included studies, the largest mean defect size, 15 cm^2, was also observed in the study with the highest failure rate [23]. Lee et al [32] previously found that patients with larger defects and higher defect

size:condyle ratio (DSCR) had increased failure rates after OCA transplantation. Further investigation is required using high quality, homogeneous studies to evaluate the factors that are associated with an increased failure rate.

The reoperation rate for isolated OCA transplant and MAT varies across the literature. In the present study, 65 out of 178 patients underwent reoperation with a weighted mean reoperation rate of 37.3% and a range of 6.7% to 54%. A previous study on isolated femoral condyle OCA reported a lower reoperation rate of 24.4% [33]. However, another review of prospectively collected data of 224 consecutive patients who underwent OCA transplantation with a mean follow up of 5 years reported a reoperation rate of 37% [34]. Gilat et al. also reported a reoperation rate of 39.4% at a mean follow-up of 7.7 years [7], which is comparable to the rate observed in our study. When looking at reoperation rate for MAT, McCormick et al reported a reoperation rate of 32% at a mean follow-up of 59 months, with arthroscopic debridement being the most common secondary procedure [35]. In a more recent retrospective review, Wagner et al found a reoperation rate of 37% at a mean follow-up of 12.7 years. However, they also found that a significant portion of these reoperations occurred within the first few years postoperatively [35]. It is challenging to accurately assess the variables that are driving reoperation in our study given the diversity in surgical technique and follow-up time. Moreover, a better understanding of the procedure types that comprise the reoperation rate may provide more insight on the etiology of the complications leading to reoperation.

Regarding malalignment, 3 out of the 6 included studies reported performing a concomitant osteotomy (high tibial osteotomy (HTO) or distal femoral osteotomy (DFO)) in at least one case of OCA transplantation with MAT; however, it is unclear what percentage of patients received treatment to address alignment and whether an opening or closing wedge osteotomy was utilized.

Despite the importance of addressing all knee joint comorbidities, including meniscal deficiency, alignment, and chondral and osteochondral defects, there is a paucity of literature reporting outcomes of these concomitant procedures [36]. In a single case series with a minimum of 2 year follow up, Harris et al [37], found no significant difference in clinical outcomes between isolated cartilage repair and combined surgery for correction of concomitant pathology of meniscal deficiency and valgus malalignment. The authors also reported a low rate of complications and reoperations with only 5 out of 35 patients undergoing 6 reoperations for 1 revision of osteochondral allograft and 5 chondroplasties. No patients were converted to total knee arthroplasty. Another recent systematic review [38] examining clinical outcomes of MAT with or without other procedures included 3 studies that reported concomitant realignment osteotomy, ligament surgery, and osteochondral autograft transfer (OAT) were risk factors for failure and 1 study that reported medial MAT with HTO shows a higher survival rate than isolated medial MAT. These studies provide valuable insight on the impact of addressing malalignment in the setting of OCA transplantation and MAT and highlight the need for more controlled studies to evaluate the interplay of these factors.

Another factor that should be considered is the variability in number of MFC versus LFC grafts. Of our included studies, only Frank et al [24] examined outcomes between OCA of the two compartments. They found that patients undergoing LFC OCA had superior International Knee Documentation Committee and KOOS sport subscale. However, they did not examine medial versus lateral MAT. The 5 additional studies that were included in this review did not examine the outcomes of medial versus lateral pathology regarding OCA or MAT. Multiple systematic reviews have demonstrated that patients undergoing lateral MAT demonstrate greater

pain relief and functional improvement than patients undergoing medial MAT but have comparable rates in survival at midterm follow up [39, 40]. Hence, further investigation is needed to evaluate the impact of medial vs lateral compartment on outcomes of concomitant OCA transplantation and MAT. The included studies also did not disaggregate outcomes based on sex. However, studies have demonstrated that males and females demonstrate comparable rates of failure and reoperation following primary OCA of the knee, but females tend to undergo reoperation sooner [41]. Similarly, in the context of MAT, it has been found that men and women demonstrate similar clinical improvement and survival rates [42]. These findings suggest that we may expect similar outcomes between sexes in combined OCA and MAT; however, further research is needed. Nonetheless, it is evident that the reoperation rate in our study is comparable to the rates observed in isolated OCA transplantation and MAT. This may suggest concomitant OCA transplantation and MAT is non-inferior to these procedures in isolation and remains a viable option for knee joint preservation for young, active patients with focal defects in the setting of meniscal deficiency.

LIMITATIONS:

We acknowledge limitations exist in the present study. First, there was heterogeneity in the reporting of outcomes and some studies failed to include various subgroup characteristics which resulted in incomplete data analysis. Additionally, there were notable differences in the surgical techniques that were used within and across studies that may have influenced outcomes, in particular the few reported cases of shell allografts which have previously been reported to have inferior outcomes in the patellofemoral joint to plug grafts [43]. Furthermore, many of the studies included in this review had procedures performed concomitantly with OCA

transplantation and MAT. However, as stated before, those are minor procedures. Regardless, we are unable to exclusively associate the observed outcomes with OCA transplantation and MAT. The included studies did not provide detailed information regarding varus or valgus alignment and how clinical decisions were made as to address or not address alignment with an osteotomy at the time of joint preservation surgery. Additionally, there is a possibility that relevant articles or patient populations were not identified, despite our thorough and detailed search criteria.

CONCLUSION

OCA transplantation with concomitant MAT for the treatment of focal chondral defects in the presence of meniscus deficiency results in improved patient-reported outcome measures with high patient satisfaction rates. Reoperation rates and failure rates at a mean follow up time of 4.7 years are 37.3% and 17.1%, respectively, which are expected and consistent with the existing literature in isolated procedures.

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TABLES

Table 1. Patient and Study Characteristics

First Author	Year	LOE	Etiology	No. of Patients, n	Sex M/F, n	Mean Follow-up (Range), y	Age, Mean ± SD (Range), y	BMI

Frank[24]	2018	3	OCA: DCL, failed prior cartilage restoration MAT: meniscus deficiency, failed prior meniscus surgery	50	25/25	4.77 ± 2.86	31.19 ± 9.39	24.98 ± 4.81
Getgood[23]	2015	4	DCL, OA, tibial plateau fracture, meniscus deficiency	48	29/19	6.8 (1.7-17.1)	35.2 ± 10.6 (15-66)	27.6 ± 5.5
Husen[25]	2024	3	OCA: DCL MAT: meniscus deficiency, failed prior meniscus surgery	33	19/14	6.2 ± 3.3	24.8 ± 7.2	26.1 ± 4.9
Abrams[22]	2014	4	Persistent symptoms after meniscectomy, DCL	32	17/15	4.4 ± NR	35.0 ± 10.0	NR
Rue[26]	2008	4	Persistent symptoms after meniscectomy with DCL	15	13/2	2.9 (1.9–5.0)	36.8 (19.6–47.9)	NR
McCulloch[44]	2007	4	DCL	10	NR	2.9 (2-5.6)	35 (17-49)	NR

[a] LOE, level of evidence; DCI, degenerative chondral lesion; OA, osteoarthritis; M, male; F, female; NR, not reported; BMI, body mass index; No, number; SD, standard deviation

Table 2. Defect Characteristics, Previous Surgeries, and Other Concomitant Procedures

First Author	Lesion Location, (n)	Lesion Size, Mean ± SD (Range), cm^2	Other Concomitant Procedures	Number of Previous Surgeries, Mean ± SD (Range)	Reoperations, n (%)	Reoperation Procedures	Mean Time to Reoperation, y	Failure, n (%)	Failure of Graft or Conversion to Arthroplasty (%), n	Mean Time to Failure (Range)
Frank[24]	MFC (29) LFC (21)	4.49 ± 1.74	HTO, DFO	3.1 ± 1.97	17 (34)	Arthroscopic debridement, loose body excision	2.16 ± 2.41	7 (14)	7 (14)	3.14 ± 0.86
Getgood[23]	MFC (16) LFC (31) MFC & LFC (1)	[a]15 (0.7-41)	NR	3.3 ± 2.4 (1-11)	26 (54)	Arthroscopic debridement	NR	11 (22.9)	11 (22.9)	NR
Husen[25]	MFC (8) LFC (25)	3.92 ± 2.8	HTO, DFO	1.9 ± 1.4	13 (39)	Hardware removal, loose body excision, chondroplasty, partial meniscectomy	2.34 ± 2.52	5 (15.2)	3 (9.1)	5.42 (1.8-9.5)
Abrams[22]	MFC (24) LFC (7) MFC & LFC (1)	4.7 ± 2.0	NR	2.2	8 (25)	Arthroscopic debridement, chondroplasty, loose body excision, lateral release, synovectomy	NR	NR	NR	NR

Rue[26]	MFC (13) LFC (2)	5.5 (2.3–9.5)	Hardware removal, HTO	NR	1 (6.7)	Arthroscopic debridement	NR	2 (13)	2 (13)	2.7
McCulloch[44]	NR	5.23	NR	NR	NR	NR	NR	NR	NR	NR

[a] Median graft area, [b] MFC, medial femoral condyle; LFC, lateral femoral condyle; NR, not reported; HTO, high tibial osteotomy; DFO, distal femoral osteotomy; SD, standard deviation

Table 3. Outcome Measures

Study	Year	No. of Patients	Outcome Measures	Preoperative	Postoperative	Change
Frank[24]	2018	50	Lysholm	49.48 ± 16.06	70.77 ± 17.94	+21.29
			IKDC	39.80 ± 15.78	66.35 ± 17.61	+26.55
			KOOS Pain	59.85 ± 15.82	80.69 ± 15.00	+20.84
			KOOS Symptom	57.75 ± 15.65	75.91 ± 18.36	+18.16
			KOOS ADL	69.03 ± 23.31	91.92 ± 9.57	+22.89
			KOOS Sport	30.86 ± 22.48	56.90 ± 26.55	+26.04
			KOOS QOL	29.22 ± 17.59	56.10 ± 23.04	+26.88
			SF-12 Physical	33.94 ± 5.72	46.20 ± 7.40	+12.26
			SF-12 Mental	52.84 ± 11.45	54.64 ± 9.34	+1.8
			Symptom Rate	4.31 ± 2.22	7.09 ± 2.20	+2.78
Getgood[23]	2015	48	IKDC	33.4 ± 21	58.1 ± 25.4	+24.7
			KS Function	56.4 ± 28.7	79.4 ± 24.6	+23
			KS Knee	61.8 ± 18.4	72.2 ± 22.2	+10.4
			D&P 18-Pt	11.7 ± 2.9	14.8 ± 2.7	+3.1
			Less Pain, n (%)			
			Yes		20 (91)	
			No		1 (9)	
			Better Function, n (%)			
			Yes		19 (90)	
			No		2 (10)	
			Have surgery again, n (%)			
			Yes		19 (90)	
			No		2 (10)	
			Satisfaction, n (%)			
			Extremely satisfied		22 (60)	
			Satisfied		7 (19)	
			Somewhat satisfied		4 (11)	
			Somewhat dissatisfied		1 (3)	

Husen[25]	2024	33	Lysholm	49.56 ± 11.26	76.25 ± 18.94	+26.69
			IKDC	48.74 ± 11.63	74.47 ± 19.54	+25.73
			KOOS Pain	68.29 ± 15.99	86.20 ± 17.18	+17.91
			KOOS Symptom	59.38 ± 14.19	76.62 ± 22.10	+17.24
			KOOS ADL	78.33 ± 16.07	90.24 ± 15.12	+11.91
			KOOS Sport	40.13 ± 22.10	66.13 ± 24.45	+26
			KOOS QOL	29.09 ± 13.42	64.10 ± 25.43	+35.01
			Tegner	4.12 ± 2.38	5.23 ± 1.57	+1.11
Abrams[22]	2014	32	Lysholm	41.9 ± 16.1	63.6 ± 24.1	+21.7
			IKDC	32.9 ± 11.4	55.3 ± 23.6	+22.4
			Satisfaction		6.9 ± 2.8	
			Have surgery again, n (%)		23 (82%)	
Rue[26]	2008	15	Lysholm	42.0 ± 14.5	68.2 ± 21.3	+26.2
			IKDC	31.4 ± 12.8	57.1 ± 17.8	+25.7
			KOOS Pain	47.3 ± 15.5	73.1 ± 19.3	+25.8
			KOOS Symptom	49.2 ± 17.9	65.1 ± 21.1	+15.9
			KOOS ADL	60.9 ± 23.3	84.3 ± 13.7	+23.4
			KOOS Sport	20.8 ± 14.8	42.7 ± 18.8	+21.9
			KOOS QOL	13.9 ± 17.5	41.3 ± 15.4	+27.4
			SF-12 Physical	37.0 ± 8.2	42.2 ± 6.9	+5.2
			SF-12 Mental	52.6 ± 11.3	55.7 ± 9.9	+3.1
			Symptom Rate	4.5 ± 1.8	7.1 ± 1.8	+2.6
			Tegner	4.4 ± 3.7	6.2 ± 2.9	+1.8
McCulloch[44]	2007	10	Lysholm	47 ±16	68 ±22	+21
			IKDC	36 ±14	55 ±16	+19
			KOOS Pain	49 ±12	75 ±19	+26
			KOOS Symptom	54 ±15	63 ±19	+9
			KOOS ADL	70 ±17	85 ±15	+15
			KOOS Sport	20 ±16	39 ±23	+19
			KOOS QOL	19 ±21	41 ±19	+22
			SF-12 Physical	37 ±9	42 ±8	+5
			SF-12 Mental	53 ±10	57 ±6	+4

[a] IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; QOL, quality of life; SF-12, 12-Item Short Form Survey; KS, knee society; D&P, disability and pain

FIGURE LEGENDS

Figure 1. PRISMA Flowchart

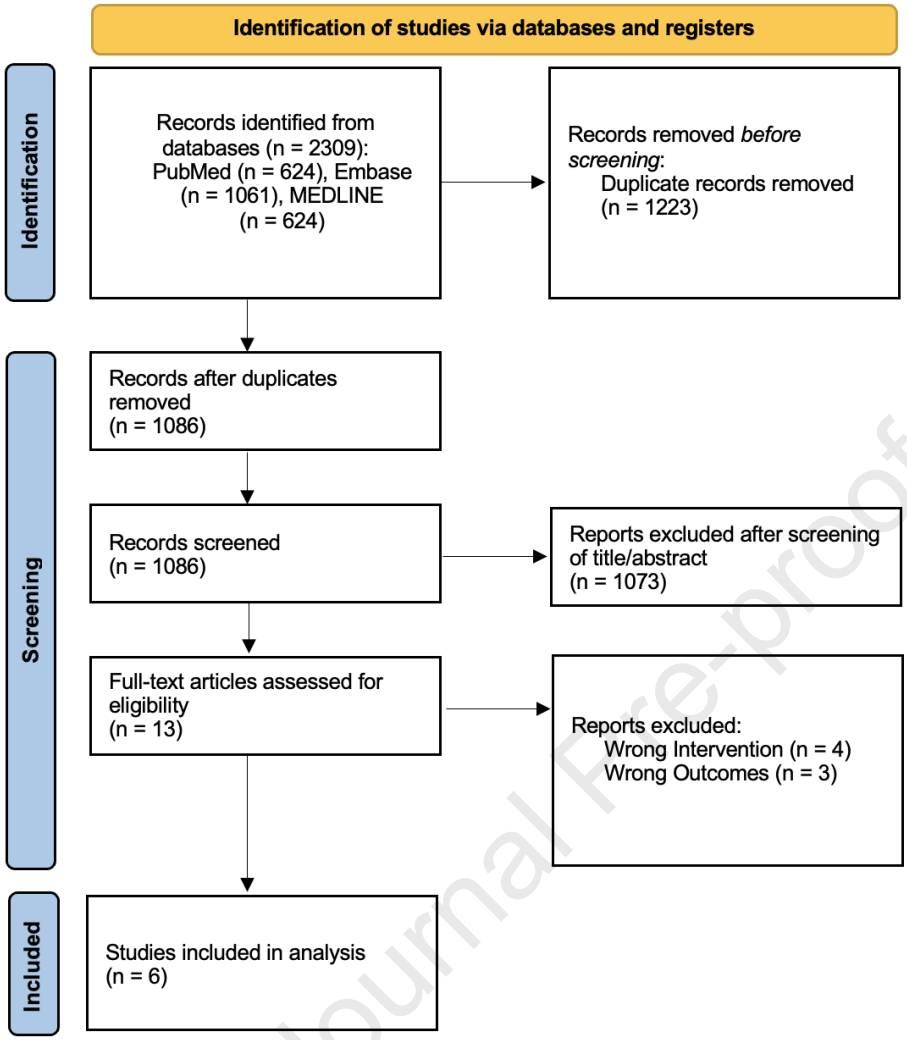
Figure 2. MINORS Scores

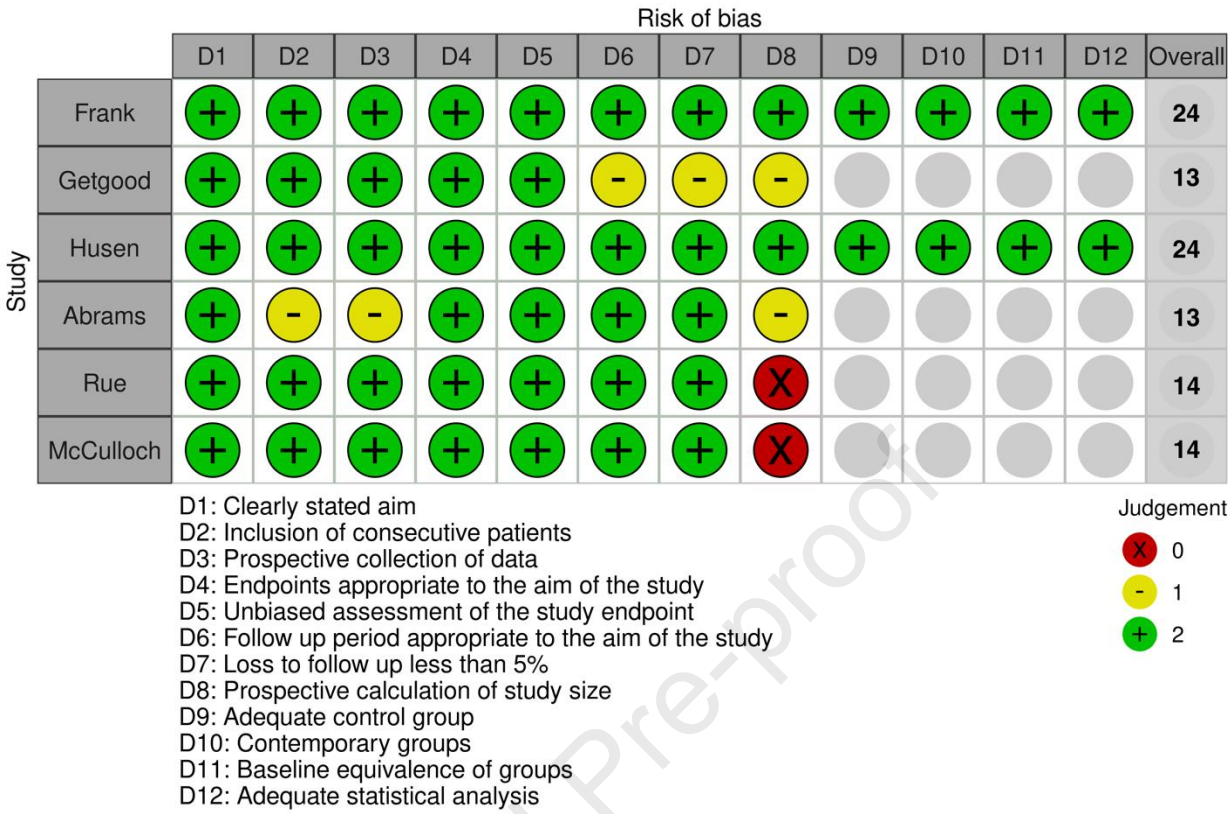
Figure 3. Mean Difference of Preoperative and Postoperative Lysholm Scores

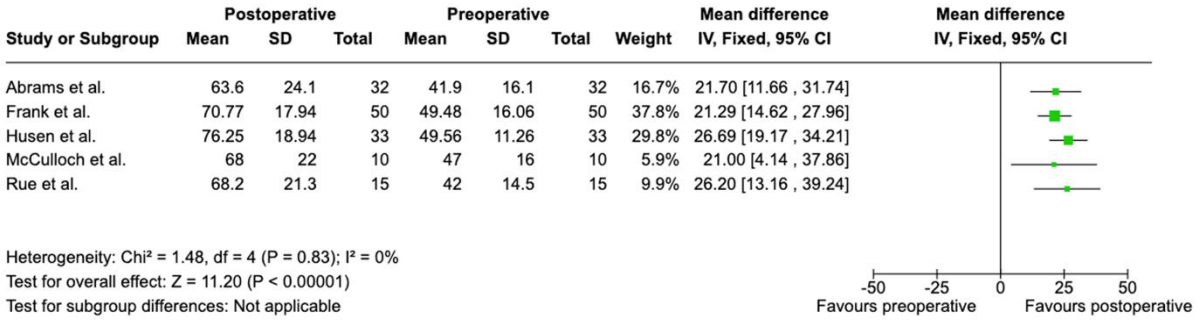
Figure 4. Mean Difference of Preoperative and Postoperative IKDC Scores

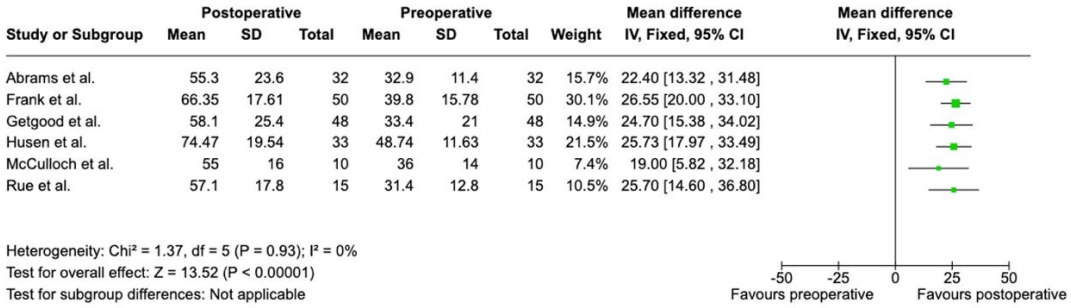
Figure 5. Mean Difference of Preoperative and Postoperative KOOS Scores

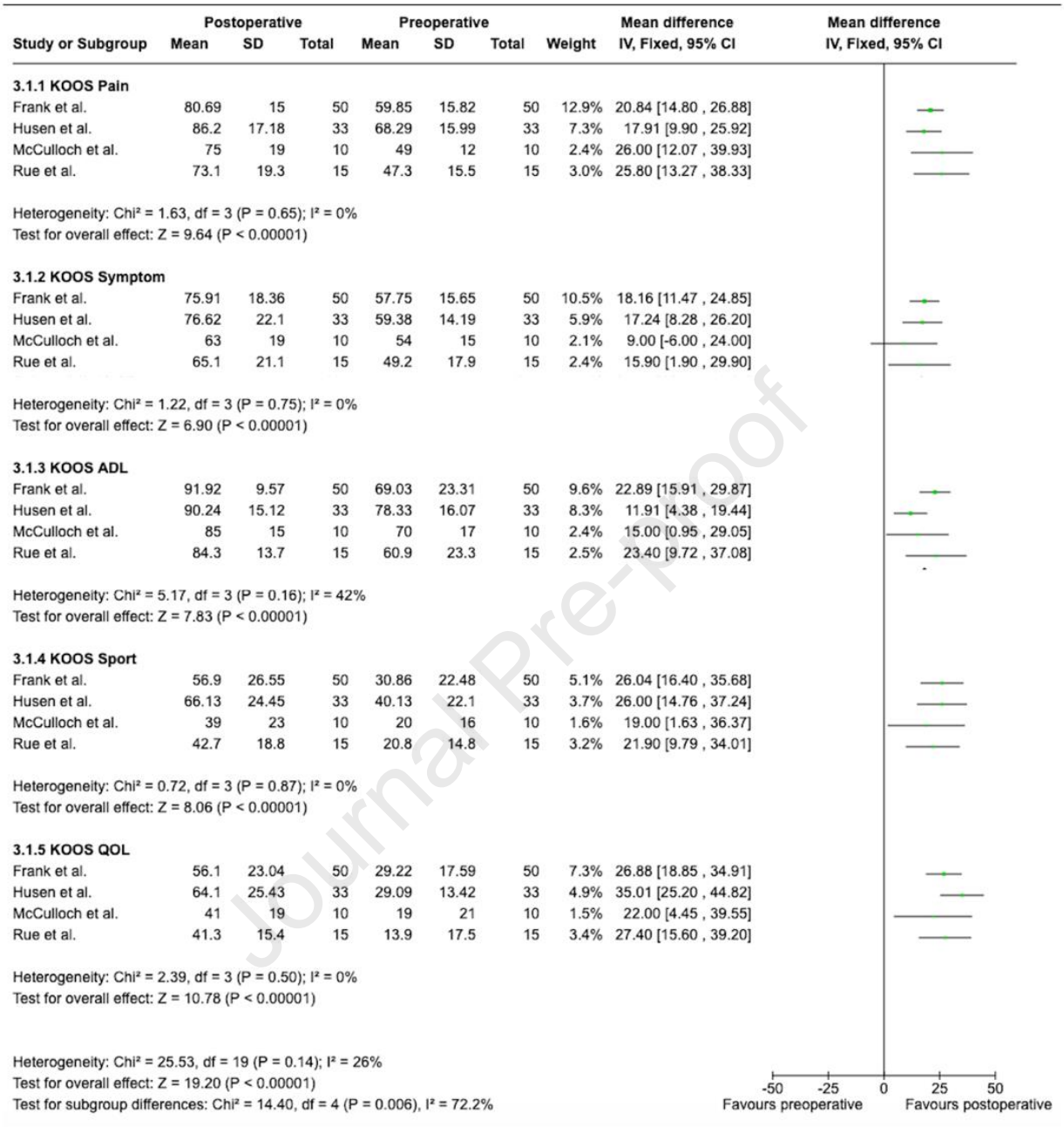
Figure 6. Mean Difference of Preoperative and Postoperative SF-12 Mental and SF-12 Physical Scores











Study or Subgroup	Postoperative Mean	SD	Total	Preoperative Mean	SD	Total	Weight	Mean difference IV, Fixed, 95% CI
4.1.1 SF-12 Physical								
Frank et al.	46.2	7.4	50	33.94	5.72	50	50.1%	12.26 [9.67 , 14.85]
McCulloch et al.	42	8	10	37	9	10	6.0%	5.00 [-2.46 , 12.46]
Rue et al.	42.2	6.9	15	37	8.2	15	11.5%	5.20 [-0.22 , 10.62]
Heterogeneity: Chi² = 7.52, df = 2 (P = 0.02); I² = 73%								
Test for overall effect: Z = 9.15 (P < 0.00001)								
4.1.2 SF-12 Mental								
Frank et al.	54.64	9.34	50	52.84	11.45	50	20.1%	1.80 [-2.30 , 5.90]
McCulloch et al.	57	6	10	53	10	10	6.4%	4.00 [-3.23 , 11.23]
Rue et al.	55.7	9.9	15	52.6	11.3	15	5.8%	3.10 [-4.50 , 10.70]
Heterogeneity: Chi² = 0.30, df = 2 (P = 0.86); I² = 0%								
Test for overall effect: Z = 1.50 (P = 0.13)								
Heterogeneity: Chi² = 23.56, df = 5 (P = 0.0003); I² = 79%								
Test for overall effect: Z = 8.38 (P < 0.00001)								
Test for subgroup differences: Chi² = 15.74, df = 1 (P < 0.0001), I² = 93.6%