Systematic Review and Meta-Analysis

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Early outcomes of primary repair versus reconstruction for acute anterior cruciate ligament injury

A systematic review and meta-analysis

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Abstract

Background: Contemporary techniques for repair of acute anterior cruciate ligament (ACL) rupture have been receiving renewed interest recently because of reports of good outcomes.

Methods: A literature search of PUBMED, MEDLINE, EMBASE, and the Cochrane Library was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Only RCTs published in English and comparing clinical outcomes of ACL repair versus reconstruction were included. Outcomes were evaluated using the International Knee Documentation Committee subjective score, Lysholm score, Tegner activity scale, visual analog scale pain score, anterior laxity, Lachman test, hop tests, knee injury and osteoarthritis outcome score, extension deficit, revision rate, and re-rupture rate. Statistical analysis was performed with Review Manager 5.4 and Stata 14.0. Two-tailed $P < .05$ was considered statistically significant.

Results: Four RCTs (with a total of 293 patients) that met the eligibility criteria were included in this review. Over short-term follow-up, none of the studies found significant differences between the repair groups and reconstruction groups with respect to International Knee Documentation Committee, Lysholm, Tegner, visual analog scale, anterior laxity, Lachman test, re-rupture rate, extension deficit, and performance of 3 hop tests ($P > .05$). In both groups, the hop tests scores were >90%.

Conclusion: ACL repair and ACL reconstruction appear to provide comparable short-term outcomes. The low revision rate after primary repair is encouraging. For patients with ACL injury, current repair techniques such as dynamic intraligamentary stabilization and bridge-enhanced ACL repair may be an effective alternative to reconstruction.

Abbreviations: ACL = anterior cruciate ligament, BEAR = bridge-enhanced ACL repair, DIS = dynamic intraligamentary stabilization, IKDC = International Knee Documentation Committee, KOOS = knee injury and osteoarthritis outcome score, LSI = limb symmetry index, QoL = quality of life, RCTs = randomized controlled trials, RTS = return to sport, VAS = visual analog scale.

Keywords: ACL reconstruction, ACL repair, ACL tear, anterior cruciate ligament, meta-analysis, systematic review

ZS, HC, MY, ZG, HL, HL, and SX contributed equally to this work.

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

Ethical approval was obtained from the local board, with waiver of the need for informed consent.

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1. Introduction

Anterior cruciate ligament (ACL) rupture is a common sport-related knee injury in young athletes and active sports enthusiasts.[1–4] Arthroscopic primary ACL reconstruction is currently recognized as the gold standard treatment for ACL injury[5–8] as it provides higher probability of return to preinjury and sport activity levels and minimizes the risk of meniscal tears and early-onset osteoarthritis of the knee[9–12]; however, problems such as long-term poor stability, re-rupture, and reconstruction failure have also been reported following ACL reconstruction.[6,7,13–17]

Primary repair of acute ACL tear was a common surgical procedure in the past and continues to be used by many surgeons even today. It has shown promising short-term results. Recently, a series of studies on primary repair of proximal tears showed better restoration of vascularity.[18,19] Theoretically, preservation of the original ACL would save nervous structures and help preserve knee proprioception.[7] Moreover, new techniques such as dynamic intraligamentary stabilization (DIS) which improves biological healing capacity and bridge-enhanced ACL repair (BEAR) grafts (with use of resorbable protein-based implant containing autologous blood to promote ligament healing) have shown encouraging results and renewed interest in the concept of primary repair of ACL.[7,15,20–27] Some authors have speculated that the promising results of primary repair could lead to a shift away from ACL reconstruction and back to ACL repair but, so far, there has been no systematic review comparing these 2 methods for treatment of acute ACL injury.[14,28,29] Therefore, we performed this systematic review of randomized controlled trials (RCTs) to examine outcomes in patients undergoing primary ACL repair versus patients undergoing ACL reconstruction. Our hypothesis was that clinical outcomes were comparable with both techniques.

2. Methods

2.1. Study selection

Two independent reviewers performed the literature search in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and reviewed the search results, with a senior author arbitrating on any disagreement.[30] The titles and abstracts of all search results were first reviewed, and potentially eligible studies were selected for a full-text review. The reference lists of the studies were also manually screened for additional articles meeting the inclusion criteria.

Studies were eligible for inclusion if they were RCTs on humans, comparing primary repair with ACL reconstruction; if patients were followed up for at least 1 year; if clinical outcomes (knee function and stability) were reported; if the studies were in English and were published in a peer reviewed journal; and if the full text was available for review. We excluded duplicate studies; non-RCTs, reviews and/or meta-analysis, case series, case report, and letters to the editor; cadaveric studies; purely anatomical, biochemical, radiologic, or technique studies; animal studies; biotherapy studies; and studies with only abstract available for review.

2.2. Data extraction and analysis

Two authors independently abstracted data using a predesigned Excel spreadsheet (Microsoft, Redmond, WA). Disagreements were resolved by discussion with a third reviewer until consensus was reached.

The following data were extracted: name of first author; year of publication; number of patients; patients' age, sex, and body mass index; time from trauma to surgery; functional and stability score; complications; and return to sport (RTS) criteria.

Two investigators independently evaluated the included RCTs with the Cochrane risk-of-bias tool. The following domains were assessed: sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other sources of bias. Risk of bias in each study was categorized as low, unclear, or high. Disagreements between reviewers were resolved by consensus.

2.3. Outcomes

The outcomes measured included the following categories: functional outcomes: International Knee Documentation Committee (IKDC) grade, Tegner score, Lysholm score, and visual analog scale (VAS) pain score; stability outcomes: Lachman, KT-1000 (MEDmetric) arthrometer measurements and Rolimeter (Aircast) for anterior laxity, and pivot shift; complications: incidence of graft re-rupture, extension deficit, and adverse events; and RTS: hop tests and Knee Injury and Osteoarthritis Outcome Score (KOOS). RTS rate was used to predict the ability to return to preinjury level of sport.

2.4. Statistical analysis

RevMan 5.4 (Cochrane Collaboration, London, UK) and Stata 14.0 (StataCorp LLC, 4905 Lakeway Drive, College Station, TX) were used to analyze the data. For dichotomous outcomes, risk ratios with 95% confidence intervals were calculated. For continuous outcomes, standard mean differences with 95% confidence intervals were calculated. A treatment effect was defined as significant if P was <.05. The random-effects model was used. Heterogeneity was explored using the chi-square test, with significance set at $P < .1$. I^2 was used for quantification, with values <25% indicating low heterogeneity, 25 to 50% indicating moderate heterogeneity, and >50% indicating substantial heterogeneity.

When means and standard deviations were not reported in the studies, we contacted the corresponding authors to obtain the unreported data. In the few cases in which a response was unavailable, the standard deviations were estimated using the formula suggested in the Cochrane Handbook for Systematic Reviews of Interventions.[21,31]

3. Results

3.1. Literature search

The initial literature search identified 2008 studies. Duplicates were first excluded, and the abstracts of the remaining studies were screened. Finally, 45 studies underwent full text review and 4 RCTs (with a total of 293 patients) that met all eligibility criteria were selected for this review. Figure 1 shows a flow diagram of the study screening procedure.

3.2. Study and patient characteristics

The 4 studies included in this meta-analysis were published from 2017 through 2020 (Table 1). Figure 2 shows the risk of bias of the included RCTs.

3.3. Clinical outcomes

ACL repair techniques used in the selected studies included DIS (3 studies) and BEAR (1 study). For ACL reconstruction, all 4 studies used 4-stranded hamstring tendon autografts.

In all 4 studies, over short-term follow-up (range of mean follow-up, 12–24 months), the repair groups and reconstruction groups were comparable with respect to IKDC (mean, [78.0–95.4] vs [84.0–96.6], $P = .84$), Lysholm score (mean, [89.8–90.0] vs [89.9–90.0], $P = .99$), Tegner activity score (mean, [5.8–7.0] vs [5.9–7.0], $P = .96$), VAS score (mean, [8.8–9.3] vs [8.4–9.1], $P = .42$), anterior laxity (mean, [1.6–1.9] vs

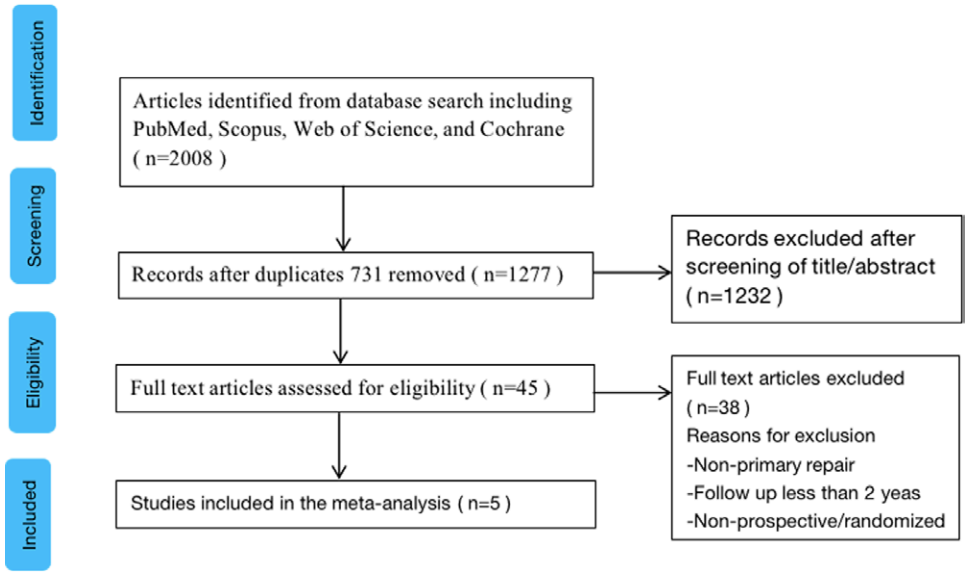

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) study selection flow diagram.

Table 1

Patient characteristics.

	Primary repairs					Reconstruction				
Author	**No.**	**Age**	**M/F**	**BMI**	**Follow-up (yr)**	**No.**	**Age**	**M/F**	**BMI**	**Follow up (yr)**
Engebretsen (1990)	50	28	29/21	NR	1	50	28	29/21	NR	1
Engebretsen' (1990)	50	28	29/21	NR	2	50	28	29/21	NR	2
Grontvedt (1996)	50	28	29/21	NR	5	50	28	29/21	NR	5
DrROGSET (2006)	33	28	NR	NR	16	36	28	NR	NR	16
Sporsheim (2019)	39	28	NR	NR	30	35	28	NR	NR	30
Schliemann (2017)	30	28	15/15	22.8	1	30	29	22/8	24.8	1
Hoogeslag (2019)	24	21	14/10	23	2	24	22	18/6	23.3	2
Kosters (2020)	43	28.7	25/18	23	2	42	27.6	31/11	24.6	2
Murray (2020)	65	17	28/37	24.7	2	35	17	16/19	23.3	2

BMI = body mass index, Follow-up = follow-up time after surgery, M/F = male:female ratio.

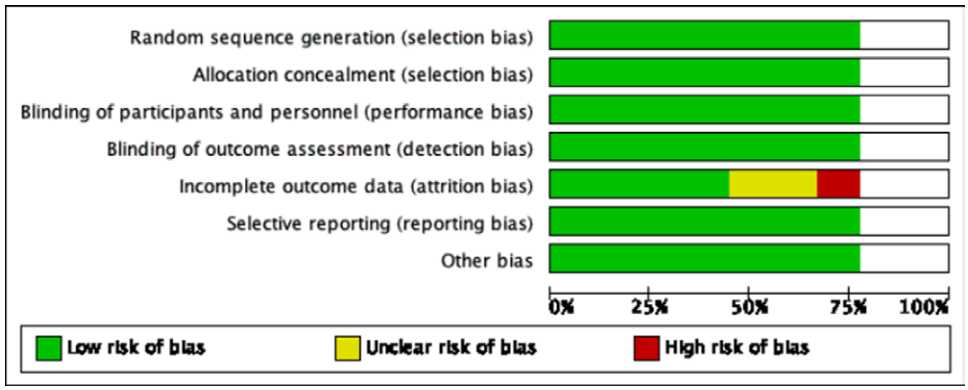

Figure 2. Risk of bias graph illustrates the proportion of included studies with each of the judgements "low risk," "high risk" "unclear risk" of bias) for each entry in the Cochrane "Risk of bias tool".

[0.9–1.8], $P = .17$), and Lachman (mean, [1.3–1.3] vs [1.0–1.6], $P = .84$) (Fig. 3–10). Revision rate ($P = .39$) and extension deficit ($P = .29$) were also similar.

Table 2 and Table 3 show the RTS data and complications of 4 RCTs by different graft type. Meanwhile, there was no difference between the repair group and the reconstruction group in 3 hop tests (single hop $P = .32$, triple hop $P = .27$, and side hop $P = .48$) (Fig. 11). StataCorp LLC, 4905 Lakeway Drive, College Station, TX was used to analyze the sensitivity of the above models, and the results were robust (Fig. 12).

4. Discussion

The purpose of this review and meta-analysis was to compare outcomes between patients undergoing primary repair of ACL and patients undergoing ACL reconstruction. To the best of our

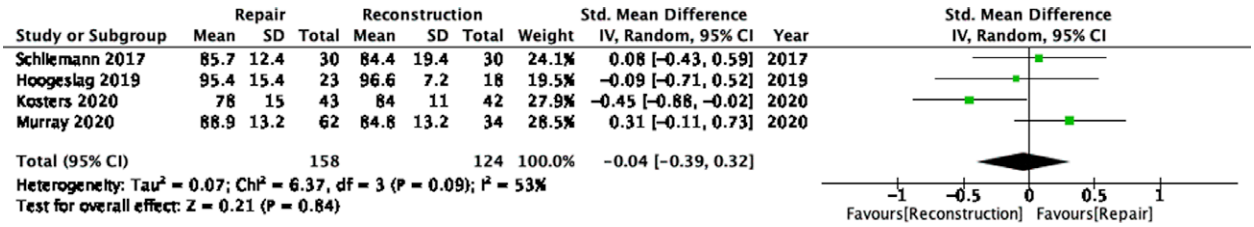

Figure 3. Forest plot of International Knee Documentation Committee (IKDC) score.

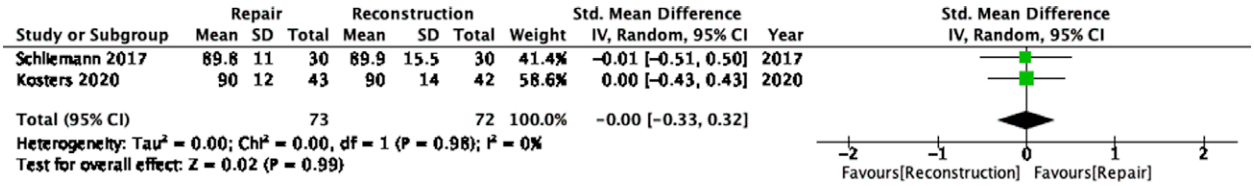

Figure 4. Forest plot of Lysholm score.

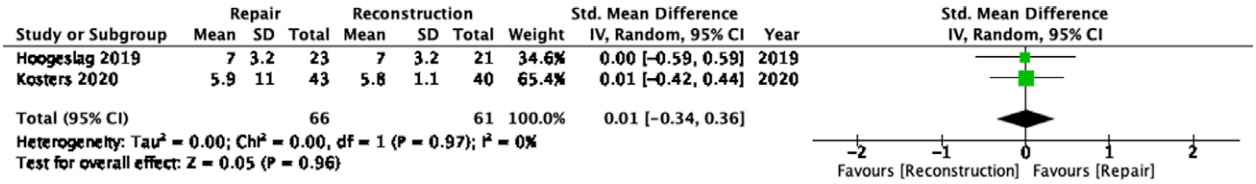

Figure 5. Forest plot of Tegner score.

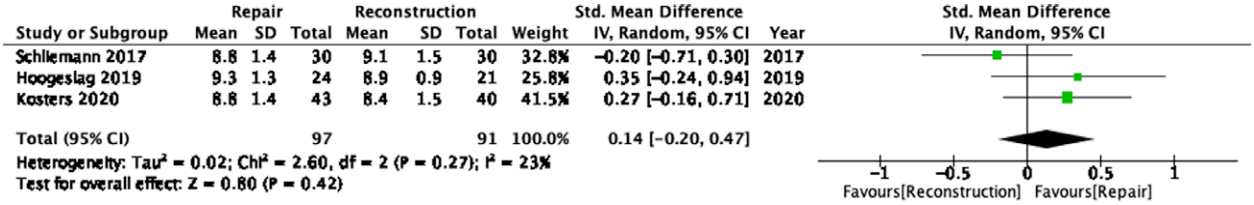

Figure 6. Forest plot of visual analog scale (VAS).

knowledge, this is the first study to compare outcomes with these 2 methods. A major strength of this systematic review is the inclusion of well-conducted clinical trials. All 4 studies used 4-stranded hamstring tendon autografts for reconstruction. Meanwhile, for ACL repair, 3 studies used the DIS technique and 1 study used the BEAR technique. Postoperative function, stability, and complications were compared between the 2 groups. RTS rate, which is an important factor in patients with ACL tears, was also compared. No significant differences were found in IKDC score, Lysholm score, Tegner score, pain VAS score, anterior laxity, and Lachman test between primary repair groups and reconstruction groups.

One prospective randomized study[12,32–34] that followed up for patients for 30 years was excluded from this meta-analysis since techniques have changed remarkably over the past 30 years. Interestingly, however, the study found no difference in function and stability between augmented repair groups and patellar tendon groups at follow-up 30 years after the surgery. Activity and functional levels at 16 years were higher in patients who had repair with bone-patellar tendon-bone graft than in the other 2 repair groups. Knees that had had repair with a patellar-ligament graft were significantly more stable than knees that underwent repair with a ligament-augmentation device. We assume that the major factors responsible for these differences may be the surgical techniques and primary repair devices used in the 1990s. Generally, contemporary repair techniques for ACL tears are considered noninferior to ACL reconstruction techniques. Arthroscopic primary ACL reconstruction is now recognized as the gold standard treatment for ACL injury as it is a cost-effective treatment and ensures better recovery of strength. However, many deficiencies have also been reported.[6,13–15] We hypothesized that contemporary ACL suture repair techniques[35–37] could be effective alternative treatments for ACL injury.

We found no significant differences in complications, including extension deficit and revision rate, between patients undergoing ACL repair and patients undergoing ACL reconstruction. The low revision rate after primary repair is particularly encouraging. Currently, for young patients, ACL reconstruction is often preferred over primary repair because some studies have reported higher revision rate and extension deficit with the latter. However, our study confirmed that short-term complications are similarly low with primary repair and with reconstruction. One prospective randomized study with long-term follow-up[12,32–34] found no significant differences in complications (infection, crepitation, and venous thrombus) at 2 years after surgery between patients undergoing repair versus reconstruction. The revision rate was 10 times higher in non-augmented repair groups than in groups that had repair with bone-patellar tendon-bone graft ($P = .003$) at 16 years after surgery, but the

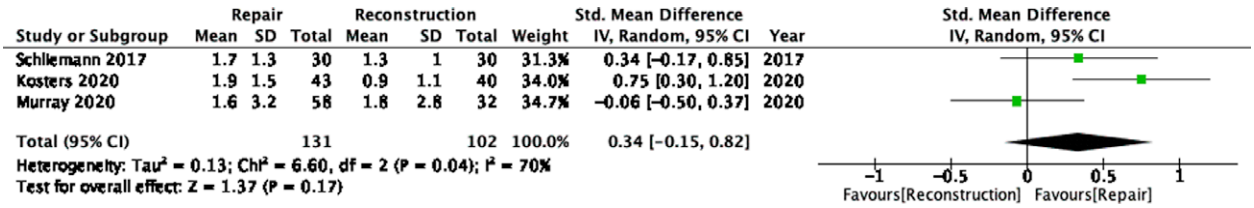

Figure 7. Forest plot of anterior laxity.

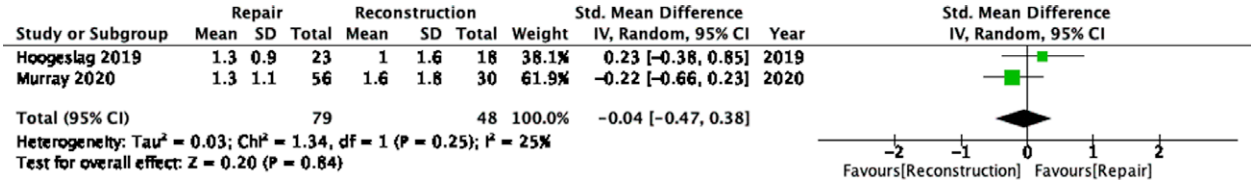

Figure 8. Forest plot of Lachman test.

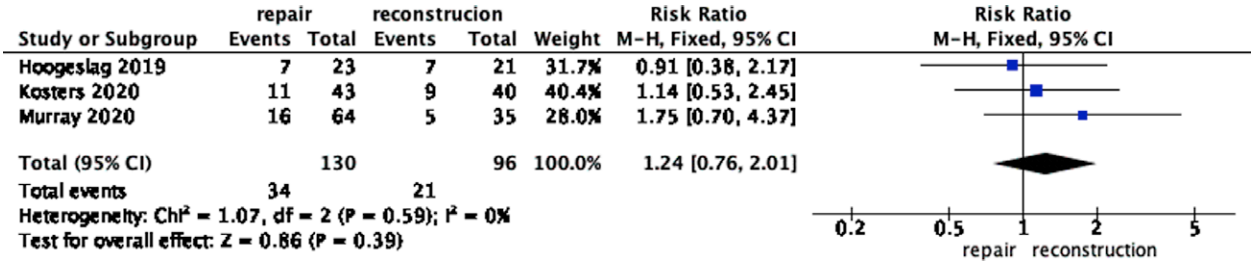

Figure 9. Forest plot of revision rate.

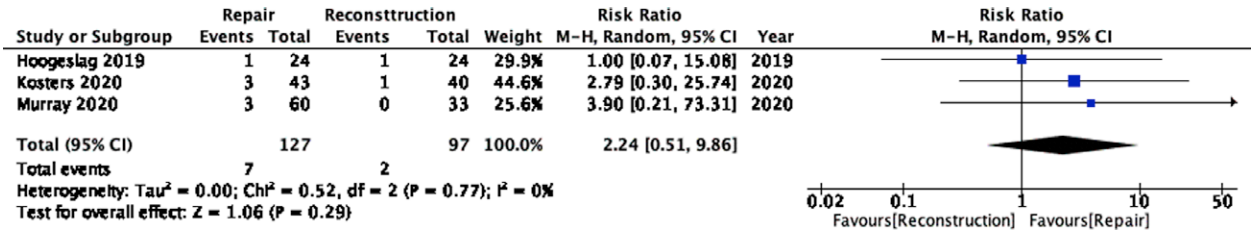

Figure 10. Forest plot of extension deficit.

revision rate was not significantly different between augmented repair groups and reconstruction groups ($P = .17$).

In our study there was no significant difference in the anterior laxity between the repair and reconstruction groups (0.9 mm–1.9 mm). Our finding is consistent with Schliemann et al[38] and Murray et al[39]; however, Kosters et al[40] found that anterior tibial translation was significantly greater in patient receiving DIS than in patients receiving ACL reconstruction (1.9 mm–0.9 mm, $P = .01$), though clinical failure (>3 mm) was similar in both groups. All 4 studies in our review[12,32–34] agreed that primary anterior laxity was significantly greater in the repair groups at 2 and 5 years ($P < .001$). Measurement error cannot be ruled out. The greater laxity may be related to the plastic deformity that the native ACL suffered at the time of injury. More data is needed to assess the level of stability.

We found no difference in the Lachman test between the repair and reconstruction groups (1 mm–1.6mm). Anterior stability in 20° of flexion was tested by the Lachman test and graded as negative, slight (1+, <5 mm), moderate (2+, 5–10 mm), or severe (3+, >10 mm). Our finding was consistent with Murray et al[33] and Hoogeslag et al.[41] However, the prospective study initiated in the 1990s[12,32–34] found that at 16 years after surgery, stability was better in patients undergoing reconstruction than in patients undergoing repair with a ligament augmentation device. There could be several reasons for the difference in conclusions. First, the statistics were treated with continuous and dichotomous ways could lead to measurement error. Second, current suture repair methods (DIS and BEAR) are vastly superior to the methods used in the 90s and can ensure levels of function and stability comparable to that achieved with reconstruction. DIS ensures better stability by preserving viable ligament tissue and sensory pathways. Meanwhile, BEAR involves implantation of autologous blood in the gap between the 2 torn ends of the torn ACL, along with suture repair of the ligament and a cinch suture to maintain reduction of the tibiofemoral joint. Third, surgical and rehabilitation protocols have also improved with time.

We found no significant difference in performance of the hop tests between the repair and reconstruction groups. Functional hop test is commonly employed for assessment of patients after ACL surgery and is often reported via a limb symmetry index (LSI), which is a measure of function of the operated limb as a percentage of the non-operated limb. According to literature, LSI ≥90% is considered normal. In our study, performance of the single, triple, and side hop tests were comparable in both

Table 2

Return to sport (RTS) data and complications by graft type.

Literature source (authors and yr)	LOE (level of evidence)	Graft type	No. (repair: reconstruction)	M:F sex, n	Age at surgery, yr	Follow-up, mo	Rate of return to preinjury levels, % (n)	Rerupture rate, % (n)	Adverse events
Hoogeslag (2019)	1	HT:DIS	80 (24:24)	32:16	21 (10–27)	24	87 (20):77.8 (14)	8.7 (2):19 (4)	73.9 (17):57.1 (12)
Murray (2020)	1	HT:BEAR	100 (65:35)	44:56	17 (16–23)	24	19 (38):11 (44)	14.1 (9):5.7 (2)	29.7 (19):20.0 (7)
Schliemann (2017)	1	HT:DIS	60 (30:30)	37:23	28 (17–42)	12	58.3 (17):42.99 (12)	NR	NR
Kosters (2020)	1	HT:DIS	85 (43:42)	56:29	28 (17–41)	24	83.7 (7):12.5 (5)	NR	25.6 (11):22.5 (9)

Adverse events include re-rupture, repeat surgery, abnormal symptoms, extension deficit, and so on.

BEAR = bridge-enhanced anterior cruciate ligament repair, DIS = dynamic intraligamentary stabilization technique, HT = hamstring tendon, M:F = male:female ratio.

Table 3

Pooled demographic data and complication rates.

Graft type	No	M:F sex, n	Age, yr	Follow-up, mo	Rate of return to preinjury levels, % (n)	Rerupture rate, % (n)	Adverse events
Repair	162	82:80	22.7	21	50.6 (82)	12.4 (11)	35.6 (47)
Reconstruction	131	87:44	24.1	21	57.3 (75)	10.2 (6)	27.7 (28)
Overall	293	169:124	23.3	21	53.6	11.5 (17)	32.2 (75)

M:F = male:female ratio.

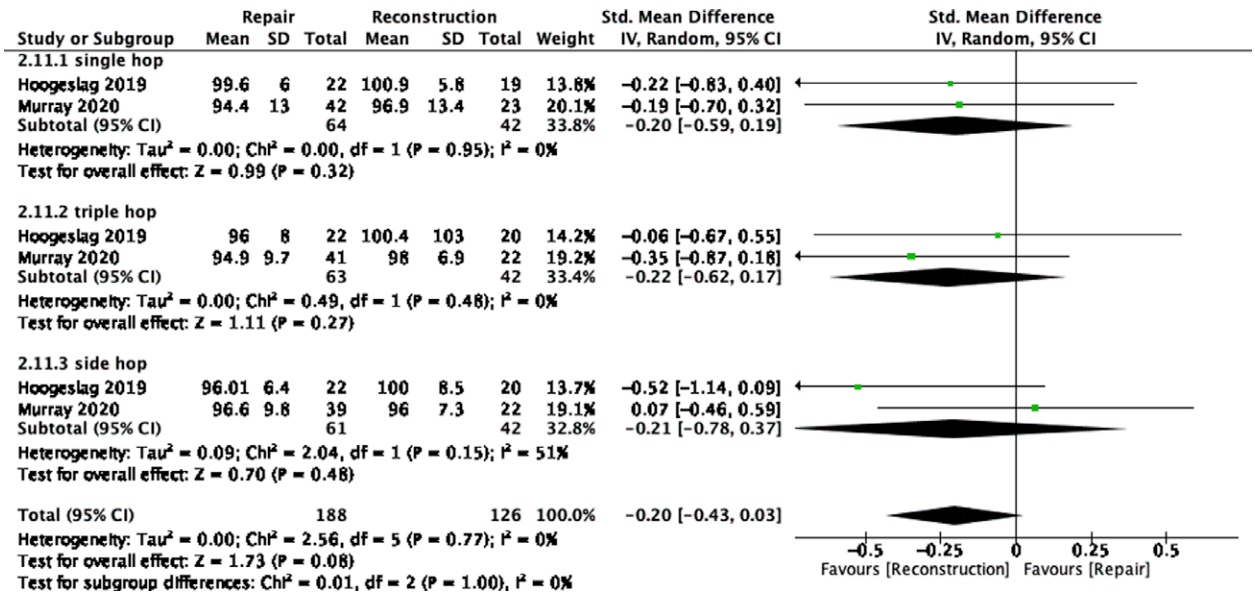

Figure 11. Forest plot of hop tests.

groups, and the mean of each test was >90%. One prospective study[12,29–31] evaluated the isokinetic muscle strength at 5 years after surgery for injury of ACL and reported that the values for peak torque in extension at 60°/s were comparable between patients receiving augmented repair and those receiving reconstruction. Satisfactory performance in the hop tests is associated with successful return to preinjury level of sport. Comparable postoperative complications, no harvest site morbidity, faster postoperative recovery, and less postoperative pain are the major advantages of current primary repair techniques for ACL injury.

KOOS-quality of life (QoL) and muscle strength were used as part of the RTS criteria. Hoogeslag et al[41] found no differences in KOOS-QoL and pain scores between patients undergoing repair and patients undergoing reconstruction; KOOS-QoL ranged from 95 to 100 points in both groups at 2 years. Further, there were no differences in muscle strength of the quadriceps and hamstring at angular velocities of 60°/s, 180°/s, and 300°/s. Schliemann et al[38] reported that early functional results and changes in gait pattern after DIS are comparable to those after ACL reconstruction. Murray et al[39] showed that patients receiving BEAR, when tested by dynamometer at 90° of flexion, had significantly higher mean hamstring muscle strength index than patients receiving ACL reconstruction with 4-stranded hamstring tendon autografts at 2 years (98.2% vs 63.2%, $P < .001$). In our study, while the levels of LSI and KOOS-QoL were high, the RTS rate was low in the 2 groups (50% and 57%, respectively); this may have been because the follow-up period was too short. The discordance between LSI/KOOS-QoL and RTS rate in our study could have several explanations. First, as Wellstandt et al[42] have reported, LSI can overestimate knee function in patients after ACL injury. Second, both physical and psychological are involved in the assessment; Webster et al[43] reported that patients having higher psychological readiness show significantly greater limb symmetry ($P < .05$).

In our study, the subjective IKDC score ranged from 78 to 96.6 and was not significantly different between the 2 groups.

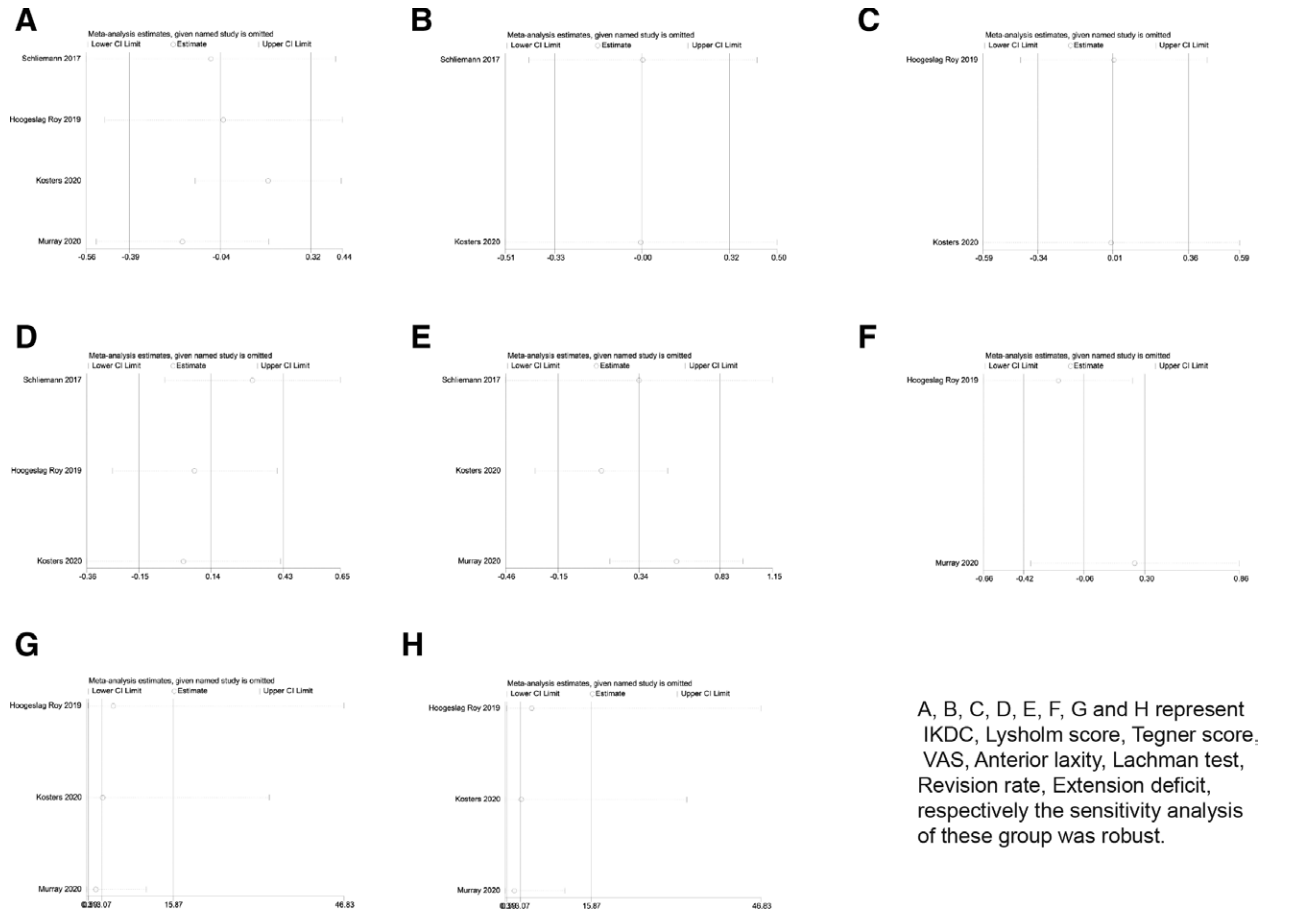

Figure 12. Sensitivity analysis. A, B, C, D, E, F, G, and H represent International Knee Documentation Committee score, Lysholm score, Tegner score, visual analog scale score, anterior laxity, Lachman test, revision rate, and extension deficit, respectively. The sensitivity analysis of these groups was robust.

According to Irrgang et al,[44] IKDC reflects the improvement after knee surgery. The results were consistent across the 4 RCTs, confirming that repair is comparable to reconstruction with regard to outcomes.

The Lysholm functional score, which ranged from 89.8 to 90, was not significantly different between the 2 groups in our study. This finding is consistent with the results reported by Schliemann et al[38] and Kosters et al[42] at 1 year in their respective studies. The prospective trial with follow-up of 30 years[12,32–34] found significant improvement in Lysholm score (almost 90 points) in patients treated with both ligament-augmentation device and bone-patellar ligament-bone graft. However, the Lysholm score decreased significantly from 90 points at 1 year to 86.7 points at 2 years in patients treated with non-augmented repair and, at the end of the 5th year, 11 of the remaining 41 patients (27%) still had poor functional scores (0–83 points). This is indirect confirmation that non-augmented repair is associated with high risks of re-rupture and revision. Interestingly, differences were not detected from 16 years to 30 years (88.0–76.0 points). This may have been because of less engagement in sports activities as age increased, as well as degradation of the ACL. Thus, overall, no significant difference was seen in Lysholm score between patients receiving primary augmented repair versus autograft.

In our study, the Tegner score, which ranged from 5.9 to 7.0, was not significantly different between the 2 groups. Hoogeslag et al[41] reported that 58.3% patients undergoing ACL repair and 42.9% undergoing ACL reconstruction in their study returned to their previous Tegner level at 1 year, and more than half of the patients in both groups returned to their previous Tegner level at 2 years. However, the prospective study with long-term follow-up[12,32–34] reported that the Tegner score remained unchanged (4.8 points) at 2 years in patients who received non-augmented repair but increased slightly (6.0 points) in patients who underwent reconstruction. However, the Tegner scores were comparable at 5 years. We believe that this is because current repair techniques promote early healing.

The VAS score, which ranged from 8.4 to 9.3 at 2 years, was not significantly different between the 2 groups in our study. This finding is consistent with the conclusions of Schliemann et al,[38] Kosters et al,[40] and Hoogeslag et al.[41] VAS scores reflect the level of satisfaction with the outcome of surgery. The high VAS scores in the 2 groups show that patients in both groups were satisfied with postoperative function level.

In this study, we concluded that repair techniques may be a good alternative to reconstruction for injury of ACL. Vermeijden et al[45] showed that ACL repair and ACL reconstruction lead to similar functional outcomes. However, patients undergoing primary repair suffer less pain and have earlier range-of-motion return and faster rehabilitation progression. The differences in outcome between repair and reconstruction of ACL injury needs further study. Particularly, the effect of different techniques on RTS rate and proprioceptive function need to be investigated in future studies.

There are several limitations in this study. First, although 4 studies were added in this study since the latest systematic review, potential bias and confounding factors cannot be completely avoided. We therefore subtly and indirectly compared the statistics of a follow-up study to explore as much as possible the effect of potential bias on the study conclusions. Second, even though all the selected studies were good-quality studies with low risk of bias, the data were not standardized across the 4

studies. Third, function, stability, complications, proprioceptive function, and RTS rate were not fully reported in all of the studies. Fourth, the lack of standard evaluation criteria such as RTS rate, 90% cutoff to different hop tests may not be applicable.

5. Conclusion

Primary repair of ACL injury using current techniques may be a reliable alternative to ACL reconstruction. It seems capable of providing equivalent outcomes in terms of function, stability, complication rates, and RTS at 2 years.

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Author contributions

Zhenli Shen, Hang Chen, and Mengmeng Ye designed the study. Zhenli Shen and Zetian Gao, Hongxiang Li, and Haoxuan Lu collected, analyzed, and interpreted the data. Guodong Xu, Zeyang Hu, Wei Shen and Shuguang Xu wrote the manuscript. Qidong Ye critically reviewed, edited, and approved the manuscript.

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