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SYSTEMATIC REVIEW

Meta-analysis of Randomized Controlled Trials: Comparing Standard versus Stump-preserving Techniques in Anterior Cruciate Ligament Reconstruction Using An Autologous Hamstring Graft

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ABSTRACT

Background. Anterior cruciate ligament (ACL) injuries are prevalent among younger demographics due to sports-related incidents, contributing to knee joint instability. Current anterior cruciate ligament reconstruction (ACLR) involves either debriding the stump (standard) or preserving the stump (stump-preserving), which retains the vascular network and mechanoreceptors in the tibial stump, aiming to improve postoperative outcomes. The autologous hamstring tendon graft is the most used, providing a higher maximum load to failure than bone-patellar tendon-bone grafts.

Objective. This meta-analysis aimed to compare outcomes between the standard and stump-preserving ACLR techniques using an autologous hamstring tendon graft. The specific objectives were to evaluate primary outcomes (Lysholm Scores and the KT-1000 Arthrometer results), secondary outcomes (International Knee Documentation Committee (IKDC) Scores, results of the Lachman and pivot shift tests), and postoperative complications.

Methodology. The authors comprehensively searched PubMed, Embase, Cochrane Library, and grey literature, identifying randomized controlled trials meeting the inclusion criteria. Study characteristics and participant information were extracted, and potential bias was assessed using the Cochrane Collaboration methodology.

Result. Ten studies, encompassing 552 patients, met the inclusion criteria. Lysholm score and KT-1000 arthrometer results favored the stump-preserving group, achieving statistical significance. IKDC, pivot shift test and Lachman test favored the stump-preserving group, without statistical significance. Postoperative complications exhibited a higher incidence in the stump-preserving group, favoring the standard group, without statistical significance.

Conclusion. The meta-analysis suggested advantages in outcomes for stump-preserving ACLR, achieving statistical significance for the Lysholm scores and the KT-1000 arthrometer results. The stump-preserving group had better results in the IKDC scores, the pivot shift test results and the Lachman test results, while the standard group had fewer postoperative complications, but statistical significance was not achieved. In conclusion, while stump-preserving ACLR demonstrated promising trends in enhancing postoperative outcomes, further studies are necessary.

Keywords. anterior cruciate ligament reconstruction, ACL, stump, preservation, stump-preserving, remnant

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INTRODUCTION

The anterior and posterior cruciate ligaments work in tandem to prevent excessive anterior and posterior movement of the tibia relative to the femur. The anterior cruciate ligament (ACL) also provides rotational stability.[1] The anterior cruciate ligament (ACL) injury is one of the most common knee injuries worldwide. An ACL rupture or tear can occur with both contact and non-contact injuries and is often caused by knee hyperextension or a sudden change in direction.[2]

ACL injuries are generally seen in the younger population, especially those 20–24 years old. Sports-related injuries are more often seen in females while the overall incidence is higher in males.[3-4] In contrast to developed countries, in developing countries, road traffic accidents are the leading cause.[5]

The nonviability of the frayed edges of the injured ACL precludes successful repair. Anterior cruciate ligament reconstruction (ACLR) is the mainstay of management. For a primary ACLR, approximately 90% of the time, single-bundle reconstruction is performed. The hamstring tendon was the most used autograft at 53%, followed by the bone-patellar tendon-bone (BPTB) graft at 36%,[6] both being the gold standard for the younger population.[7] The standard or conventional ACLR technique involves debridement of the ACL stump before placement of the autograft.

In recent years, the stump-preserving technique has received more attention, but studies are few, with small populations and short follow-up periods. Preserving the ACL stump may promote cell proliferation, healing, and improved proprioception due to the presence of a vascular network and viable mechanoreceptors.[8-12] Takahashi et al. concluded that preserving the ACL remnant enhanced the overall cell proliferation, cell vascularization, and regeneration of the proprioceptive organs in the ACL graft, and ultimately reduced anterior tibial translation.[13-16] This was further supported by Gohil et al., who noticed increased tissue intensity on Magnetic Resonance Imaging (MRI), suggesting earlier revascularization.[17] The stump may also be used as a landmark for the placement of the autograft.[18] Current practice largely depends on the surgeon's preference.

The cyclops lesion was described by Jackson and Schaeffer in 1990 as an incidental finding of a fibrous nodule of granulation tissue anterior to the graft.[19-21] This occurred in 3.9% of patients who underwent stump-preserving ACLR.[20-24] Most cases are asymptomatic, but symptomatic lesions can be surgically excised.[24-28]

Previous meta-analyses by Wang et al. and Allende et al. have studied this topic. However, there is concerning heterogeneity in the studies and variability among the grafts used (inclusion of grafts other than autologous hamstring).[29,30]

We investigated whether individuals who underwent ACL stump-preserving techniques had better patient-reported outcomes compared to the traditional standard ACL reconstruction. Specifically, we used the following outcomes: 1) the Lysholm score, which assesses subjective knee-specific symptoms; 2) the measurement of anterior tibial translation using the KT-1000 Arthrometer; 3) the International Knee Documentation Committee (IKDC) score, which subjectively measures functional outcomes; 4) the Lachman test, which also passively tests anterior tibial translation; 5) the pivot shift test, a dynamic test of the knee to assess rotational instability, and 6) the prevalence of postoperative complications.

Our rationale was to establish whether the stump-preserving technique's theoretical anatomic and physiological benefits translate into measurable clinical improvement in terms of patient-reported outcomes and objective measurements. To address existing limitations, we focused exclusively on randomized controlled trials using autologous hamstring grafts. We assessed both functional outcome scores and objective measurements for a comprehensive evaluation.

OBJECTIVES

General objective

The study aimed to evaluate the effectiveness of ACL reconstruction using the stump-preserving technique compared to the standard technique.

Specific objectives

1. Evaluate the Lysholm score to assess knee function and symptoms
2. Measure anterior tibial translation using the KT-1000 Arthrometer
3. Assess overall knee function using the IKDC Score
4. Evaluate anterior knee laxity with the Lachman and pivot shift tests
5. Monitor and document any postoperative complications, including the incidence of cyclops lesions, to compare the safety

METHODOLOGY

Search strategy

A comprehensive search of literature in PubMed, Embase, Cochrane Library, and grey literature was performed. Studies published from 2007 to 2024 were considered for meta-analysis. The initial search began in August 2024, and then a more comprehensive search was conducted between November and December 2024. Search terms include "anterior cruciate ligament reconstruction," "ACL," "stump," and "remnant." The Boolean terms "OR" and "AND" were applied along with the search terms in the PubMed database for randomized controlled trials, as follows "remnant OR stump" AND "anterior cruciate ligament reconstruction" AND "ACL," which resulted in four hundred thirty-five studies.

Inclusion and exclusion criteria

We included randomized controlled trials comparing the standard ACLR technique and the stump-preserving ACLR technique in humans using autologous hamstring grafts. Studies must have had a minimum of six months of follow-up with documentation of the Lysholm scores, KT-1000 arthrometer results, IKDC scores, Lachman test results, pivot shift test results and incidence of postoperative complications for both techniques. Non-comparative clinical trials, studies using any graft other than an autologous hamstring allograft, animal experiments, retrospective studies, reviews, case reports, and non-English language publications were excluded.

Risk of bias assessment

The researchers evaluated potential bias using the Cochrane Handbook for Systematic Reviews of Interventions criteria. The following domains were examined: bias related to the randomization process, bias resulting from deviations from intended interventions, bias due to missing outcome data, bias in outcome measurement, bias in result selection, and any other sources of bias.

Each potential source of bias was categorized as "high," "low," or "some concerns," and presented in a "Risk of Bias" table. The researchers provided a summary of the "Risk of Bias" judgments across the various studies for each of the specified domains. An overall assessment, categorized as low risk of bias, some concerns, or high risk of bias, was assigned to each study. The researchers did not exclude studies based on their potential for bias.

Data extraction

The researchers extracted data on study characteristics (such as publication year, author names, study countries, study duration, and participant withdrawals), as well as participant information (comprising sample size, age, sex, and inclusion and exclusion criteria).

Outcomes

The outcomes of the studies that were included were the postoperative Lysholm score, the KT-1000 Arthrometer, the IKDC score, the Lachman test, the pivot shift test, and the incidence of postoperative complications.

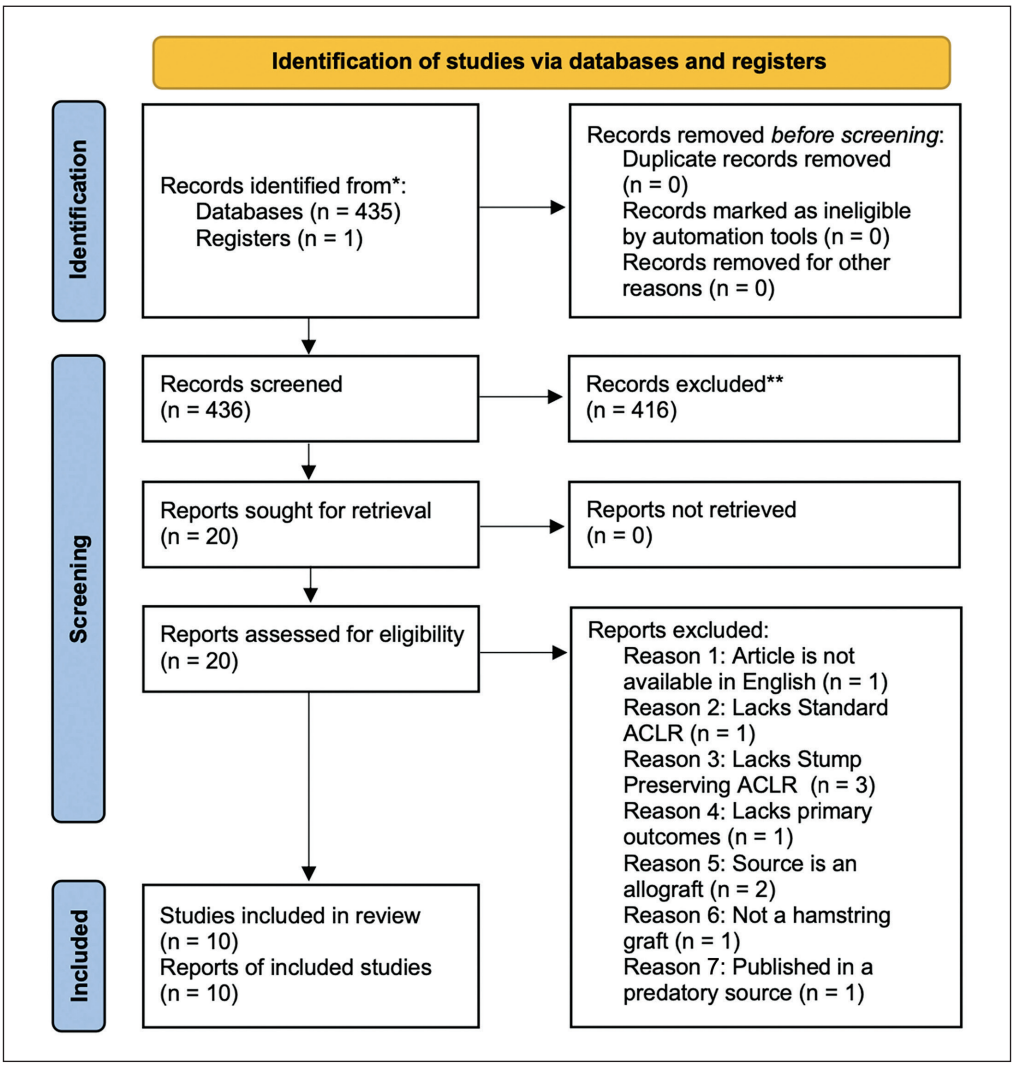

Figure 1. Systematic selection of articles.

Assessment of heterogeneity

Heterogeneity was assessed using the Chi-square test and I^2 Index. An I^2 of less than 50% indicates no statistical heterogeneity between studies while an I^2 of greater than 50% indicates statistical heterogeneity.

Statistical analysis

Data synthesis and analysis were conducted using RevMan 5.4 software. A Forest plot was generated to tabulate and visually represent the data from the selected studies.

This study was conducted by four members of the Department of Orthopaedic Surgery at Veterans Memorial Medical Center, including a Fellow of the Philippine Orthopaedic Society of Sports Medicine and a Fellow of the Philippine Orthopaedic Association. Disagreements between the researchers were settled by a majority vote.

RESULTS

Using the search terms above, 435 records were retrieved from PubMed, Embase, and Cochrane Library, and one published record was retrieved from a different source (Figure 1). After screening the titles and abstracts, twenty articles fulfilled the criteria. We excluded ten studies for the following reasons: one study was not available in English, one study lacked the Standard ACLR, three studies lacked the Stump Preserving ACLR, one study lacked the primary outcomes, two studies utilized a hamstring allograft, one study utilized a bone patellar tendon bone graft, and one study was published in a predatory source. A total of ten studies were assessed to be eligible and were included in this research.

All ten studies demonstrated a low risk of selective reporting bias, with most studies also showing a low risk of detection and attrition bias regarding blinding of outcome assessment and handling of incomplete outcome data (Figures 2 and 3). However, there were notable concerns regarding selection bias in most studies, particularly related to random sequence generation and allocation concealment. Additionally, the studies exhibited possible performance bias due to limitations in the blinding process, and other sources of bias partly due to the sample sizes involved.

A total of 552 patients were included, with 283 patients in the standard ACLR group (Group A) and 269 patients in the stump-preserving group (Table 1). Years of publication ranged from 2012 to 2022 (Table 2). Six studies reported Lysholm scores, six studies used the KT-100 arthrometer, three studies reported IKDC scores, two studies reported Lachman test, and three studies reported the pivot shift test results and the incidence of postoperative complications.

The pooled difference of -1.15 of the Lysholm score (95% CI [-2.06, -0.25], p = 0.01, I2 0%) favored stump-preserving ACLR (Figure 4). This difference was statistically significant.

The pooled KT-100 arthrometer measurement was 0.28 (95% CI [0.13, 0.43], p = 0.002, I2 54%), indicating greater postoperative laxity in the standard ACLR group (Figure 5). The difference was statistically significant.

The pooled IKDC score was 0.73 (95% CI [0.39, 1.35], p = 0.31, I^2 60%), favoring the stump-preserving group, but not achieving statistical significance (Figure 6).

The pooled Lachman test result was 1.46 (95% CI [0.54, 3.96], p = 0.45, I2 0%) indicating greater postoperative laxity in the standard ACLR group, without achieving statistical significance (Figure 7).

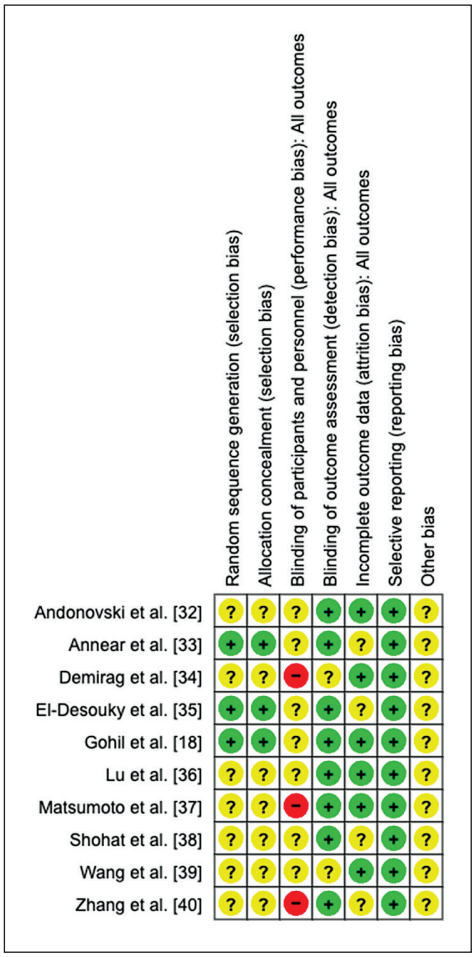

Figure 3. Individual risk of bias assessment.

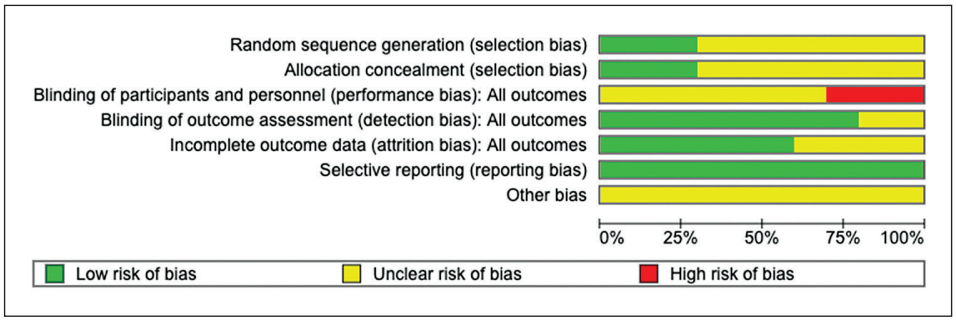

Figure 2. Overall risk of bias assessment.

The pooled pivot shift test result was 1.17 (95% CI [0.39, 3.48], p = 0.78, I2 0%), which indicates greater postoperative laxity in the standard group, without statistical significance (Figure 8). In the three studies that reported complications, 22 complications occurred in the 98 cases in the standard group and 28 complications occurred in the 100 cases in the stump-preserving group. The pooled result was 0.69 (95% CI [0.35, 1.37], p = 0.29, I2 0%) indicating a greater incidence of postoperative complications in the stump-preserving group, without statistical significance (Figure 9).

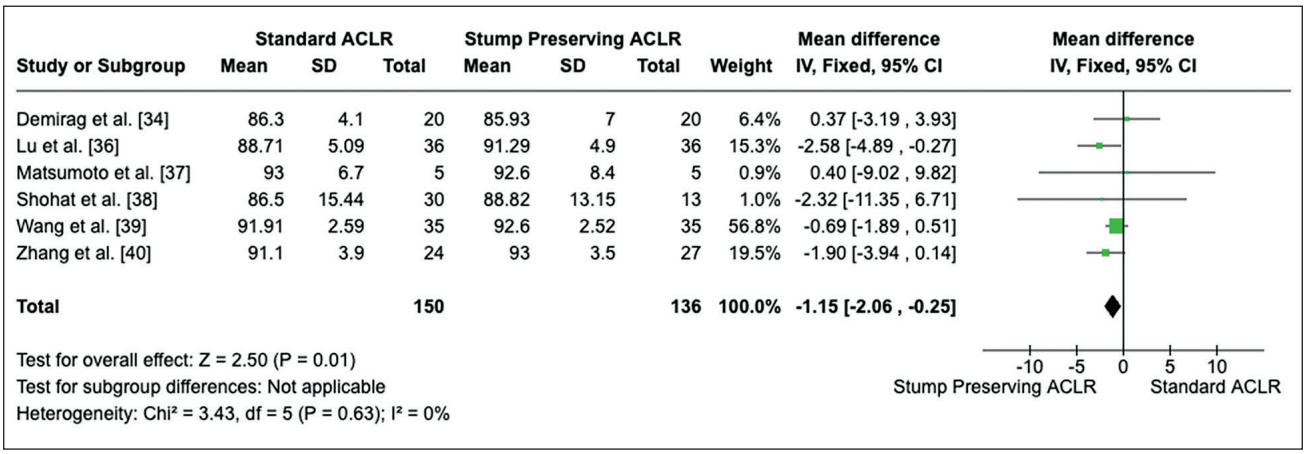

Figure 4. Forest plot for the Lysholm scores.

CI: Confidence Interval; IV: Inverse Variance.

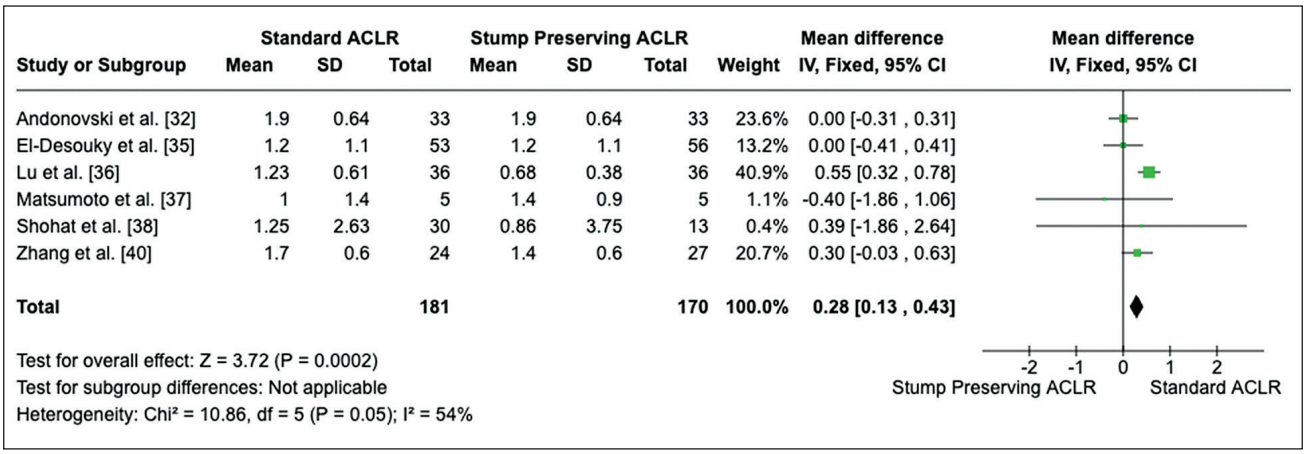

Figure 5. Forest plot for the KT-1000 arthrometer.

CI: Confidence Interval; IV: Inverse Variance.

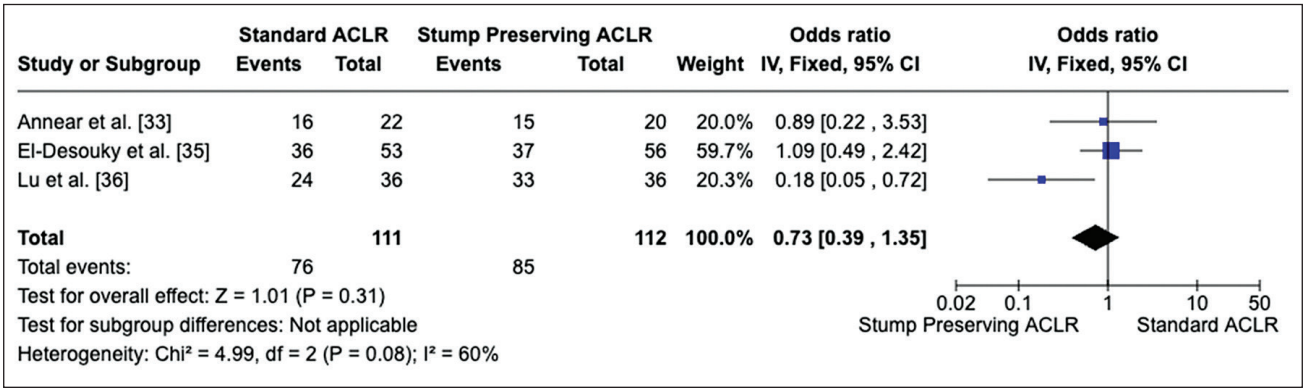

Figure 6. Forest plot for the IKDC score.

CI: Confidence Interval; MH: Mantel-Haenszel.

DISCUSSION

The principal findings of this meta-analysis were as follows: 1) Stump-preserving ACLR resulted in higher Lysholm Scores, with the difference being statistically significant. 2) Stump-preserving ACLR resulted in less postoperative anteroposterior knee laxity as measured by the KT-100 arthrometer, with the difference being statistically significant. 3) Stump-preserving ACLR resulted in superior IKDC scores, however the difference was not statistically significant. 4) Stump-preserving ACLR had less postoperative laxity as measured by the Lachman test and the pivot shift test, with the difference not being statistically significant. 5) Stump-preserving ACLR resulted in more postoperative complications, with the difference not being statistically significant.

Table 1. Study data characteristics

Study	Patients	Follow-up	Outcome Measure	Results	Complications	Conclusion
***Andonovski et al*[32]**	Group A: 33 Group B: 33	6-8 months	KT-1000, *Lysholm Score, *Tegner Activity Score	Statistically significant postoperative improvement in anteroposterior knee stability, favoring Group B. Improvement in Lysholm Score and Tegner Activity for Group B, however, significance was not mentioned.	N/A	The stump-preserving technique provides better anteroposterior knee stability and a better proprioceptive function.
***Annear et al*[33]**	Group A: 22 Group B: 20	10 years	IKDC Score	No significant difference in IKDC scores.	N/A	No long-term clinical. the benefit of remnant preserved ACLR
***Demirag et al*[34]**	Group A: 20 Group B: 20	24.3 months	*IKDC Score, Lysholm Score, Lachman, Pivot Shift Test, Cyclops Lesion	IKDC and Lysholm scores improved, however not significant, favoring Group B.	Cyclops lesion (Group B: 1) Arthrofibrosis (Group A: 7; Group B: 7)	The stump-preserving technique is comparable to the standard technique concerning clinical. outcome and complications
***El-Desouky et al*[35]**	Group A: 53 Group B: 56	24 months	IKDC Score, *Lysholm and Tegner Activity scores, and KT-1000, Cyclops Lesion	No significant difference between Group A and B for the IKDC, Lysholm, and Tegner Activity scores	Infection (Group B: 1) Hematoma (Group A: 2; Group B: 3) Quadriceps wasting (Group A: 3; Group B: 3) DVT (Group A: 1)	Stump preserving had better IKDC, Lysholm, and Tegner Activity scores, however it did not achieve statistical. significance. KT-1000 assessment reveal. ed no statistical. significance between the two groups.
***Gohil et al*[18]**	Group A: 25 Group B: 24	12 months	*KT-1000, *IKDC Score, Cyclops Lesion, *Lachman Test	No significant difference between the KT-1000 measurement, IKDC Score, Cyclops Lesion, and Lachman Test.	Cyclops lesion (Group A: 9) Group B: 13)	Minimal debridement leads to earlier revascularization, accelerating the strength of recovery.
***Lu et al*[36]**	Group A: 36 Group B: 36	24 months	KT-1000, *Tegner Activity Score, Lysholm Score, IKDC Score, Pivot Shift Test	A significant difference in KT-2000 arthrometer measurement and Lysholm scores, favoring Group B.	Knee Instability (Group A: 2)	ACLR utilizing the existing remnant footprint shows superior postoperative results in anteroposterior laxity, functional outcome scoring, ROM recovery, and revision cases.
***Matsumoto et al*[37]**	Group A: 5 Group B: 5	24 months	Lysholm Score, KT-1000, Pivot Shift Test	No significant difference between Group A and B for the Lysholm Score, KT-1000 assessment, and the Pivot Shift Test	N/A	No significant difference between the clinical outcomes of stump-preserving and the standard ACLR technique.
***Shohat et al*[38]**	Group A: 30 Group B: 13	24 months	*Knee Society Score (KSS), *Visual Analog Scale (VAS), Lysholm Score, *Tegner Activity Score, *Short Form Health Survey 36, KT-1000, *Thigh and Calf Circumference Measurement	No significant difference in functional outcome scores, VAS, or KSS. KT-1000 arthrometer measurements favored Group B, however not statistically significant.	N/A	No statistically significant difference between the two groups, however further studies are required on a larger group of patients.
***Wang et al*[39]**	Group A: 35 Group B: 35	12 months	Lysholm Score, *IKDC Score, Lachman Test,	Lysholm and IKDC scores were superior in Group B, but the difference was not statistically significant.	N/A	Utilizing the modified Crain classification, remnant preserving techniques can be used to preserve the remnant ligament tissue to improve knee joint function and joint stability with few complications.
***Zhang et al*[40]**	Group A: 24 Group B: 27	24.5 months	Lysholm Score, KT-1000	The Lysholm Score for Group B had a higher increase however it was not statistically significant. The difference between the KT-1000 assessment was not statistically significant.	N/A	Stump preservation does not affect short-term clinical outcomes even though there are higher Lysholm Scores and better knee laxity.

Group A = Standard ACLR; Group B = Stump Preserving ACLR; IKDC = International Knee Documentation Committee; KT- 1000/2000 = Knee Arthrometer; N/A = Not applicable; *Not included in the study

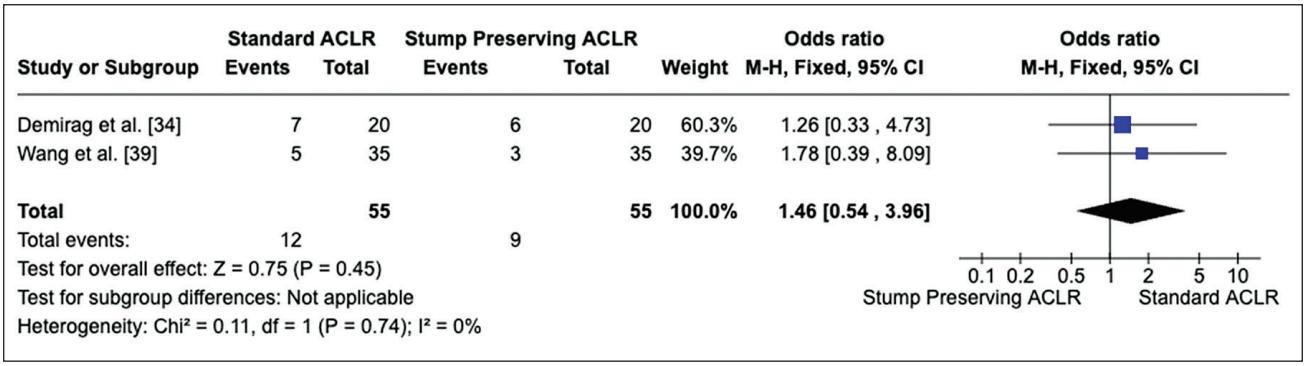

Figure 7. Forest plot for the Lachman test.

CI: Confidence Interval; MH: Mantel-Haenszel.

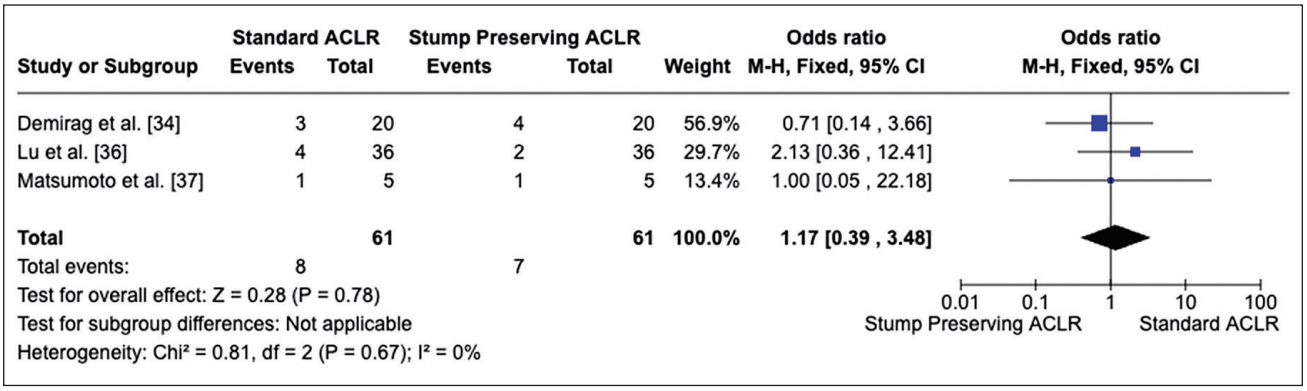

Figure 8. Forest plot for the pivot shift test.

CI: Confidence Interval; MH: Mantel-Haenszel.

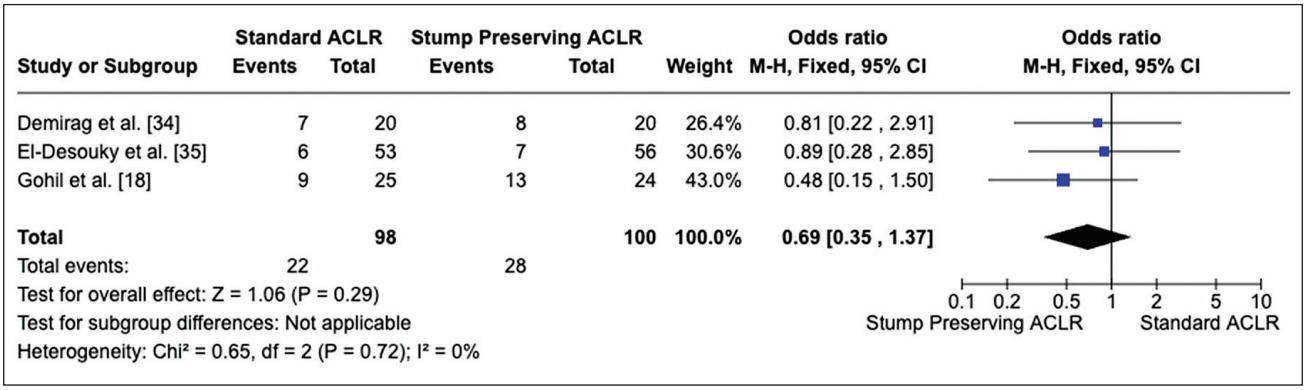

Figure 9. Forest plot for the postoperative complications.

CI: Confidence Interval; MH: Mantel-Haenszel.

Table 2. Study characteristics

Study	Publication Year	Country	Type of Study	Level Evidence
Andonovski et al.[32]	2017	Macedonia	Randomized Controlled Trial	II
Annear et al.[33]	2018	Australia	Randomized Controlled Trial	I
Demirag et al.[34]	2012	Turkey	Randomized Controlled Trial	II
El-Desouky et al.[35]	2022	Egypt	Randomized Controlled Trial	I
Gohil et al.[18]	2007	Australia	Randomized Controlled Trial	II
Lu et al.[36]	2015	China	Randomized Controlled Trial	II
Matsumoto et al.[37]	2013	Japan	Randomized Controlled Trial	II
Shohat et al.[38]	2017	Israel	Randomized Controlled Trial	II
Wang et al.[39]	2022	China	Randomized Controlled Trial	II
Zhang et al.[40]	2012	China	Randomized Controlled Trial	I

A similar recent meta-analysis by Wang et al. compared the same two groups,[29] but lacked high-quality studies. Allende et al.'s meta-analysis also lacked high-quality studies and additionally included different grafts.[30] To minimize bias, this research exclusively focused on randomized controlled trials studying autologous hamstring grafts. Both this study and the Allende et al. meta-analysis found no statistically significant difference in IKDC scores and incidence of complications between the two groups. In contrast to this study, Allende et al. found a statistically significant difference in pivot shift test results, no significant difference in Lysholm scores and KT-1000 results, and did not report on the results of the Lachman test.

The stump-preserving ACLR technique is gaining popularity as an alternative to the standard technique due to the stump's vascular network which improves cell proliferation, and mechanoreceptors providing proprioception.

CONCLUSION

Stump-preserving ACLR resulted in better Lysholm scores and less anteroposterior laxity as measured by the KT-100 arthrometer. For all other outcomes, no statistically significant difference was found between the groups. The choice of the Standard ACLR technique or the stump-preserving ACLR technique will ultimately depend on the surgeon's preference, since at this time, one technique does not hold an advantage over the other.

We encountered several limitations, one of which is the scarcity of published studies that fit our criteria. This may be due to the procedure's novelty.[31] One of the ten studies included was sourced from a database outside of PubMed, Embase, and the Cochrane Library. We also had a short follow-up duration of less than two years, with one study (Andonovski et al.) reporting a follow-up period of only 6–8 months.[32] We also encountered bias across multiple domains. Some studies had a high risk of performance bias due to inadequate blinding. Detection bias related to blinding of outcome assessment was also prevalent, raising concerns about the objectivity of the results. Furthermore, selection bias was unclear, particularly regarding allocation concealment, while attrition bias and reporting bias were generally well managed.

More clinical trials with larger populations are needed. In addition to increasing the sample size, alternative outcome measures, such as the hop test, can be studied. Another important outcome is the time required to return to sport.

STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

AUTHOR DISCLOSURE

The authors declared no conflict of interest.

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