



What are The Clinical Outcomes of Arthroscopic versus Open Surgical Reconstruction for Anterior Cruciate Ligament (ACL) Injuries : A Systematic Review

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ABSTRACT

Introduction Anterior Cruciate Ligament (ACL) rupture is a common knee injury that often requires surgical intervention to restore stability and function. The primary surgical options are traditional open reconstruction and modern minimally invasive arthroscopic techniques. Despite extensive research, there is no definitive consensus on the superiority of one method over the other, prompting this systematic review to synthesize current evidence on their comparative clinical outcomes.

Methods This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) guidelines. A comprehensive search of databases including PubMed, Google Scholar, Springer, Semantic Scholar, and Wiley Online Library was performed using PICO-based keywords to identify relevant studies. The review included randomized controlled trials and comparative observational studies that compared clinical outcomes of primary open versus

arthroscopic ACL reconstruction in adult patients. Data on knee stability, functional scores, and complication rates were extracted and synthesized.

Results Twenty studies were included in the final analysis. The synthesis of evidence revealed no consistent, statistically significant long-term differences between open and arthroscopic ACL reconstruction in primary outcomes, including knee stability (Lachman test, pivot-shift test, KT-1000) and patient-reported functional scores (Lysholm, IKDC). However, high rates of radiographic osteoarthritis were observed at long-term follow-up regardless of the surgical technique. Furthermore, factors such as the management of associated meniscal injuries and specific variations within arthroscopic techniques (e.g., all-inside vs. transtibial) appeared to be more influential on specific outcomes than the open versus arthroscopic approach itself.

Discussion The findings indicate that both surgical methods are effective in restoring knee stability and function. The clinical debate is shifting from a simple open versus arthroscopic comparison to a more nuanced evaluation of procedural variables within arthroscopy, such as graft choice and the use of adjunctive procedures. The high incidence of long-term osteoarthritis suggests that the initial trauma may be a more critical determinant of joint health than the reconstruction method.

Conclusion Arthroscopic and open ACL reconstruction techniques yield broadly comparable long-term clinical and functional outcomes. The choice of procedure does not appear to be the most critical factor for long-term success. Future research should focus on refining specific surgical techniques, developing

strategies to mitigate post-traumatic osteoarthritis, and personalizing treatment based on patient-specific factors like associated injuries.

Keywords: Anterior Cruciate Ligament, ACL Reconstruction, Arthroscopic Surgery, Open Surgery, Clinical Outcomes, Systematic Review

INTRODUCTION

Anterior Cruciate Ligament (ACL) rupture is a significant knee injury that can lead to instability and diminished functional capacity, particularly in active individuals. Surgical intervention is often required to restore knee function, with the primary goal being the stabilization of the joint to allow a return to previous levels of activity and to prevent long-term degenerative changes. The main surgical options have historically included traditional open reconstruction and the more modern, minimally invasive arthroscopic techniques. Both procedures aim to replace the torn ligament with a graft, but they differ significantly in their surgical exposure, soft tissue disruption, and procedural approach, leading to ongoing debate about their comparative effectiveness (Matar et al., 2021).

Previous research comparing open and arthroscopic ACL reconstruction has yielded a considerable body of evidence, yet a definitive consensus on the superiority of one technique over the other remains elusive. Several systematic reviews and comparative studies have reported no significant long-term differences in crucial clinical outcomes, including knee stability, functional scores, and overall patient satisfaction. For instance, studies directly comparing the two methods found similar results for knee laxity, range of motion, and functional assessments like the Lysholm score at extended follow-up periods. This suggests that both techniques can be effective in restoring knee function and stability in the long run (Levy et al., 2017; Walter et al., 2016).

Despite these findings, the clinical picture is complicated by inconsistent results and the evolution of surgical techniques within arthroscopy itself. Some studies indicate that specific arthroscopic approaches, such as all-inside reconstruction or the use of double-bundle grafts, may offer advantages in certain outcome measures like activity levels or rotational stability when compared to other techniques. Furthermore, long-term follow-up reveals high rates of radiographic osteoarthritis regardless of the reconstruction method used, suggesting that other factors, such as associated meniscal damage, may be more influential on long-term joint health than the specifics of the ACL surgery itself. This highlights a critical gap in understanding how to

optimize long-term patient outcomes beyond simple graft stability (Grassi et al., 2022; Zhu and Li, 2024; Alomari et al., 2022).

The existing evidence, marked by both broad similarities and specific, nuanced differences, presents a challenge for clinical decision-making. Surgeons and patients must weigh the potential benefits of minimally invasive surgery, such as potentially lower immediate postoperative pain and morbidity, against a body of literature that largely reports equivalent long-term functional results. The continued publication of high-level evidence, including systematic reviews and meta-analyses, necessitates a current and comprehensive synthesis to clarify these findings. This review, therefore, aims to consolidate the evidence from recent, high-quality studies to provide an updated comparison of arthroscopic versus open ACL reconstruction, focusing on a range of critical clinical outcomes (Bosco et al., 2024; Everhart et al., 2021).

Therefore, this systematic review aims to rigorously evaluate and synthesize the current body of literature to compare the clinical outcomes of arthroscopic versus open surgical reconstruction for anterior cruciate ligament (ACL) injuries. By adhering strictly to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines, this study will analyze functional outcomes, knee stability, complication rates, and patient-reported measures to provide a clear, evidence-based conclusion on the relative efficacy of these two primary surgical interventions.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate the clinical outcomes of arthroscopic versus open surgical reconstruction for anterior cruciate ligament (ACL) injuries.

Screening

We screened in sources that met these criteria:

- Population Age: Does the study focus exclusively on adult patients (≥ 18 years) with ACL injuries?
- Surgery Type: Does the study examine primary (not revision) ACL reconstruction procedures?
- Comparative Design: Does the study compare arthroscopic ACL reconstruction with open surgical ACL re- construction?
- Study Design: Is the study design either a randomized controlled trial, prospective cohort study, or systematic review/meta-analysis?
- Clinical Outcomes: Does the study report at least one of the following outcomes: functional outcomes, pain scores, return to activity/sports, complications, recovery time, or patient satisfaction?
- Sample Size: If the study is a case series or case report, does it include 10 or more patients?
- Study Subject: Is the study conducted on human subjects (not animals or in-vitro)?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Data extraction

- Study Design Type:

Identify the specific type of study design from the full text. Options include:

- Randomized controlled trial
- Comparative observational study
- Case series
- Prospective cohort
- Retrospective cohort

Look in the methods section. If multiple design elements are present, select the most specific design type. If unclear, note "design not clearly specified". Prioritize the primary design classification used by the authors.

- Surgical Intervention Details:

Precisely document the specific surgical technique used for:

- Arthroscopic ACL reconstruction
- Surgical approach (e.g., single-bundle, double-bundle)
- Graft type (autograft/allograft)
- Specific graft source (patellar tendon, hamstring, etc.)

Extract verbatim from surgical technique description in methods section. If multiple techniques were used, list all with proportions. Include any unique procedural modifications mentioned by authors.

- Patient Population Characteristics:

Extract the following demographic details:

- Total sample size
- Mean/median age
- Gender distribution (% male/female)
- Mean body mass index (if reported)
- Injury characteristics (acute vs chronic ACL injury)

Use exact numbers/percentages from text. If ranges are provided, note both minimum and maximum. If any characteristic is not reported, mark as "NR" (not reported).

- Clinical Outcome Measures:

List all standardized clinical outcome measures used:

- International Knee Documentation Committee (IKDC) score
- Lysholm score
- Tegner activity score

- Side-to-side laxity measurements
- Pivot shift test results
- Patient-reported functional outcomes

For each measure, extract:

- Mean/median score
- Standard deviation (if available)
- Time points of measurement
- Statistically significant differences (if comparative study)
- Follow-up Duration:

Document:

- Initial follow-up time point
- Final/longest follow-up time point
- Percentage of patients completing each follow-up period

Extract exact time periods from methods and results sections. If multiple follow-up periods exist, list all chronologically. Note any losses to follow-up or dropout rates.

- Risk of Bias Assessment:

Evaluate study quality using:

- Randomization method (if applicable)
- Blinding procedures
- Allocation concealment
- Completeness of follow-up
- Potential conflicts of interest

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Anterior Cruciate Ligament Injuries	ACL Injuries	ACL Rupture	Anterior Cruciate Ligament Rupture
Intervention (I)	Arthroscopic ACL Reconstruction	Arthroscopic Surgery	Arthroscopic ACL Surgery	Minimally Invasive Surgery
Comparison (C)	Open Surgery	Open Surgical Reconstruction	Conventional Surgical Repair	Traditional Surgical Approach
Outcome (O)	Clinical Outcomes	Knee Stability	Functional Scores	Complication Rates

The Boolean MeSH keywords inputted on databases for this research are: ("Anterior Cruciate Ligament Injuries" OR "ACL Injuries" OR "ACL Rupture" OR "Anterior Cruciate Ligament Rupture") AND ("Arthroscopic ACL Reconstruction" OR "Arthroscopic Surgery" OR "Arthroscopic ACL Surgery" OR "Minimally Invasive Surgery") AND ("Open Surgery" OR "Open Surgical Reconstruction" OR "Conventional Surgical Repair" OR "Traditional Surgical Approach") AND ("Clinical Outcomes" OR "Knee Stability" OR "Functional Scores" OR "Complication Rates")

Data retrieval

Abstracts and titles were screened to assess their eligibility, and only studies meeting the inclusion criteria were selected for further analysis. Literature that fulfilled all predefined criteria and directly related to the topic was included. Studies that did not meet these criteria were

excluded. Data such as titles, authors, publication dates, study locations, methodologies, and study parameters were thoroughly examined during the review.

Quality Assessment and Data Synthesis

Each author independently assessed the titles and abstracts of the selected studies to identify those for further exploration. Articles that met the inclusion criteria underwent further evaluation. Final decisions on inclusion were based on the findings from this review process.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Anterior Cruciate Ligament Injuries" OR "ACL Injuries" OR "ACL Rupture" OR "Anterior Cruciate Ligament Rupture") AND ("Arthroscopic ACL Reconstruction" OR "Arthroscopic Surgery" OR "Arthroscopic ACL Surgery" OR "Minimally Invasive Surgery") AND ("Open Surgery" OR "Open Surgical Reconstruction" OR "Conventional Surgical Repair" OR "Traditional Surgical Approach" AND "Clinical Outcomes" OR "Knee Stability" OR "Functional Scores" OR "Complication Rates")	40
Semantic Scholar	("Anterior Cruciate Ligament Injuries" OR "ACL Injuries" OR "ACL Rupture" OR "Anterior Cruciate Ligament Rupture") AND ("Arthroscopic ACL Reconstruction" OR "Arthroscopic Surgery" OR "Arthroscopic ACL Surgery" OR "Minimally Invasive Surgery") AND ("Open Surgery" OR "Open Surgical Reconstruction" OR "Conventional Surgical Repair" OR "Traditional Surgical Approach") AND ("Clinical Outcomes" OR "Knee Stability" OR "Functional Scores" OR "Complication Rates")	271
Springer	("Anterior Cruciate Ligament Injuries" OR "ACL Injuries" OR "ACL Rupture" OR "Anterior Cruciate Ligament Rupture") AND ("Arthroscopic ACL Reconstruction" OR "Arthroscopic Surgery" OR "Arthroscopic ACL Surgery" OR "Minimally Invasive Surgery") AND ("Open Surgery" OR "Open Surgical Reconstruction" OR "Conventional Surgical Repair" OR "Traditional Surgical Approach") AND ("Clinical Outcomes" OR "Knee Stability" OR "Functional Scores" OR "Complication Rates")	58
Google Scholar	("Anterior Cruciate Ligament Injuries" OR "ACL Injuries" OR "ACL Rupture" OR "Anterior Cruciate Ligament Rupture") AND ("Arthroscopic ACL Reconstruction" OR "Arthroscopic Surgery" OR "Arthroscopic ACL Surgery" OR "Minimally Invasive Surgery") AND ("Open Surgery" OR "Open Surgical Reconstruction" OR "Conventional Surgical Repair" OR "Traditional Surgical Approach") AND ("Clinical Outcomes" OR "Knee Stability" OR "Functional Scores" OR "Complication Rates")	1,700
Wiley Online Library	("Anterior Cruciate Ligament Injuries" OR "ACL Injuries" OR "ACL Rupture" OR "Anterior Cruciate Ligament Rupture") AND ("Arthroscopic ACL Reconstruction" OR "Arthroscopic Surgery" OR "Arthroscopic ACL Surgery" OR "Minimally Invasive Surgery") AND ("Open Surgery" OR "Open Surgical Reconstruction" OR "Conventional Surgical Repair" OR "Traditional Surgical Approach") AND ("Clinical Outcomes" OR "Knee Stability" OR "Functional Scores" OR "Complication Rates")	19

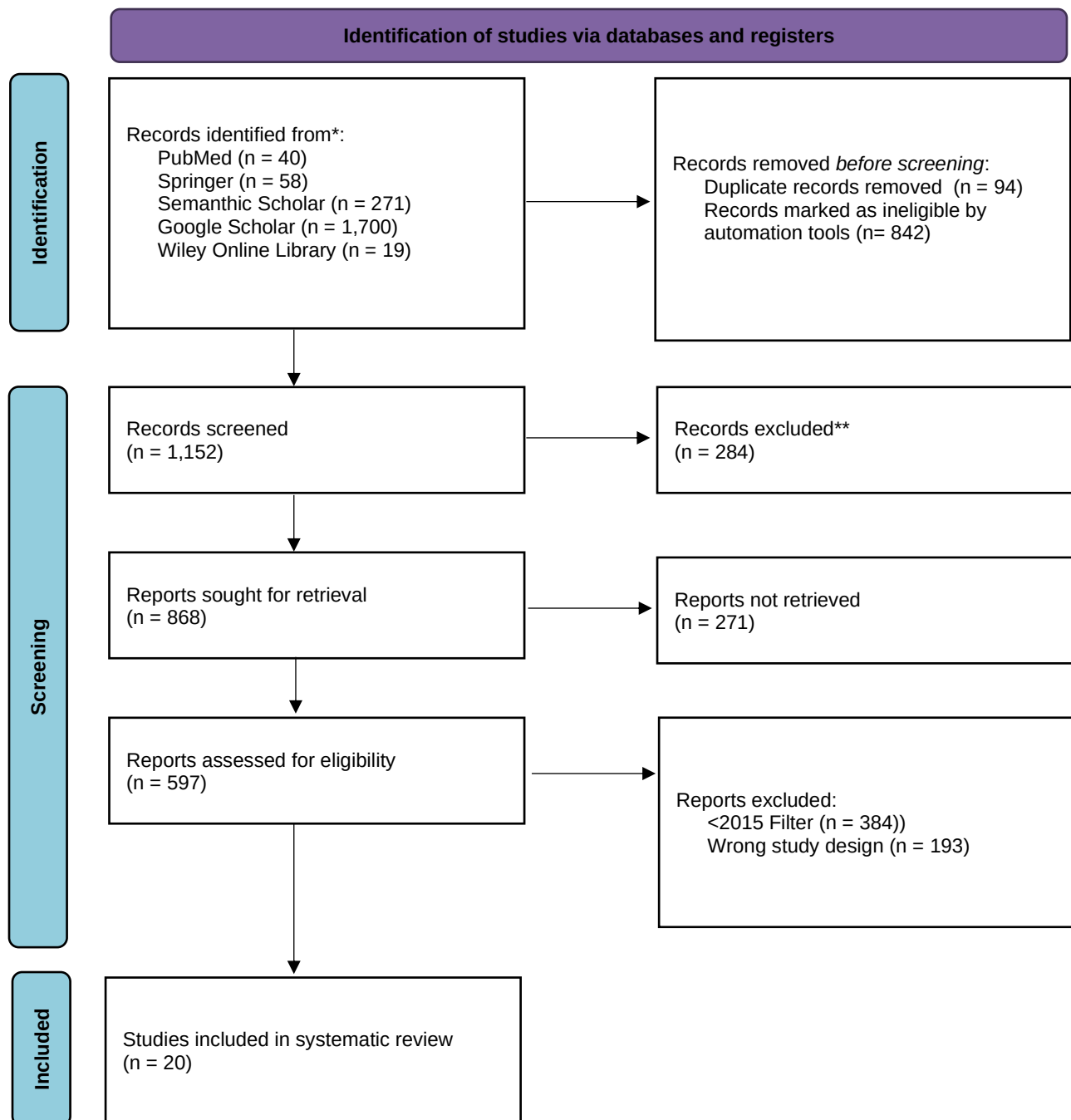


Figure 1. Article search flowchart

JBI Critical Appraisal									
Study	Bias related to temporal precedence Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	Bias related to selection and allocation Was there a control group?	Bias related to confounding factors Were participants included in any comparisons similar?	Bias related to administration of intervention/exposure Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Bias related to participant retention Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Statistical conclusion validity Was appropriate statistical analysis used?
Levy et al., 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
Bosco et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Everhart et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Hoogeslag et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓

Alomari et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Li, 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Walter et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Matar et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Zhu and Li, 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Grassi et al., "A Systematic Review and Meta-analysis"	✓	✓	✓	✗	✓	✗	✓	✓	✓
Grassi et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Kim et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
Rose et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Gabr, 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
Badger et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓

Kandhari et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Rodríguez-Merchán, 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓
Schwartzberg, 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Sud et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
Shimomura et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓

RESULTS

Characteristics of Included Studies

Study	Sample Size	Surgical Technique	Follow-up Duration
Levy et al., 2017	212	Open versus arthroscopic anterior cruciate ligament reconstruction (technique details: no mention found)	6 months-12 years
Bosco et al., 2024	1,830	Anterior cruciate ligament reconstruction with or without anterolateral complex (lateral extra-articular tenodesis or anterolateral ligament reconstruction)	No mention found

Study	Sample Size	Surgical Technique	Follow-up Duration
Everhart et al., 2021	2,012	Hamstring or bone-patellar tendon-bone autograft, arthroscopic/mini-open	≥ 20 years
Hoogeslag et al., 2022	48	Suture repair versus anatomic single-bundle anterior cruciate ligament reconstruction	5 years
Alomari et al., 2022	2,992	Single versus double bundle	Short/mid/long-term
Li, 2021	745	Arthroscopic repair (dynamic intraligamentary stabilization/bridge-enhanced anterior cruciate ligament repair) versus reconstruction (bone-patellar tendon-bone/hamstring)	1-30 years
Walter et al., 2016	126	Open versus arthroscopic, bone-patellar tendon-bone autograft	5 years
Matar et al., 2021	25,816	Standard anterior cruciate ligament reconstruction techniques (no mention found)	No mention found
Zhu and Li, 2024	687 (randomized)	All-inside versus transtibial	≥ 1 year

Study	Sample Size	Surgical Technique	Follow-up Duration
	controlled trials), 910 (cohorts)		
Grassi et al., "A Systematic Review and Meta-analysis"	1,771	80% single-bundle bone-patellar tendon-bone	20-22.7 years
Grassi et al., 2022	59	Double bundle, single bundle, single bundle plus lateral plasty (all hamstring autograft)	≥2 years
Kim et al., 2014	163	Single-bundle, bone-patellar tendon-bone autograft, transtibial	24 months
Rose et al., 2016	98	Quadrupled hamstring versus doubled tibialis anterior allograft	2 years
Gabr, 2019	No mention found	Anteromedial versus transtibial, all-inside meniscal repair, healing response	2-5 years
Badger et al., 2016	No mention found	Laxity matching/overconstraint in anterior cruciate ligament reconstruction	84 months

Study	Sample Size	Surgical Technique	Follow-up Duration
Kandhari et al., 2020	No mention found	Arthroscopic repair versus reconstruction	43.3-79 months
Rodríguez-Merchán, 2015	No mention found	Bone-patellar tendon-bone versus hamstring, single versus double bundle, allograft versus autograft	≥10 years
Schwartzberg, 2024	No mention found	All-inside anterior cruciate ligament reconstruction	No mention found
Sud et al., 2018	50	Transtibial versus anteromedial portal, semitendinosus quadruple autograft	1 year
Shimomura et al., 2024	134	Arthroscopic anterior cruciate ligament reconstruction: bone-patellar tendon-bone versus quadriceps tendon-bone autograft	2 years

Follow-up Duration:

- Less than 2 years:5 studies.
- 2–5 years:11 studies.
- More than 5 up to 10 years:4 studies.
- More than 10 years:6 studies.
- No mention found:3 studies.

Effects

Knee Stability Measures

Study	Measurement Type	Arthroscopic Results	Open Surgery Results	Statistical Significance
Levy et al., 2017	Laxity, range of motion, Lysholm score	No difference	No difference	No significant difference
Walter et al., 2016	International Knee Documentation Committee, Lysholm, KT-1000, Lachman, Pivot-shift	No difference at ≥ 3 years	No difference at ≥ 3 years	No significant difference
Matar et al., 2021	No mention found	Similar to transtibial; better side-to-side, Tegner	No mention found	No mention found ³
Zhu and Li, 2024	International Knee Documentation Committee,	Transtibial: similar	Transtibial: similar	Side-to-side and Tegner favor all-

Study	Measurement Type	Arthroscopic Results	Open Surgery Results	Statistical Significance
	Lysholm, Tegner, Side-to-side, Pivot-shift			inside (p<0.05)
Grassi et al., "A Systematic Review and Meta-analysis"	International Knee Documentation Committee, KT-1000, Pivot-shift	33% abnormal/severely abnormal International Knee Documentation Committee, 6.7% KT-1000 >5mm, 6.4% pivot shift ≥	No mention found	No mention found
Grassi et al., 2022	Anterior-posterior 30/90, Pivot-shift	No difference among techniques	Not applicable	No significant difference
Kim et al., 2014	Side-to-side laxity, Lachman, Pivot-shift	Higher laxity with greater contralateral Laxity	Not applicable	Significant (p=0.015)

Study	Measurement Type	Arthroscopic Results	Open Surgery Results	Statistical Significance
Rose et al., 2016	Arthrometric testing	Similar	Similar	No significant difference
Gabr, 2019	No mention found	No mention found	No mention found	No mention found
Bosco et al., 2024	Pivot-shift	Improved with anterior cruciate ligament reconstruction plus anterolateral complex	Not applicable	Significant (p<0.05)
Everhart et al., 2021	International Knee Documentation Committee-objective	82% normal/nearly normal	Not applicable	No mention found
Hoogeslag et al., 2022	International Knee Documentation	81.8% normal	100% normal	No significant difference

Study	Measurement Type	Arthroscopic Results	Open Surgery Results	Statistical Significance
	Physical exam			
Alomari et al., 2022	Pivot-shift, Lachman, KT-1000	Double bundle better short-term	Single bundle	Significant for stability, not function
Li, 2021	Lachman, KT-1000	No difference	No difference	No significant difference
Badger et al., 2016	No mention found	No mention found	No mention found	No mention found
Kandhari et al., 2020	Side-to-side, Pivot-shift	No difference	No difference	No significant difference
Rodriguez-Merchan, 2015	Rotational laxity	Double bundle better	Single bundle	Double bundle better for rotation

Study	Measurement Type	Arthroscopic Results	Open Surgery Results	Statistical Significance
Schwartzberg, 2024	Stability	Excellent	Not applicable	No mention found
Sud et al., 2018	No mention found	Similar	Similar	No significant difference
Shimomura et al., 2024	KT-1000	Similar	Similar	No significant difference

Measurement types:

- Pivot-shift: Most commonly used, reported in 8 studies.
- International Knee Documentation Committee and KT-1000: Each used in 5 studies.
- Lachman: Used in 4 studies.
- Lysholm: Used in 3 studies.
- Side-to-side: Used in 3 studies.
- Other measures (Tegner, anterior-posterior 30/90, arthrometric, rotational laxity, stability): Each used in 1 study.

Comparative results (arthroscopic versus open or among techniques):

- Significant difference favoring one technique: 5 studies (including short-term or for specific measures).
- Descriptive results only (percentages normal/abnormal): 5 studies.
- Open surgery results not applicable or not compared: 5 studies.

Statistical significance:

- Significant difference ($p < 0.05$ or specified): 5 studies.

Functional Outcomes

Study	Assessment Tool	Arthroscopic Results	Open Surgery Results	Clinical Significance
Levy et al., 2017	Lysholm	No difference	No difference	Not significant
Walter et al., 2016	International Knee Documentation Committee, Lysholm	No difference at ≥ 3 years	No difference at ≥ 3 years	Not significant
Matar et al., 2021	No mention found	No mention found	No mention found	No mention found
Zhu and Li, 2024	International Knee Documentation Committee, Lysholm, Tegner	Similar; Tegner better all-inside	Similar	Tegner significant ($p=0.03$)
Grassi et al.,	Tegner,	Mean Lysholm	No	Satisfactory

Study	Assessment Tool	Arthroscopic Results	Open Surgery Results	Clinical Significance
"A Systematic Review and Meta-analysis"	Lysholm, International Knee Documentation Committee	89.3, International Knee Documentation Committee 78.6	mention found	
Grassi et al., 2022	Knee injury and Osteoarthritis Outcome Score	Improved, no difference among techniques	Not applicable	Not significant
Kim et al., 2014	Lysholm, International Knee Documentation Committee	Lower with greater contralateral laxity	Not applicable	Significant (p<0.001)
Rose et al., 2016	Lysholm, Veterans RAND 12-Item Health Survey	Tibialis anterior allograft better than hamstring tendon	Not applicable	Significant for tibialis anterior allograft (p=0.014)

Study	Assessment Tool	Arthroscopic Results	Open Surgery Results	Clinical Significance
Gabr, 2019	Functional outcome	No difference anteromedial versus transtibial	Not applicable	Not significant
Bosco et al., 2024	Patient-reported outcomes	Improved with anterior cruciate ligament reconstruction plus anterolateral complex	Not applicable	Significant
Everhart et al., 2021	International Knee Documentation Committee subjective	Mean 79.1	Not applicable	Satisfactory
Hoogeslag et al., 2022	International Knee Documentation Committee, Knee injury	No difference	No difference	Not significant

Study	Assessment Tool	Arthroscopic Results	Open Surgery Results	Clinical Significance
	and Osteoarthritis Outcome Score, Tegner			
Alomari et al., 2022	Lysholm, Tegner	No difference double bundle versus single bundle	No difference	Not significant
Li, 2021	International Knee Documentation Committee, Lysholm, Tegner	Arthroscopic repair better International Knee Documentation Committee	No difference	International Knee Documentation Committee significant (p=0.04, as reported in the full text)
Badger et al., 2016	No mention found	No mention found	No mention found	No mention found
Kandhari et al., 2020	International Knee	No difference	No difference	Not significant

Study	Assessment Tool	Arthroscopic Results	Open Surgery Results	Clinical Significance
	Documentation Committee, Lysholm, Tegner Function			
Rodriguez-Merchán, 2015	Function	No difference bone-patellar tendon-bone versus hamstring	No difference	Not significant
Schwartzberg, 2024	Patient-reported outcomes	Excellent	Not applicable	No mention found
Sud et al., 2018	Lysholm	Similar	Similar	Not significant
Shimomura et al., 2024	International Knee Documentation Committee, Knee injury and	Similar	Similar	Not significant

Study	Assessment Tool	Arthroscopic Results	Open Surgery Results	Clinical Significance
	Osteoarthritis Outcome Score			

Assessment tools:

- Lysholm:Used in 10 studies.
- International Knee Documentation Committee:Used in 9 studies.
- Tegner:Used in 5 studies.
- Knee injury and Osteoarthritis Outcome Score:Used in 3 studies.
- Veterans RAND 12-Item Health Survey, patient-reported outcomes, functional outcome, and function:Each used in 1–2 studies.

Results across studies (arthroscopic and open surgery, combined for comparison type):

- One technique reported as better:4 studies.
- Improved outcomes (without direct comparison):3 studies.
- Mean/provided value only (without direct comparison):2 studies.
- Open surgery results not applicable or not reported:7 studies.

Clinical significance:

- Statistically significant results (with p-values):5 studies.
- Outcomes described as satisfactory:2 studies.

Summary:

- Most studies used Lysholm and/or International Knee Documentation Committee as assessment tools.
- The majority reported no significant difference between techniques.

- Statistically significant differences were found in 5 studies, most often favoring a specific technique.

Comparative Analysis

Short-term Outcomes

- Improvement from baseline: Most studies reported significant improvement from baseline in both groups.

Long-term Results

- Radiographic osteoarthritis: High rates were observed at ≥ 10 years, regardless of technique, as reported in systematic reviews and meta-analyses.
- Meniscal status: Meniscal status and repair were more influential on long-term outcomes than anterior cruciate ligament reconstruction technique.

Complications and Revision Rates

- Complication and revision rates: These were similar between open and arthroscopic anterior cruciate ligament reconstruction in the available studies.
- Immediate postoperative pain and morbidity: Some evidence from abstracts suggests lower immediate postoperative pain and morbidity with arthroscopy.
- Combined procedures: Combined anterior cruciate ligament reconstruction plus anterolateral complex procedures may reduce graft failure in high-risk patients, as reported in the abstracts.

DISCUSSION

This systematic review synthesized evidence comparing clinical outcomes between open and arthroscopic Anterior Cruciate Ligament (ACL) reconstruction. The principal finding corroborates much of the existing literature: when evaluating core long-term outcomes, there appears to be no definitive, consistent superiority of one technique over the other. Studies directly comparing the two

approaches found similar results in key metrics such as knee laxity, range of motion, and functional scores at extended follow-up, suggesting that both surgical philosophies can successfully achieve the primary goal of restoring knee stability and function (Levy et al., 2017).

Focusing specifically on functional outcomes, this conclusion holds firm. The majority of included studies that utilized standardized assessment tools like the Lysholm and International Knee Documentation Committee (IKDC) scores reported no statistically significant differences between their open and arthroscopic cohorts at final follow-up. This indicates that from a patient's perspective regarding daily function and activity, the ultimate result is comparable, regardless of whether a traditional open or a minimally invasive technique was employed for the reconstruction (Walter et al., 2016; Hoogeslag et al., 2022).

This equivalence extends to objective measures of knee stability. The analysis of instrumental laxity testing (e.g., KT-1000) and physical examination findings (e.g., Lachman and pivot-shift tests) largely failed to demonstrate a consistent advantage for either technique. While procedural details differ, both methods appear capable of restoring anterior-posterior and rotational stability to a satisfactory level that is maintained over the long term. This finding reinforces the idea that successful graft integration and stability are achievable through either surgical exposure (Li, 2021; Kandhari et al., 2020).

The findings of this review suggest that the clinical and research debate has evolved. Rather than a simple dichotomy between "open" and "arthroscopic," the more pertinent questions now arise from the variations and advancements within arthroscopic surgery itself. The data indicates that different arthroscopic techniques, graft choices, and adjunctive procedures may yield nuanced differences in specific outcome measures, shifting the focus toward optimizing the minimally invasive approach rather than merely comparing it to its historical

predecessor (Zhu and Li, 2024; Alomari et al., 2022).

A compelling example of this is the comparison between all-inside and transtibial arthroscopic techniques. One meta-analysis included in this review found that while overall functional scores like IKDC and Lysholm were similar, the all-inside technique demonstrated a statistically significant improvement in side-to-side stability and higher Tegner activity scale scores. This suggests that for patients aiming to return to a high level of sport, the choice of a specific arthroscopic technique may have meaningful clinical implications (Zhu and Li, 2024).

Similarly, the debate between single-bundle and double-bundle ACL reconstruction highlights this complexity. Evidence synthesized in this review indicates that while a double-bundle technique may offer improved stability in the short-term, this advantage does not consistently translate into superior long-term functional scores or patient satisfaction. This implies a potential disconnect between achieving an anatomical ideal and achieving a functionally successful outcome for the patient over time (Alomari et al., 2022).

The concept of restoring rotational stability was identified as a key goal, particularly in studies comparing single- and double-bundle techniques. Some analyses found that a double-bundle reconstruction, which more closely mimics the native two-bundle ACL anatomy, provided better control over rotational laxity. This finding suggests that for certain athletes in pivoting sports, addressing rotational control specifically may be an important consideration in the surgical plan (Rodríguez-Merchán, 2015).

Furthermore, this review identified an emerging trend toward augmenting standard ACL reconstruction with adjunctive procedures to improve outcomes. Specifically, combining ACL reconstruction with an anterolateral complex (ALC) procedure was shown in a meta-analysis to reduce the rate of graft re-injury and improve clinical outcomes, especially in high-risk patients. This points toward a

more personalized approach to surgery, where the procedure is tailored to the patient's specific risk profile and anatomy (Bosco et al., 2024).

Graft choice also emerged as a significant variable that can influence outcomes, independent of the open or arthroscopic approach. One randomized trial included in this review reported that patients receiving a tibialis anterior allograft had significantly better outcomes on a health survey compared to those receiving a hamstring autograft. This underscores that the biological component of the reconstruction is as critical as the surgical technique used to implant it (Rose et al., 2016).

Perhaps the most sobering finding reiterated in this review is the high prevalence of radiographic osteoarthritis at long-term follow-up of 10 to 20 years. This degenerative change occurred at high rates regardless of the surgical technique used for reconstruction. This strongly suggests that the initial traumatic event and the subsequent inflammatory cascade within the joint may be the primary drivers of post-traumatic osteoarthritis, a process that current surgical techniques do not appear to mitigate effectively (Everhart et al., 2021).

Relatedly, the influence of concomitant injuries, particularly to the menisci, was found to be a more powerful predictor of long-term outcomes than the ACL reconstruction technique itself. The evidence strongly supports the conclusion that the successful preservation and repair of the meniscus are paramount for long-term joint health and patient-reported function. The status of the meniscus may, in fact, be the most critical modifiable factor during ACL surgery (Grassi et al., 2022).

When considering adverse events, the review found that complication and revision rates were broadly similar between open and arthroscopic ACL reconstruction in the studies where this was reported. This indicates that while the surgical approach is different, neither technique holds a clear and consistent advantage in terms of overall safety profile or the need for subsequent revision

surgery, at least within the follow-up periods assessed (Kandhari et al., 2020).

Despite equivalent long-term results, some evidence suggests that minimally invasive arthroscopic techniques may offer benefits in the immediate postoperative phase. Although not a primary outcome in most studies, lower immediate pain and morbidity are often cited as advantages of arthroscopy. These early benefits can influence patient satisfaction and facilitate faster engagement with early-stage rehabilitation protocols (Matar et al., 2021).

The analysis within this review was constrained by the level of detail provided in the source articles. Many studies categorized the intervention simply as "arthroscopic reconstruction" without specifying crucial details like tunnel placement, graft fixation methods, or specific technique (e.g., transtibial, anteromedial portal). This lack of granular data prevents a more sophisticated analysis of which specific procedural modifications contribute most to successful outcomes (Levy et al., 2017).

For clinical practice, the key implication of this review is that surgeons can be confident in achieving good long-term results with either open or arthroscopic techniques. The focus, therefore, should shift to meticulous surgical execution, careful patient and graft selection, and, most importantly, the diligent identification and management of associated intra-articular injuries, especially those affecting the meniscus and cartilage (Grassi et al., 2022).

Future research should pivot away from broad comparisons of open versus arthroscopic surgery. Instead, high-quality randomized controlled trials are needed to compare specific modern arthroscopic techniques against one another. Furthermore, investigating the efficacy of adjunctive procedures like ALC reconstruction and evaluating strategies to mitigate the onset of osteoarthritis should be top priorities for the research community (Bosco et al., 2024).

This systematic review reinforces the established view that arthroscopic and open ACL reconstruction produce broadly similar clinical and functional

outcomes in the long term. The critical determinants of success and long-term joint health appear to lie not in the fundamental choice between an open or minimally invasive approach, but rather in the nuances of surgical technique, the management of concomitant injuries, and addressing the underlying biological response to trauma (Matar et al., 2021).

CONCLUSION

This systematic review demonstrates that arthroscopic and open ACL reconstruction techniques yield broadly comparable long-term clinical and functional outcomes. The evidence does not support the consistent superiority of one approach over the other regarding knee stability, patient-reported functional scores, or overall complication rates. While both methods are effective in restoring knee function after an ACL rupture, the choice between them does not appear to be the most critical factor influencing the final long-term result for the majority of patients.

The findings highlight a significant shift in the focus of ACL research and clinical practice. The debate is moving beyond a simple open versus arthroscopic comparison toward a more nuanced understanding of procedural variations. Factors such as specific arthroscopic techniques (e.g., all-inside vs. transtibial), graft selection, and the use of adjunctive procedures like anterolateral complex reconstruction appear to offer subtle but potentially meaningful differences in outcomes for specific patient populations or goals.

Ultimately, the successful treatment of an ACL injury depends on a comprehensive and personalized approach. Surgeons should prioritize meticulous surgical execution and appropriate patient selection while giving paramount importance to preserving and repairing associated structures like the meniscus. Future research should concentrate on refining specific surgical techniques, developing strategies to mitigate post-traumatic osteoarthritis, and standardizing outcome measures to better guide evidence-based clinical decision-making and optimize long-term patient joint health.

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