Journal of Research in
Orthopedic Science
August 2026. Volume 13. Number 3

Review Paper

Anterior Cruciate Ligament Graft Choice in Patients With Generalized Joint Hypermobility, Generalized Joint Laxity, or Knee Hyperextension: A Narrative Review

Mahmoud Jabalameli[1], Abolfazl Bagherifard[1], Alireza Askari[2, 3], Hooman Yahyazadeh[3, 4], Amir Azimi[2], Kamal Arjmand[2*], Bushra Zareie[2], Behnam Sour[2, 3]

1. Bone and Joint Reconstruction Research Center, Shafa Yahyaeian Hospital, Iran University of Medical Sciences, Tehran, Iran.
2. Department of Orthopedics, Bone and Joint Reconstruction Research Center, School of Medicine, Iran University of Medical Sciences, Tehran, Iran.
3. Department of Orthopedic Surgery, Bone and Joint Reconstruction Research Center, Shafa Yahyaeian Hospital, Tehran, Iran.
4. Department of Orthopedic Surgery, Farhikhtegan Hospital, TeMS.C., Islamic Azad University, Tehran, Iran.

Use your device to scan and read the article online

Citation Jabalameli M, Bagherifard A, Askari A, Yahyazadeh H, Azimi A, Arjmand K, et al. Anterior Cruciate Ligament Graft Choice in Hypermobile Knees. Journal of Research in Orthopedic Science. 2026; 13(3):87-98. http://dx.doi.org/10.22034/JROSJ.13.3.2748.1

http://dx.doi.org/10.22034/JROSJ.13.3.2748.1

Article info:
Received: 01 Feb 2026
Revised: 29 Feb 2026
Accepted: 15 Mar 2026

Keywords:
Anterior cruciate ligament (ACL) reconstruction, Graft choice, Generalized joint hypermobility (GJH), Generalized joint laxity (GJL), Knee hyperextension, Bone-patellar tendon-bone (BPTB), Hamstring tendon, Quadriceps tendon

ABSTRACT

Background: Generalized joint hypermobility (GJH), generalized joint laxity (GJL), and knee hyperextension may increase anterior and rotational loads after anterior cruciate ligament (ACL) reconstruction. In these patients, graft choice may influence postoperative stability and failure risk.

Objectives: This study aimed to review the clinical and mechanistic evidence on graft choice for ACL reconstruction in patients with GJH, GJL, or knee hyperextension.

Methods: This narrative review used a structured, evidence-based, graft-stratified approach to clinical studies. Outcomes included graft rupture, second ACL injury, measured anterior laxity, pivot shift, and patient-reported knee scores. Mechanistic evidence on graft stiffness, fixation, elongation, and healing was used to interpret the clinical findings.

Results: Available evidence is limited and mostly observational. Across graft-stratified studies, bone-patellar tendon-bone (BPTB) autograft was associated with lower measured anterior translation than hamstring autograft in laxity-pattern knees. Limited pooled data also favored BPTB for anterior translation and Lysholm score at approximately 24 months. Registry evidence after return to sports suggested higher second ACL rupture and graft rupture rates after hamstring autograft than after BPTB autograft. Quadriceps tendon autograft with a bone block appears promising, especially in knee hyperextension, but direct evidence in systemic hypermobility remains limited.

Conclusion: In patients with GJH, GJL, or marked knee hyperextension, ACL graft choice should be considered a stability-focused decision. Current evidence most consistently supports BPTB autograft when objective stability is prioritized. Quadriceps tendon autograft with a bone block is promising but requires further study.

*** Corresponding Author:**
Kamal Arjmand, MD.
Address: *Department of Orthopedics, Bone and Joint Reconstruction Research Center, School of Medicine, Iran University of Medical Sciences, Tehran, Iran.*
Phone: *+98 (937) 4805991*
E-mail: *arjmand.kamal@gmail.com*

Copyright © 2026 The Author(s);
This is an open access article distributed under the terms of the Creative Commons Attribution License (CC-By-NC: https://creativecommons.org/licenses/by-nc/4.0/legalcode.en), which permits use, distribution, and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

Introduction

Anterior cruciate ligament reconstruction (ACLR) is not performed in the same mechanical environment in every patient. Some patients have generalized joint hypermobility (GJH), generalized joint laxity (GJL), or marked knee hyperextension. These phenotypes are not identical; however, each may increase the functional demand placed on the graft [1-5].

After ACLR, the graft must resist anterior tibial translation and rotational loading during rehabilitation and return to sports. In a hyperlax knee, small graft elongation, fixation slippage, or residual pivot shift may lead to clinically relevant residual laxity. Therefore, graft choice may be more consequential in this subgroup than in knees with normal baseline stability [3, 5-8].

Graft selection is often discussed in relation to donor-site morbidity, surgeon preference, graft size, and outcomes in the general population. These factors remain important. However, in patients with systemic laxity or marked hyperextension, the stability profile of the graft construct deserves greater emphasis (Figures 1, 2 and 3).

This review aimed to summarize the available evidence on ACL graft choice in patients with GJH, GJL, or knee hyperextension. This review emphasizes graft failure, secondary ACL injury, objective knee stability, and plausible biomechanical mechanisms.

Materials and Methods

Review design

This manuscript is a narrative review. The search and study selection were conducted using a structured, preferred reporting items for systematic reviews and meta-analyses (PRISMA)-informed methodology [9]. A systematic database search was performed, records were screened, and data were extracted from eligible studies. The synthesis and interpretation of findings are presented in narrative form rather than as a formal systematic review or meta-analysis. This hybrid approach — structured search, narrative synthesis — was chosen to organize the available graft-stratified evidence in a clinically usable format.

The clinical evidence base was derived from a structured search of PubMed/MEDLINE, Embase, and Scopus performed on February 16, 2026. The search used terms related to ACL reconstruction, graft choice, hypermobility, joint laxity, Beighton score, knee hyperextension, and genu recurvatum. The search identified 685 records. After removal of 391 duplicates, 294 unique records were screened. Seven graft-stratified comparative clinical studies were included [2, 3, 6, 10-13].

Eligibility principles

Clinical studies were considered relevant if they met the following criteria:

Patients who underwent primary ACL reconstruction. A laxity phenotype was defined, such as GJH, GJL, or knee hyperextension. Outcomes were reported by graft type or graft-related construct. Clinically relevant outcomes were reported, including graft rupture, second ACL injury, revision ACLR, measured anterior laxity, pivot shift, or patient-reported knee scores.

The included studies were mainly cohort and registry studies. No randomized trial directly compared graft choices in patients with systemic GJH or GJL. Therefore, these findings should be interpreted as clinically important associations rather than definitive proof of causation [2, 3, 6, 10-14]. Because studies applied different operational definitions for GJH and knee hyperextension, the diagnostic criteria used in each included study are summarized in (Tables 1, 2, 3, 4 and 5) to facilitate direct comparison.

Synthesis approach

The findings were grouped by clinical question: whether GJH, GJL, or knee hyperextension increases risk after ACLR; whether bone-patellar tendon-bone (BPTB) performs differently from hamstring autograft; what is known about quadriceps tendon autograft and allograft; and which mechanisms may explain the observed clinical patterns.

A broad pooled analysis of failure outcomes was not performed because studies used different definitions of failure. Some studies counted graft rupture, some counted revision surgery, some counted second ACL injury, and some included excessive residual laxity. Although these outcomes are related, they are not equivalent.

Limited pooling was considered only for compatible continuous outcomes reported at similar follow-up intervals. Mechanistic studies were used to support interpretation, but they were not treated as direct clinical proof.

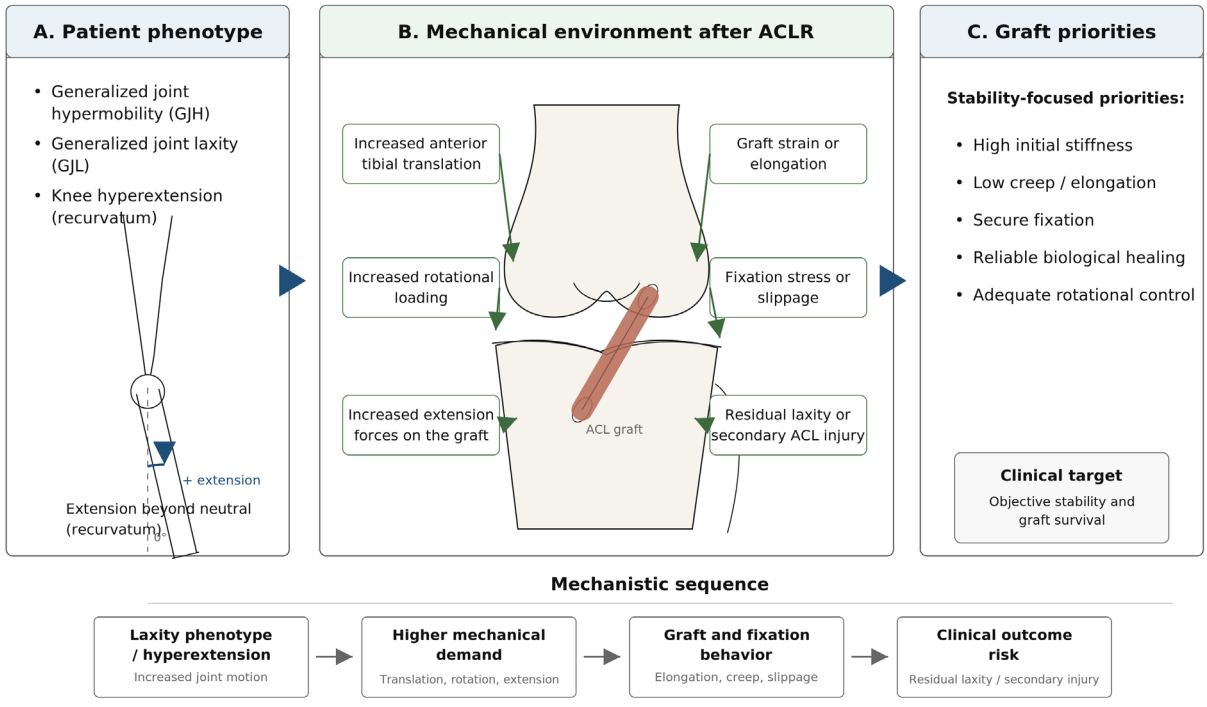


Figure 1. Conceptual model of increased mechanical demand on theACL graft in laxity-pattern knees

Abbreviations: ACLR: Anterior cruciate ligament reconstruction; GJH: Generalized joint hypermobility; GJL: Generalized joint laxity.

Note: GJH, GJL, and knee hyperextension may increase anterior tibial translation, rotational loading, and extension forces after ACL reconstruction. These factors may increase the importance of graft strain, fixation behavior, biological healing, and residual laxity risk when selecting the graft construct.

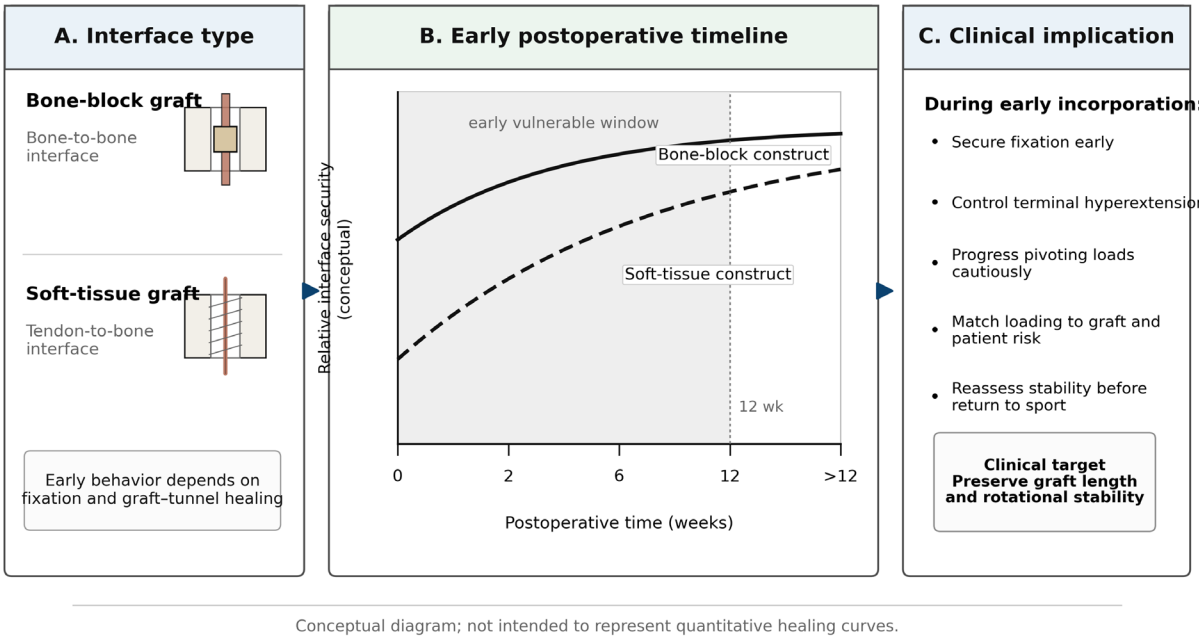


Figure 2. Conceptual early weak-link timeline after anterior cruciate ligament reconstruction

ACLR: Anterior cruciate ligament reconstruction.

Note: Early graft behavior is influenced by fixation security and graft-tunnel healing. Bone-block grafts may provide earlier bone-to-bone interface security, whereas soft-tissue grafts depend on tendon-to-bone healing and may remain more vulnerable to elongation or fixation slippage during early incorporation. The curves are conceptual and not intended to represent quantitative healing data.

Table 1. Included clinical studies and main graft-related findings

Authors (y)	Laxity Phenotype	Comparison	Main Finding
Kim et al. 2008 [10]	Excessive joint laxity	BPTB vs 4-bundle hamstring	At approximately 24 months, the BPTB group had lower anterior translation and higher Lysholm scores.
Kim et al. 2009 [11]	Generalized ligamentous laxity	Single-bundle BPTB vs double-bundle QTB	QTB had a lower anterior translation, but interpretation is limited because graft type and bundle technique differed.
Kim et al. 2010 [12]	Knee hyperextension subgroup	BPTB vs hamstring	BPTB showed better anterior stability and a higher Lysholm score than hamstring autograft.
Kim et al. 2018 [2]	GJL by Beighton-Horan criteria	BPTB vs hamstring	BPTB had a lower KT-2000 side-to-side difference than hamstring at 2 and 5 years.
Larson et al. 2017 [3]	Hypermobile vs nonhypermobile patients	Mixed grafts	Clinical failure was higher in hypermobile patients than in controls (24.4% vs 7.7%).
Yamasaki et al. 2024 [13]	Knee hyperextension >8 degrees	QTB vs hamstring	QTB had better objective stability and MRI graft maturation; Lysholm score was similar.
Lindskog et al. 2025 [6]	GJH after return to sport	Hamstring vs BPTB	Second ACL and graft ruptures were more frequent after hamstring autograft than after BPTB.

Journal of Research in Orthopedic Science

Abbreviations: BPTB: Bone-patellar tendon-bone; GJH: Generalized joint hypermobility; GJL: Generalized joint laxity; QTB: Quadriceps tendon with bone block; ACL: Anterior cruciate ligament.

Definitions and clinical phenotypes

GJH and GJL refer to a systemic pattern of increased joint motion. They are commonly assessed using the Beighton or Beighton-Horan score [1, 2]. Knee hyperextension, also called genu recurvatum, is a local knee finding. These phenotypes may overlap but should not be considered identical.

This distinction matters for evidence interpretation. A study on knee hyperextension may not fully represent patients with systemic GJH. Similarly, a patient with a high Beighton score may not have the same surgical risk profile as a patient whose main finding is marked knee recurvatum. In this review, the term laxity-pattern knees is used only as an umbrella term for the shared clinical problem of a reconstructed ACL graft functioning in a knee with increased baseline motion.

Clinical evidence

Generalized hypermobility or laxity and risk after anterior cruciate ligament reconstruction (ACLR)

Several studies have suggested that hypermobility or generalized laxity is associated with worse stability or higher failure risk after ACLR. Larson et al. reported clinical failure in 24.4% of hypermobile patients compared with 7.7% of nonhypermobile controls at a mean follow-up of 6 years [3]. Zsidai et al. reported that patients with GJH had higher odds of a second ACL injury within 12 months after return to sport (odds ratio=5.53; 95% confidence interval [CI], 1.67%, 18.29%) [5].

Early postoperative function may not fully capture this risk. Sundemo et al. found that GJH did not have a major influence on one-year patient satisfaction or functional outcome after ACLR [15]. This finding does not exclude later injury risk. Rather, it suggests that early functional

Table 2. Key outcome signals supporting the clinical interpretation

Outcome Signal	Estimate	Interpretation
Pooled anterior translation at approximately 24 months	Mean difference -0.94 mm; 95% CI, -1.37%, -0.50%; I^2=0% [2, 10, 12]	BPTB knees had approximately 1 mm less anterior translation than hamstring knees.
Pooled Lysholm score at approximately 24 months	Mean difference +6.37 points; 95% CI, 3.53%, 9.22%; I^2=40% [2, 10, 12]	Patients with BPTB had higher knee function scores in the pooled studies.
Lindskog et al. second ACL rupture	29.6% after hamstring vs 7.1% after BPTB [6]	After return to sport, second ACL rupture was more frequent after hamstring autograft.
Lindskog et al. graft rupture	22.2% after hamstring vs 0% after BPTB [6]	No graft ruptures were reported in the BPTB group at latest follow-up.
Larson et al. clinical failure	24.4% in hypermobile patients vs 7.7% in controls [3]	Patients with hypermobility had a higher clinical failure rate.
Zsidai et al. second ACL injury	Odds ratio 5.53; 95% CI, 1.67%, 18.29% [5]	GJH was associated with higher odds of second ACL injury after return to sport.

Journal of Research in Orthopedic Science

Abbreviations: CI: Confidence interval; GJH: Generalized joint hypermobility; BPTB: Bone-patellar tendon-bone; ACL: Anterior cruciate ligament.

Table 3. Practical graft-choice framework

Clinical Scenario	Most Defensible Strategy	Main Caution
Young pivoting athlete with clear GJH or GJL	Strongly consider BPTB. Consider QTB if BPTB morbidity is a concern and the surgeon has experience with this technique.	Do not rely only on early patient-reported functions to judge safety.
Marked knee hyperextension	Favor a low-stretch, secure graft construct such as BPTB or QTB.	Hyperextension-only evidence is not identical to systemic GJH or GJL evidence.
Hamstring autograft selected in a high-laxity patient	Optimize graft diameter, strand tensioning, fixation security, possible tibial backup fixation, and rotational control.	Treat hamstring autograft as a high-risk construct, not as a routine default.
Older or lower-demand patient with mild laxity	Individualize graft choice according to activity, symptoms, donor-site concerns, and surgeon experience.	Stability benefit must be balanced with morbidity and patient goals.
Considering allograft in a young active hypermobile patient	Avoid routine allograft unless there is a specific indication.	Direct GJH allograft evidence is limited, but general young athlete allograft risk is concerning.

Journal of Research in
Orthopedic Science

Abbreviations: BPTB: Bone-patellar tendon-bone; GJH: Generalized joint hypermobility; GJL: Generalized joint laxity; QTB: Quadriceps tendon with bone block.

recovery and later return-to-sport risks should be considered separately.

Bone-patellar tendon-bone versus hamstring autograft

The most consistent graft-stratified comparison in laxity-pattern knees was the BPTB autograft versus hamstring autograft. Across the available studies, BPTB autograft was associated with better objective anterior stability than hamstring autograft [2, 10, 12].

Kim et al. reported that, in patients with excessive joint laxity, BPTB autograft had lower anterior translation and a higher Lysholm score than 4-bundle hamstring autograft at approximately 24 months [10]. Kim et al. later reported a similar direction of effect in patients with knee hyperextension, with better anterior stability and Lysholm score after BPTB than after hamstring autograft [12].

In the 2018 study by Kim et al. patients with GJL had lower KT-2000 side-to-side difference after BPTB autograft than after hamstring autograft at both 2 and 5 years. At 2 years, the side-to-side difference was 2.7 +/- 1.4 mm after BPTB and 3.5 +/- 1.4 mm after hamstring autograft. At 5 years, it was 3.2 +/- 1.8 mm after BPTB and 4.4 +/- 1.8 mm after hamstring autograft [2].

Limited pooled data from three compatible studies at approximately 24 months favored BPTB. The pooled mean difference in anterior translation was -0.94 mm (95% CI, -1.37%, -0.50%; I^2=0%). The pooled mean difference in Lysholm score was +6.37 points (95% CI, 3.53%, 9.22%; I^2=40%) [2, 10, 12]. The clinical meaningfulness of the approximately 1 mm anterior translation difference requires careful interpretation. On KT-1000 or KT-2000 arthrometry, anterior side-to-side differences relative to the contralateral knee are conventionally graded as normal (2 mm or less), nearly normal

Table 4. Mechanistic considerations and clinical implications

Mechanism	Clinical Meaning	Implication
Graft elongation	If the graft becomes longer, anterior and rotational control may decrease.	Choose and protect low-elongation constructs in high-laxity knees.
Fixation movement	Fixation slippage can make the graft functionally longer.	Use secure fixation; consider backup fixation for soft-tissue grafts.
Tendon-to-bone healing	Soft-tissue grafts need time to heal inside the tunnel.	Protect the early healing period, especially during the first 6 to 12 weeks.
Bone-block healing	Bone-block grafts may provide a more secure early tunnel interface.	Consider BPTB or QTB when objective stability is a priority.
Rotational laxity	A positive pivot shift may increase graft loading.	Consider lateral augmentation in selected high-risk patients.
Return-to-sport exposure	Sport-level pivoting loads may reveal risks not seen during early recovery.	Use stricter return-to-sport criteria in patients with GJH or GJL.

Journal of Research in
Orthopedic Science

Abbreviations: BPTB: Bone-patellar tendon-bone; GJH: Generalized joint hypermobility; GJL: Generalized joint laxity; QTB: Quadriceps tendon with bone block.

Note: These mechanisms support clinical reasoning but do not replace direct comparative clinical studies.

Table 5. Diagnostic criteria used for GJH and knee hyperextension in each included study

Authors (y)	Laxity Phenotype	Diagnostic Tool or Criterion	Threshold Used
Kim et al. 2008 [10]	Excessive joint laxity	Beighton-Horan criteria	≥4 of 5 positive findings, including contralateral knee hyperextension >10°
Kim et al. 2009 [11]	Generalized ligamentous laxity	Beighton-Horan criteria	≥4 of 5 positive findings
Kim et al. 2010 [12]	Knee hyperextension subgroup	Beighton-Horan criteria (0-5 scale)	≥4 (GJL); knee hyperextension independently predicted stability
Kim et al. 2018 [2]	GJL by Beighton-Horan criteria	Beighton-Horan score	≥4 of 8 (injured knee excluded from score)
Larson et al. 2017 [3]	Hypermobile vs nonhypermobile; knee hyperextension also assessed	Beighton score; goniometric hyperextension	≥3 of 4: 5th MCP >90°, thumb-to-forearm, elbow ≥10°, knee ≥10° or heel height >5 cm
Yamasaki et al. 2024 [13]	Knee hyperextension	Goniometric measurement of hyperextension	>8° hyperextension
Lindskog et al. 2025 [6]	GJH (registry-diagnosed)	Beighton score (project ACL)	≥5/9 (females); ≥5/9 (males)

Journal of Research in Orthopedic Science

Abbreviations: ACL: Anterior cruciate ligament; GJH: Generalized joint hypermobility; GJL: Generalized joint laxity; MCP: Metacarpophalangeal.

Note: Thresholds are taken from each study's primary report. Beighton-based scoring differed across studies: the Yonsei group (Kim et al.) applied a 5-item Beighton-Horan scale and, in the 2018 study, an 8-point modification that excluded the injured knee from the score; Larson et al. used a modified 4-item set scored out of 4; and Lindskog et al. used the 9-point Beighton score "with a cutoff of ≥5 points. These differences in diagnostic criteria should be considered when comparing findings across studies.

(3 to 5 mm), or abnormal (greater than 5 mm) [16], and graft failure has been defined at a side-to-side difference greater than 5 mm [17]; a pooled mean difference of approximately 1 mm therefore lies within the normal range, well below the threshold for objective failure, and within the range of measurement error for an individual patient. However, in a high-demand or hyperlax knee, even submillimetric mean differences at a population level may reflect a consistent mechanical signal that translates into meaningful cumulative graft loading during return to sports. Therefore, the magnitude should be interpreted alongside the failure-rate data from Lindskog et al. [6] rather than in isolation. These results support a consistent objective stability signal, although the evidence remains limited.

Failure and second anterior cruciate ligament injury after return to sport

Failure outcomes are harder to combine because definitions differ across studies. The most direct post-return-to-sport graft comparison is the registry study by Lindskog et al. in patients with GJH who returned to sports [6].

At the latest follow-up, a second ACL rupture occurred in 16 of 54 patients (29.6%) after hamstring autograft and 2 of 28 patients (7.1%) after BPTB autograft. Graft rupture alone occurred in 12 of 54 patients (22.2%) after hamstring autograft and in 0 of 28 patients (0%) after BPTB autograft. The reported hazard ratio for second ACL rupture with hamstring autograft compared with BPTB autograft was 4.98 [6].

This result is clinically important but should be interpreted cautiously. It comes from observational registry data rather than random graft allocation. Surgeon preference, patient selection, sports exposure, and other unmeasured factors may have influenced graft choice and outcome [6, 14].

Quadriceps tendon autograft

Quadriceps tendon autograft is important because it can provide a large graft. When harvested with a bone block, quadriceps tendon with bone block (QTB) also shares part of the bone-block fixation rationale of BPTB.

Yamasaki et al. studied patients with knee hyperextension greater than 8 degrees and reported better objective stability and magnetic resonance imaging (MRI) graft maturation after QTB than after hamstring autograft. Lysholm score was similar between groups, with a median score of 99 in both groups [13].

This finding supports QTB as a promising option in patients with marked knee hyperextension. However, the study population was defined by knee hyperextension rather than full systemic GJH or GJL. Therefore, QTB should be described as promising, not proven equivalent to BPTB in systemic hypermobility.

Kim et al. compared single-bundle BPTB with double-bundle QTB in patients with generalized ligamentous laxity [11]. QTB showed lower anterior translation, but interpretation is limited because graft type and bundle technique differed. This study should not be used as a simple isolated comparison between BPTB and QTB.

In the broader ACLR literature, QTB and BPTB differ in their donor-site morbidity profiles. BPTB harvest carries a well-documented risk of anterior knee pain and difficulty kneeling, related in part to infrapatellar nerve injury during graft harvest [18]. QTB harvest spares the patellar tendon; a comprehensive review of the graft and a comparative meta-analysis indicate that it is associated with significantly less anterior knee pain than BPTB, while still carrying its own donor-site morbidity [19, 20]. With respect to outcomes, pooled comparative data suggest broadly similar functional results between QTB and BPTB [20], although head-to-head data in laxity-pattern knees specifically are not yet available. This donor-site consideration is clinically relevant: in a high-laxity patient where a bone-block strategy is preferred but anterior knee symptoms would compromise rehabilitation or sports, QTB may offer a comparable fixation rationale with a different morbidity profile. This remains an area that requires prospective comparative study in hypermobile populations.

Allograft

Direct evidence on allograft use in patients with GJH or GJL is limited. Larson et al. included small allograft subgroups, but the numbers were too small for firm conclusions [3].

In the broader ACLR literature, allograft has been associated with higher failure risk in young and active patients compared to autograft [21]. Because systemic laxity and return-to-sport exposure may already increase risk, routine allograft use in young active hypermobile patients should be approached with caution. This recommendation is based on indirect risk alignment rather than strong GJH-specific allograft evidence [3, 5, 21].

Lateral extra-articular augmentation

Residual rotational instability may increase graft loading. Therefore, lateral extra-articular augmentation may be relevant in selected high-risk patients, even though it is not a graft choice by itself.

The STABILITY trial showed that adding lateral extra-articular tenodesis to hamstring ACLR reduced graft failure in young high-risk patients [22]. This trial was not limited to patients with GJH. Toker et al. reported improved KT-1000 and pivot-shift outcomes when an anterolateral ligament internal brace was added in patients with GJH [23]. These findings support individualized consideration of rotational augmentation in high-risk laxity-pattern knees.

Mechanistic rationale

Mechanistic evidence cannot replace the clinical outcome studies. However, this can explain why graft choice may matter more in hypermobile or hyperlax knees.

The graft construct includes the graft tissue, fixation devices, and healing interface. If any part of this construct elongates, the graft becomes functionally longer. In a knee with increased baseline motion, even a small increase in graft length may produce clinically relevant anterior or rotational laxity [7, 8].

Soft-tissue grafts, including hamstring autografts, rely on tendon-to-bone healing inside the tunnel. This healing process takes time and has an early vulnerable period. Bone-block grafts such as BPTB and QTB can provide bone-to-bone or bone-in-tunnel healing, which may offer a more secure early interface [24, 25].

Graft stiffness and failure load also matter, but they are not the only determinants of outcome. Fixation level, cyclic loading behavior, tunnel position, graft diameter, rehabilitation, and return-to-sport exposure all contribute to the final stability profile [7, 8, 26, 27].

Some hypermobility-spectrum conditions may involve differences in collagen structure or connective-tissue behavior [28]. This makes altered graft behavior biologically plausible. However, current clinical evidence does not prove that collagen biology is the main cause of failure in every Beighton-positive patient. The safer interpretation is that systemic laxity increases the importance of choosing and protecting a stable graft construct.

Clinical implications

Preoperative assessment

Before graft selection, the surgeon should document the laxity phenotype. Useful variables include Beighton or Beighton-Horan score, degree of knee hyperextension, pivot-shift grade, age, sport type, return-to-sport plan, contralateral ACL history, and donor-site concerns.

This assessment helps separate a low-demand patient with mild laxity from a young pivoting athlete with systemic GJH and marked hyperextension. These patients should not be treated as having the same risk profile.

Graft selection

For young, active patients with clear GJH, GJL, or marked knee hyperextension, BPTB autograft has the

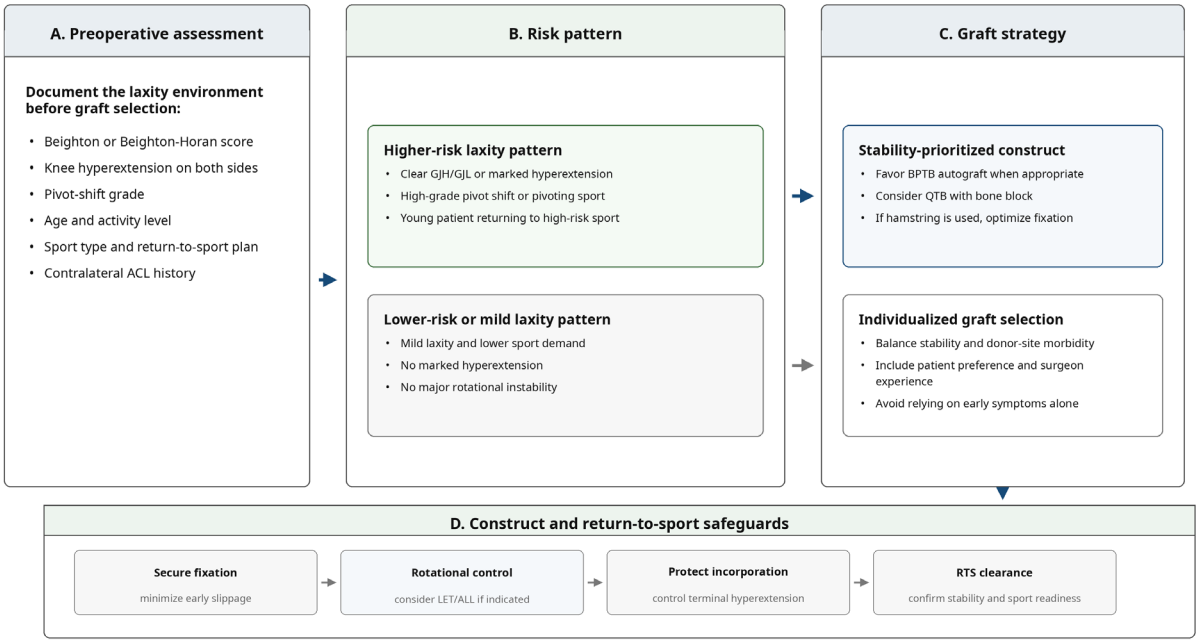


Figure 3. Practical decision framework for graft choice in laxity-pattern ACL reconstruction

Abbreviations: ACL: Anterior cruciate ligament; ACLR: Anterior cruciate ligament reconstruction; ALL: Anterolateral ligament; BPTB: Bone-patellar tendon-bone; GJH: Generalized joint hypermobility; GJL: Generalized joint laxity; LET: Lateral extra-articular tenodesis; QTB: Quadriceps tendon with bone block; RTS: Return to sports.

Note: Preoperative assessments should include generalized laxity scoring, knee hyperextension, pivot-shift grade, age, activity level, sport type, return-to-sport plan, and contralateral ACL history. Higher-risk laxity patterns may favor a stability-prioritized construct, including BPTB autograft or QTB with a bone block when appropriate. If hamstring autograft is used, fixation security and rotational control should be deliberately optimized. The framework is based on limited observational evidence and mechanistic rationale and is not intended as a validated prediction rule.

strongest direct clinical support. The main advantage is not only graft strength, but the consistent association with better objective stability in the available laxity-pattern studies [2, 6, 10, 12].

QTB is a reasonable option when a bone-block strategy is desired, and BPTB donor-site morbidity is a concern. At present, its strongest direct support is in patients with knee hyperextension rather than systemic GJH or GJL [13].

Hamstring autograft should not be considered contraindicated. However, it should not be used as a routine default in high-laxity knees. When selected, graft diameter, strand preparation, equal tensioning, fixation security, tibial backup fixation, rotational augmentation, and return-to-sport criteria should be deliberately optimized [2, 6-8, 22, 23].

Allograft should be used cautiously in young active hypermobile patients. This caution is based on the general young-athlete allograft failure signal and the added risk profile of laxity-pattern knees [3, 5, 21].

Rehabilitation and return to sport

The early healing period should be protected. This does not imply immobilization. This means that unnecessary terminal hyperextension loading, repetitive pivoting stress, and aggressive progression before fixation and biological healing are secure should be avoided [24, 25].

Return-to-sport decisions should not be based only on comfort or early functional scores. In patients with GJH or GJL, assessment should include strength, movement quality, hop performance, psychological readiness, objective laxity, pivot shift, hyperextension control, graft type, and planned sport exposure [5, 6, 15].

Limitations

First, the evidence base is small. Only seven graft-stratified clinical studies were included in the structured evidence base [2, 3, 6, 10-13].

Second, most of the evidence was observational. The graft choice was not randomly assigned; therefore, confounding by indication is possible [14].

Third, studies used different definitions of GJH, GJL, and knee hyperextension. These phenotypes overlap, but they are not identical [1, 2, 13].

Fourth, failure outcomes were not consistently defined. Graft rupture, revision ACLR, contralateral ACL rupture, second ACL injury, and residual laxity are related but different outcomes.

Fifth, mechanistic evidence is indirect. Biomechanical and biological studies support plausibility, but they do not prove clinical superiority in living GJH or GJL patients [7, 8, 24-28].

Future directions

Future studies should use standardized laxity assessment. At minimum, they should report Beighton score, knee hyperextension, and pivot-shift grade. They should also report graft diameter, fixation method, tunnel technique, lateral augmentation, rehabilitation protocol, return-to-sport criteria, and actual return-to-sport exposure.

The most useful study would be a prospective comparison of BPTB, QTB, and optimized soft-tissue autograft in patients with clearly defined GJH or GJL. Outcomes should include graft rupture, revision ACLR, contralateral ACL rupture, second ACL injury after return to sports, KT-1000 or KT-2000 side-to-side difference, pivot-shift grade, IKDC, KOOS, Lysholm score, sports function, anterior knee pain, and kneeling pain.

A key unanswered question is whether QTB can provide BPTB-like stability with a different donor-site profile in systemic hypermobility. This question is clinically important and should be tested directly.

Conclusion

In patients with GJH, GJL, or marked knee hyperextension, ACL graft choice should be treated as a stability-related decision. The available evidence is limited and mostly observational; however, the most consistent clinical signal favors BPTB autograft over hamstring autograft for objective anterior stability in laxity-pattern knees.

Registry data after return to sports also suggest higher second ACL rupture and graft rupture rates after hamstring autograft than after BPTB autograft in patients with GJH. QTB is a promising option, particularly in patients with knee hyperextension; however, direct evidence of systemic hypermobility remains limited. When hamstring autograft is selected, graft size, fixation security, rotational control, and return-to-sport criteria should be carefully optimized.

Ethical Considerations

Compliance with ethical guidelines

This article is a review paper and does not involve human or animal samples.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

Conceptualization, and supervision: Mahmoud Jabalameli and Abolfazl Bagherifard; Methodology and search strategy: Bushra Zareie, Behnam Sour, and Kamal Arjmand; Investigation: Behnam Sour, Kamal Arjmand, Alireza Askari, and Hooman Yahyazadeh; Writing the original draft: Behnam Sour; Visualization: Behnam Sour; Review & editing: Behnam Sour, Alireza Askari, Hooman Yahyazadeh, Amir Azimi, and Kamal Arjmand; Data collection: Bushra Zareie, Behnam Sour, and Kamal Arjmand; Data analysis: Behnam Sour and Bushra Zareie; Funding administration: Kamal Arjmand; Final approval All authors.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors would like to thank the Bone and Joint Reconstruction Research Center, Iran University of Medical Sciences, Tehran, Iran, for its support.

References

[1] Beighton P, Solomon L, Soskolne CL. Articular mobility in an African population. Ann Rheum Dis. 1973; 32(5):413-8. [DOI:10.1136/ard.32.5.413] [PMID]

[2] Kim SJ, Choi CH, Kim SH, Lee SK, Lee W, Kim T, et al. Bone-patellar tendon-bone autograft could be recommended as a superior graft to hamstring autograft for ACL reconstruction in patients with generalized joint laxity: 2- and 5-year follow-up study. Knee Surg Sports Traumatol Arthrosc. 2018; 26(9):2568-79. [DOI:10.1007/s00167-018-4881-y] [PMID]

[3] Larson CM, Bedi A, Dietrich ME, Larson CM, Bedi A, Dietrich ME, Swaringen JC, Wulf CA, Rowley DM, et al. Generalized hypermobility, knee hyperextension, and outcomes after anterior cruciate ligament reconstruction: Prospective, case-control study with mean 6 years follow-up. Arthroscopy. 2017; 33(10):1852-8. [DOI:10.1016/j.arthro.2017.04.012] [PMID]

[4] Krebs NM, Barber-Westin S, Noyes FR. Generalized joint laxity is associated with increased failure rates of primary anterior cruciate ligament reconstructions: A systematic review. Arthroscopy. 2021; 37(7):2337-47. [DOI:10.1016/j.arthro.2021.02.021] [PMID]

[5] Zsidai B, Piussi R, Thomeé R, Sundemo D, Musahl V, Samuelsson K, et al. Generalised joint hypermobility leads to increased odds of sustaining a second ACL injury within 12 months of return to sport after ACL reconstruction. Br J Sports Med. 2023; 57(15):972-8. [DOI:10.1136/bjsports-2022-106183] [PMID]

[6] Lindskog J, Högberg J, Hamrin Senorski R, Piussi R, Zsidai B, Samuelsson K, et al. Primary anterior cruciate ligament reconstruction performed with hamstring tendon autograft leads to an over 4 times greater rate of second anterior cruciate ligament rupture after return to sport in patients with generalized joint hypermobility compared with bone-patellar tendon-bone autograft. Arthroscopy. 2025; 41(9):3336-45.e1. [DOI:10.1016/j.arthro.2025.01.028] [PMID]

[7] Scheffler SU, Sudkamp NP, Gockenjan A, Hoffmann RFG, Weiler A. Biomechanical comparison of hamstring and patellar tendon graft anterior cruciate ligament reconstruction techniques: The impact of fixation level and fixation method under cyclic loading. Arthroscopy. 2002; 18(3):304-15. [DOI:10.1053/jars.2002.30609] [PMID]

[8] Smith CK, Hull ML, Howell SM. Does graft construct lengthening at the fixations cause an increase in anterior laxity following anterior cruciate ligament reconstruction in vivo? J Biomech Eng. 2010; 132(8):081001. [DOI:10.1115/1.4001027] [PMID]

[9] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ. 2021; 372:n71. [DOI:10.1136/bmj.n71] [PMID]

[10] Kim SJ, Kim TE, Lee DH, Oh KS. Anterior cruciate ligament reconstruction in patients who have excessive joint laxity. J Bone Joint Surg Am. 2008; 90(4):735-41. [DOI:10.2106/JBJS.F.01173] [PMID]

[11] Kim SJ, Chang JH, Kim TW, Jo SB, Oh KS. Anterior cruciate ligament reconstruction with use of a single or double-bundle technique in patients with generalized ligamentous laxity. J Bone Joint Surg Am. 2009; 91(2):257-62. [DOI:10.2106/JBJS.H.00009] [PMID]

[12] Kim SJ, Moon HK, Kim SG, Chun YM, Oh KS. Does severity or specific joint laxity influence clinical outcomes of anterior cruciate ligament reconstruction? Clin Orthop Relat Res. 2010; 468(4):1136-41. [DOI:10.1007/s11999-009-0961-0] [PMID]

[13] Yamasaki S, Hashimoto Y, Iida K, Han C, Kinoshita T, Nishino K, et al. Quadriceps tendon with bone autograft has better stability and magnetic resonance imaging maturation than hamstring tendon autograft after anterior cruciate ligament reconstruction in patients with knee hyperextension. Arthroscopy. 2024; 40(4):1234-44. [DOI:10.1016/j.arthro.2023.08.013] [PMID]

[14] Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016; 355:i4919. [DOI:10.1136/bmj.i4919] [PMID]

[15] Sundemo D, Svärd Jacobsson M, Karlsson J, Samuelsson K, Beischer S, Thomeé R, et al. Generalized joint hypermobility does not influence 1-year patient satisfaction or functional outcome after ACL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2022; 30(12):4173-80. [DOI:10.1007/s00167-022-07008-0] [PMID]

[16] Hefti F, Muller W, Jakob RP, Staubli HU. Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc. 1993; 1(3-4):226-34. [DOI:10.1007/BF01560215] [PMID]

[17] Lindanger L, Strand T, Molster AO, Solheim E, Inderhaug E. Effect of early residual laxity after anterior cruciate ligament reconstruction on long-term laxity, graft failure, return to sports, and subjective outcome at 25 years. Am J Sports Med. 2021; 49(5):1227-35. [DOI:10.1177/0363546521990801] [PMID]

[18] Kartus J, Movin T, Karlsson J. Donor-site morbidity and anterior knee problems after anterior cruciate ligament reconstruction using autografts. Arthroscopy. 2001; 17(9):971-80. [DOI:10.1053/jars.2001.28979] [PMID]

[19] Slone HS, Romine SE, Premkumar A, Xerogeanes JW. Quadriceps tendon autograft for anterior cruciate ligament reconstruction: A comprehensive review of current literature and systematic review of clinical results. Arthroscopy. 2015; 31(3):541-54. [DOI:10.1016/j.arthro.2014.11.010] [PMID]

[20] Mouarbes D, Menetrey J, Marot V, Courtot L, Berard E, Cavaignac E. Anterior cruciate ligament reconstruction: a systematic review and meta-analysis of outcomes for quadriceps tendon autograft versus bone-patellar tendon-bone and hamstring-tendon autografts. Am J Sports Med. 2019; 47(14):3531-40. [DOI:10.1177/0363546518825340] [PMID]

[21] Kaeding CC, Aros B, Pedroza A, Pifel E, Amendola A, Andrish JT, et al. Allograft versus autograft anterior cruciate ligament reconstruction: Predictors of failure from a MOON prospective longitudinal cohort. Sports Health. 2011; 3(1):73-81. [DOI:10.1177/1941738110386185] [PMID]

[22] Getgood AMJ, Bryant DM, Litchfield R, Heard M, McCormack RG, Rezansoff A, et al. Lateral Extra-articular Tenodesis Reduces Failure of Hamstring Tendon Autograft Anterior Cruciate Ligament Reconstruction: 2-Year Outcomes From the STABILITY Study Randomized Clinical Trial. Am J Sports Med. 2020; 48(2):285-97. [DOI:10.1177/0363546519896333] [PMID]

[23] Toker MB, Erden T, Toprak A, Taser OF. Does anterolateral ligament internal bracing improve the outcomes of anterior cruciate ligament reconstruction in patients with generalized joint hypermobility? Ulus Travma Acil Cerrahi Derg. 2022; 28(3):320-7. [DOI:10.14744/tjtes.2022.39998] [PMID]

[24] Weiler A, Hoffmann RF, Bail HJ, Rehm O, Südkamp NP. Tendon healing in a bone tunnel. Part II: Histologic analysis after biodegradable interference fit fixation in a model of anterior cruciate ligament reconstruction in sheep. Arthroscopy. 2002; 18(2):124-35. [DOI:10.1053/jars.2002.30657] [PMID]

[25] Tomita F, Yasuda K, Mikami S, Sakai T, Yamazaki S, Tohyama H. Comparisons of intraosseous graft healing between the doubled flexor tendon graft and the bone-patellar tendon-bone graft in anterior cruciate ligament reconstruction. Arthroscopy. 2001; 17(5):461-76. [DOI:10.1053/jars.2001.24059] [PMID]

[26] Noyes FR, Butler DL, Grood ES, Zernicke RF, Hefzy MS. Biomechanical analysis of human ligament grafts used in knee-ligament repairs and reconstructions. J Bone Joint Surg Am. 1984; 66(3):344-52. [DOI:10.2106/00004623-198466030-00005]

[27] Shani RH, Umpierez E, Nasert M, Hiza EA, Xerogeanes J. Biomechanical comparison of quadriceps and patellar tendon grafts in anterior cruciate ligament reconstruction. Arthroscopy. 2016; 32(1):71-5. [DOI:10.1016/j.arthro.2015.06.051] [PMID]

[28] Claes S, Verdonk P, Forsyth R, Bellemans J. The ligamentization process in anterior cruciate ligament reconstruction: What happens to the human graft? A systematic review of the literature. Am J Sports Med. 2011; 39(11):2476-83. [DOI:10.1177/0363546511402662] [PMID]

This Page Intentionally Left Blank