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ROTATIONAL STABILITY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION COMBINED WITH ANTEROLATERAL AUGMENTATION

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ABSTRACT

Background and Objective: Residual rotational instability after anterior cruciate ligament reconstruction remains a clinically relevant problem, particularly in young and active patients returning to cutting and pivoting sports. This structured narrative review evaluates whether anterior cruciate ligament reconstruction combined with anterolateral augmentation improves rotational stability compared with isolated reconstruction.
Methods: A structured PubMed search was conducted for English-language studies published between 2013 and 2025 addressing anterior cruciate ligament reconstruction, anterolateral ligament reconstruction, lateral extra-articular tenodesis, rotational instability, and pivot shift. Comparative clinical studies, randomized trials, systematic reviews, meta-analyses, and relevant biomechanical investigations were prioritized.
Results: Current evidence suggests that combined reconstruction provides more consistent pivot-shift control than isolated anterior cruciate ligament reconstruction, especially in selected high-risk groups such as young athletes, patients with high-grade pivot shift, and selected revision cases. Randomized and pooled evidence also indicates reduced graft failure rates in some high-risk cohorts, although patient-reported functional outcomes are often similar between isolated and combined procedures.
Conclusions: Combined anterior cruciate ligament reconstruction with anterolateral augmentation may enhance rotational stability and reduce failure risk in selected patients. However, routine use in all primary reconstructions cannot be recommended without stronger standardized long-term evidence.

KEYWORDS

Anterior Cruciate Ligament; Anterolateral Ligament; Lateral Extra-Articular Tenodesis; Rotational Instability; Pivot Shift

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Introduction

Anterior cruciate ligament (ACL) reconstruction is widely performed, yet a clinically relevant subset of patients continues to demonstrate residual rotational instability after isolated reconstruction. This instability is commonly reflected by a residual pivot shift and has been associated with inferior functional outcomes, subjective instability, and increased risk of graft failure (Kunze et al., 2021; Na et al., 2021).

Although modern surgical techniques restore anteroposterior stability in many patients, physiological rotational kinematics remain difficult to reproduce, particularly in young and active individuals returning to cutting or pivoting sports. Persistent rotatory laxity is therefore increasingly recognized as a clinically meaningful problem even after technically successful intra-articular reconstruction (Getgood et al., 2020a; Sonnery-Cottet et al., 2017).

The concept of addressing extra-articular lateral structures is not new. Before widespread arthroscopic intra-articular ACL reconstruction, numerous lateral extra-articular procedures were described. Contemporary approaches have evolved toward anatomically informed anterolateral augmentation, including anterolateral ligament (ALL) reconstruction and refined lateral extra-articular tenodesis (LET) (Getgood et al., 2019; Sonnery-Cottet et al., 2017).

Growing recognition of the anterolateral complex as a secondary restraint to internal tibial rotation has renewed interest in these combined procedures. Biomechanical investigations suggest that anterolateral structures contribute to rotational control in the ACL-deficient knee and act synergistically with the reconstructed ACL (Nitri et al., 2016; Rasmussen et al., 2016).

ACL reconstruction combined with anterolateral augmentation has therefore been proposed to enhance rotational control and potentially reduce graft failure. In young high-risk patients, the STABILITY randomized clinical trial reported lower clinical failure and graft rupture rates when LET was added to hamstring autograft

ACL reconstruction (Getgood et al., 2020a). However, the magnitude of benefit remains debated because of variability in surgical techniques, patient selection, follow-up duration, and outcome definitions (Na et al., 2021; Sørensen et al., 2023).

The aim of this structured narrative review is to summarize anatomical, biomechanical, and clinical evidence regarding ACL reconstruction combined with anterolateral augmentation, with emphasis on rotational stability and clinical outcomes compared with isolated ACL reconstruction.

Beyond restoring knee mechanics, improved rotatory stability may have broader implications for patient-centered care by reducing the burden of revision surgery, supporting safer return to sport and work, and informing evidence-based management of anterior cruciate ligament injuries in young and active populations.

Methodology

A structured literature search was conducted in PubMed for studies published between 2013 and 2025. The search strategy used combinations of the following terms with Boolean operators: “anterolateral ligament,” “ALL reconstruction,” “ACL reconstruction,” “rotational instability,” “lateral extra-articular tenodesis,” and “pivot shift.” Only English-language studies reporting clinical, biomechanical, or imaging outcomes were considered.

Comparative clinical studies evaluating isolated ACL reconstruction versus combined ACL reconstruction with anterolateral augmentation were prioritized. Systematic reviews, meta-analyses, randomized clinical trials, prospective comparative studies, and biomechanical investigations were included to contextualize the anatomical and functional role of anterolateral structures. Case reports and purely technical descriptions without clinical outcomes were excluded.

Study selection and screening were performed by the authors according to predefined relevance criteria applied to titles, abstracts, and full texts when necessary. Reference lists of selected publications were also screened to identify additional eligible studies. No formal protocol registration or Preferred Reporting Items for Systematic Reviews and Meta-Analyses workflow was applied, consistent with the structured narrative review design.

Because this study was a narrative review of previously published literature and did not involve human participants, animals, or identifiable patient data, ethical approval and informed consent were not required.

Results

Anatomical and Biomechanical Background

The anterolateral ligament has been described as a capsular structure extending from the region of the lateral femoral epicondyle to the proximal tibia. Cadaveric studies have reported variability in the femoral origin and tibial insertion of this structure (Claes et al., 2013; Dodds et al., 2014). Some authors regard the ALL as a distinct ligament, whereas others interpret it as part of a broader anterolateral complex, which may partly explain inconsistencies in anatomical descriptions (Getgood et al., 2019).

The ALL has also been linked to the Segond fracture as a possible bony avulsion related to the anterolateral tibial insertion. Imaging and anatomical studies suggest involvement of multiple structures, including the iliotibial band and other components of the anterolateral complex, in this injury pattern (Claes et al., 2014; De Maeseneer et al., 2015).

Magnetic resonance imaging identification of the ALL remains heterogeneous. A systematic review of imaging studies reported wide variability in the ability to identify normal and injured anterolateral structures, reflecting differences in imaging protocols, definitions, and interpretation (Andrade et al., 2019; Getgood, 2019). This heterogeneity has important implications for both diagnosis and surgical planning.

Biomechanical investigations demonstrate that combined sectioning of the ACL and anterolateral structures increases internal tibial rotation and contributes to pivot-shift kinematics. Robotic cadaveric studies have shown that additional compromise of anterolateral structures increases internal tibial rotation compared with isolated ACL deficiency, whereas combined reconstruction can restore rotational behavior closer to the intact state (Nitri et al., 2016; Rasmussen et al., 2016).

The effect of anterolateral augmentation depends on graft placement, fixation angle, and surgical technique. Studies by Inderhaug and colleagues showed that anterolateral procedures can alter tibiofemoral contact pressures and rotational kinematics when combined with ACL reconstruction, emphasizing the importance of avoiding non-physiological graft tensioning and overconstraint (Inderhaug et al., 2017a, 2017b, 2017c).

Clinical Outcomes of Combined Reconstruction

Several comparative studies and meta-analyses have reported improved rotational stability after ACL reconstruction combined with anterolateral augmentation compared with isolated ACL reconstruction (de Lima et al., 2021; Bosco et al., 2024; Kunze et al., 2021; Na et al., 2021). The most consistent clinical finding is a reduction in residual positive pivot shift.

In the STABILITY randomized clinical trial, adding LET to hamstring autograft ACL reconstruction reduced graft rupture and clinical failure at two-year follow-up in young active patients (Getgood et al., 2020a). The same trial also found no major difference in functional outcomes when LET was added, suggesting that objective stability and failure prevention may improve even when patient-reported scores remain similar (Getgood et al., 2020b).

Meta-analyses of randomized controlled trials have similarly found that combined reconstruction reduces graft reinjury and improves pivot-shift control compared with isolated reconstruction (Bosco et al., 2024; Kunze et al., 2021). However, reported effect sizes differ across analyses because of differences in inclusion criteria, surgical technique, graft choice, follow-up duration, and definitions of failure.

Prospective and matched comparative studies also suggest that combined reconstruction may be most relevant for patients participating in pivoting sports or presenting with high-grade pivot shift. Mogoș et al. (2023) reported superior rotational stability in high-grade pivoting sport patients treated with combined ACL and ALL reconstruction. Pioger et al. (2022) reported favorable outcomes in a large matched-pair analysis of combined ACL and ALL reconstruction compared with isolated ACL reconstruction using bone-patellar tendon-bone grafts.

Return-to-sport rates are not consistently higher after combined procedures. Rezansoff et al. (2024) reported similar return-to-sport rates for ACL reconstruction plus LET and ACL reconstruction alone, but lower failure rates in the combined group. These findings indicate that anterolateral augmentation may mainly influence stability and durability rather than the overall rate of return to activity.

In revision settings, combined intra- and extra-articular reconstruction has been proposed to address persistent rotational instability and reduce recurrent failure. Observational multicenter data support potential benefit in selected revision cases (Louis et al., 2017). However, randomized evidence is not uniformly favorable: Sørensen et al. (2023) reported that ALL reconstruction added to ACL revision did not improve two-year outcomes compared with isolated revision, underscoring the need for careful interpretation and patient selection.

Rotational Stability Assessment

Assessment of rotational stability remains challenging. The pivot shift test is widely used but is examiner dependent and subject to variability. Some studies have attempted to standardize pivot-shift grading or quantify rotational laxity using instrumented devices, but these methods are not universally adopted (Gibbs et al., 2023).

Despite methodological heterogeneity, the reduction in high-grade residual pivot shift is one of the most reproducible benefits of anterolateral augmentation. Even when subjective scales such as International Knee Documentation Committee or Lysholm scores show only modest differences, improved pivot-shift control may be clinically important in high-demand athletes (Getgood et al., 2020a, 2020b; Kunze et al., 2021).

The relationship between preoperative quantitative pivot shift and postoperative in vivo kinematics is complex. Gibbs et al. (2023) found that preoperative quantitative pivot shift did not necessarily correlate with postoperative kinematics after ACL reconstruction with or without LET, demonstrating that clinical rotational laxity is influenced by multiple interacting factors.

Complications and Technical Limitations

Potential concerns related to combined procedures include overconstraint of the lateral compartment, altered tibiofemoral contact pressures, increased surgical time, and technique-related morbidity. Biomechanical studies suggest that LET may increase lateral compartment pressures more than anatomical ALL reconstruction under some testing conditions (Neri et al., 2021).

Available clinical trials have not consistently demonstrated a major increase in overall complication rates when anterolateral augmentation is added to ACL reconstruction (Getgood et al., 2020a, 2020b). Nevertheless, differences among LET, ALL reconstruction, graft selection, fixation angle, and tensioning protocols complicate direct comparison between studies (Inderhaug et al., 2017a, 2017b, 2017c; Neri et al., 2021).

Graft failure is multifactorial and influenced by graft choice, tunnel placement, rehabilitation, return-to-sport exposure, compliance, and biological healing. Helito et al. (2023) showed that small-diameter hamstring grafts combined with ALL reconstruction had failure rates similar to larger hamstring graft reconstruction alone, suggesting that anterolateral augmentation may partially compensate for specific risk factors in selected patients.

Discussion

The cumulative evidence suggests that ACL reconstruction combined with anterolateral augmentation improves rotational stability compared with isolated ACL reconstruction in selected patients. Reduction in residual pivot shift is the most consistent endpoint across randomized trials, comparative studies, and meta-analyses (Bosco et al., 2024; Kunze et al., 2021; Na et al., 2021).

The clinical relevance of improved pivot-shift control depends on patient characteristics. Recreationally active patients may achieve satisfactory stability after isolated ACL reconstruction, whereas young athletes returning to cutting and pivoting sports may be more sensitive to residual rotatory laxity. This distinction supports individualized rather than routine use of anterolateral augmentation (Getgood et al., 2020a; Sonnery-Cottet et al., 2017).

High-risk features commonly discussed in the literature include young age, generalized ligamentous laxity, high-grade pivot shift, Segond fracture, revision reconstruction, participation in pivoting sports, and potentially small-diameter hamstring grafts. However, thresholds for these indications are not yet standardized, and available studies differ substantially in inclusion criteria and surgical technique (Helito et al., 2023; Na et al., 2021; Sonnery-Cottet et al., 2017).

Routine augmentation for all primary ACL reconstructions is not supported by current evidence. Although combined procedures may reduce graft failure in selected high-risk cohorts, they add technical complexity and may theoretically increase the risk of overconstraint if graft placement or tensioning is non-physiological (Inderhaug et al., 2017a, 2017b, 2017c; Neri et al., 2021).

The literature is limited by heterogeneity in study design, surgical technique, outcome measures, follow-up duration, and definitions of graft failure. Many studies are retrospective or matched cohort analyses rather than randomized trials. Even among randomized trials, the procedures studied differ, with some evaluating LET and others evaluating anatomical ALL reconstruction. This makes it difficult to determine whether observed benefits are attributable to restoration of anterolateral stability in general or to specific technical details.

Another limitation is the frequent lack of long-term outcomes. Most available randomized evidence reports short- to mid-term follow-up. Whether improved rotational stability translates into sustained graft survival, reduced meniscal or chondral injury, and lower rates of post-traumatic osteoarthritis remains uncertain.

Future Research Directions

Future research should prioritize high-quality randomized controlled trials comparing isolated ACL reconstruction with ACL reconstruction combined with ALL reconstruction or LET using standardized surgical techniques. Harmonized outcome definitions are needed for graft failure, clinical failure, residual pivot shift, return-to-sport quality, and complications.

Objective rotational assessment tools should be incorporated more consistently to complement clinical pivot-shift grading. Comparative studies between anatomical ALL reconstruction and LET are also needed to clarify whether one approach provides superior stability, lower complication risk, or more physiological joint kinematics.

Long-term follow-up is essential. The key unresolved question is whether improved short-term rotational stability results in durable graft survival, sustained return to preinjury sport level, reduced secondary intra-articular injury, and meaningful joint preservation over time.

Conclusions

Current evidence indicates that ACL reconstruction combined with anterolateral augmentation can enhance rotational stability compared with isolated ACL reconstruction, most consistently reflected by improved pivot-shift control. Randomized trials and meta-analyses suggest lower graft failure rates in selected high-risk cohorts, especially young active patients undergoing hamstring autograft reconstruction with added LET.

However, heterogeneity in surgical technique, patient selection, outcome assessment, and follow-up duration limits definitive conclusions. Routine anterolateral augmentation for all primary ACL reconstructions cannot be universally recommended. Individualized patient selection remains essential, and further standardized long-term research is required to define indications, compare techniques, and clarify whether improved rotational control translates into durable clinical and joint-preservation benefits.

Ethical Considerations: Ethics approval was not required because this structured narrative review used previously published data only and did not involve human participants, animal subjects, or identifiable patient data. Informed consent was not applicable.

Conflict of Interest Statement: No conflicts of interest to declare.

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