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Bridge-Enhanced ACL Repair Throughout Varied Patient Populations: Clinical Outcomes, Patient Priorities, and Equity-Focused Research Gaps

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Abstract

Background. Bridge-enhanced anterior cruciate ligament repair (BEAR) alternative to ACL reconstruction Interest has grown due to its ability to maintain tissue continuity, preserve hamstring strength, and support faster recovery. However, evidence of its effectiveness across diverse patient populations remains limited.

Aim. Integrate current evidence on clinical outcomes, patient-centered benefits, safety, and equity-related research gaps associated with BEAR in varied patient groups and clinical settings.

Material and methods. This review includes evidence from randomized clinical trials, first-in-human cohort studies, registry data, post-market observational studies, case reports, surgical technique publications, and patient preference research.

Results. Early real-world data suggest good short-term safety and functional outcomes across broader adult groups, including women and middle-aged patients. However, evidence remains concentrated in young, active populations, with limited subgroup analyses and insufficient long-term data in older or non-elite patients.

Conclusions. BEAR is a promising alternative to standard ACL reconstruction for selected patients with acute ACL tears, offering comparable stability and function with better muscle preservation and faster early recovery. Larger, long-term, and more inclusive studies are still needed to clarify its role across diverse patient populations and support individualized clinical decision-making.

Keywords: Bridge-enhanced ACL repair, Anterior cruciate ligament, ACL reconstruction, Knee stability, Hamstring strength, Return to sport Patient-centered outcomes, Health equity

1. Introduction

Anterior cruciate ligament (ACL) injury is a prevalent and important concern in sports medicine, impacting athletes and physically active individuals across a wide range of ages, sports, and activity levels [16,19]. In team-ball sports, most ACL injuries result from non-contact mechanisms, with a particularly high incidence among female athletes and during competitive play [16]. In addition to immediate functional loss, ACL rupture necessitates prolonged rehabilitation, often leads to reduced rates of return to pre-injury activity, recurrent instability, increased risk of secondary meniscal and chondral injuries, and a raised likelihood of developing post-traumatic osteoarthritis (PTOA) over time [5,6,17,19]. These outcomes point out the importance of ACL management strategies that restore knee stability and optimize long-term joint health, physical performance, and patient quality of life.

For several decades, anterior cruciate ligament reconstruction (ACLR) has been the gold standard intervention for symptomatic ACL rupture, particularly in young, active patients aiming to return to pivoting sports [19]. While reconstruction improves stability and function for many patients, it does not fully restore normal ligament biology or native knee biomechanics [5,17,19]. Graft harvesting can result in donor-site morbidity, postoperative weakness, and persistent deficits in strength or neuromuscular control. The risks of reinjury and incomplete return to pre-injury performance remain significant, especially among younger athletes [6,17,19]. These limitations have prompted the development of strategies focused on preserving original body tissue, promoting biologic healing, and improving functional and structural recovery following ACL injury.

BEAR is a novel alternative to traditional reconstruction for selected patients [2-4]. This technique is indicated for complete ACL ruptures in patients with an intact tibial stump and sufficient tissue quality, typically within a defined period following injury [3,4,13,20]. By preserving the native ligament, BEAR may reduce graft-harvest morbidity and maintain anatomical continuity that conventional reconstruction cannot achieve.

The proposed advantages of BEAR go beyond simple structural repair. Conceptual and mechanistic work suggests that preservation of native ACL tissue may better maintain or re-establish mechanoreceptor continuity, with possible consequences for proprioception, neuromuscular control, return-to-sport decision-making, reinjury risk, and ultimately PTOA development [5]. Clinical studies to date have shown encouraging results, with early trials and

prospective randomized evidence demonstrating non-inferior patient-reported outcomes and knee stability compared with hamstring autograft ACLR, as well as superior hamstring strength recovery [1,2,6,9]. Additional studies suggest earlier symptom improvement and greater short-term psychological readiness to return to sport after BEAR [9,10]. Post-commercial registry and prospective observational findings have further suggested that BEAR may be feasible and safe among broader real-world populations, including adult patients outside the narrowly defined cohorts represented in early trials [11,12].

Although these promising findings, significant doubts remain. Most robust evidence for BEAR is derived from young, highly active, and relatively homogeneous patient cohorts [1,2,6]. Data on outcomes in older adults, younger adolescents, female-dominant athletic populations, non-elite or occupationally demanding groups, and patients managed in routine clinical practice throughout diverse health systems remain limited [11-13,16-18]. Long-term data on joint preservation and post-traumatic osteoarthritis (PTOA) risk are also insufficient, and comparative studies have primarily focused on hamstring autograft reconstruction rather than alternative graft options [6,19]. Furthermore, as with many surgical advancement, successful implementation of BEAR depends not only on clinical results but also on patient preferences, access to care, rehabilitation protocols, and fair delivery [15]. Therefore, this review evaluates current evidence on BEAR across multiple patient populations, emphasizing clinical outcomes, patient priorities, and key research gaps. By synthesizing findings from randomized trials, cohort studies, registry data, mechanistic literature, and contextual evidence from sports medicine and patient preference research, the review seeks to clarify BEAR's current role in anterior cruciate ligament (ACL) management and to identify necessary steps for equitable, patient-centered adoption of this technology [1-20].

2. Research materials and methods

2.1. Materials and Methods

This review analyzes bridge-enhanced anterior cruciate ligament repair (BEAR) across diverse patient populations, with emphasis on clinical outcomes, patient-centered priorities, and equity-related research gaps. The review addresses whether current evidence supports BEAR as a viable alternative to anterior cruciate ligament reconstruction throughout various ages, sexes, activity levels, and clinical practice settings, and identifies areas where evidence is still insufficient [1,2,6,11,12].

2.2. Review design

A structured narrative review approach was selected because the literature on BEAR includes heterogeneous evidence sources, including randomized clinical trials, prospective cohort studies, registry analyses, post-market observational studies, case reports, surgical technique papers, mechanistic commentaries, and patient preference studies [2-5,11-15,17-20]. This design allowed integration of efficacy, effectiveness, implementation, and patient-experience evidence within a single clinically oriented framework.

2.3. Search strategy

Targeted electronic searching and citation related to studies of BEAR, anterior cruciate ligament repair, anterior cruciate ligament reconstruction, patient-reported outcomes, return to sport, psychological readiness, mechanoreceptor preservation, post-traumatic osteoarthritis, and applied implementation. Searches were oriented toward peer-reviewed human studies, but mechanistic and contextual papers were also included where relevant to explain biological rationale and research gaps [3-6,16-20].

Priority was given to studies directly evaluating BEAR clinical outcomes, including first-in-human investigations, randomized trials, longitudinal follow-up studies, registry cohorts, and post-commercial reports [1,2,6,9-12,14]. Additional studies were included to contextualize patient values, ACL epidemiology, broader reconstruction practice, and execution considerations [15-20].

2.4. Eligibility criteria

Studies were considered eligible if they met one or more of the following criteria:

1. Reported original data on BEAR in humans
2. Compared BEAR with standard ACL reconstruction
3. Evaluated functional outcomes, knee stability, muscle strength, psychological readiness, complications, reoperation, retear, or return-to-sport outcomes after BEAR
4. Examined BEAR in registry, post-market, or real-life populations
5. Addressed mechanistic, surgical, or implementation issues directly relevant to BEAR interpretation
6. Provided contextual evidence on patient preferences, ACL injury epidemiology

The following publication types were included:

1. Randomized clinical trials [2,7,10]

2. Prospective cohort studies and longitudinal follow-up studies [1,6,8,9]
3. Registry and post-market observational studies [11,12,14]
4. Case reports [13]
5. Surgical technique and clinical experience articles [3,4,20]
6. Mechanistic and conceptual papers [5]
7. Preference studies and broader review literature for contextual interpretation [15-19]

Studies were excluded if they did not address BEAR directly, did not contain interpretable outcomes, remains in animal study or conceptual data irrelevant to the review. When conference-style or companion publications reported overlapping cohorts, the most complete dataset was prioritized, while related reports were used to support consistency of findings where appropriate [2,7; 1,8; 11,14].

2.5 Overall finding

Across the included literature, BEAR consistently revealed:

- Non-inferior patient-reported and objective clinical outcomes compared with hamstring autograft ACLR at 2 years [1,2,7-9]
- Sustained equivalence in most long-term outcomes through 6 years, with persistent superiority in hamstring strength preservation [6]
- Low short-term complication and retear rates in both trial and actual settings [2,11,12]
- Potential early advantages in symptom resolution, psychological readiness, and rehabilitation experience [9,10]
- Emerging use among broader, more female-dominant and middle-aged populations, though with inadequate subgroup analysis [11-13]
- Important pending questions regarding sex-specific outcomes, equity, long-term joint health, and implementation throughout diverse care settings [5,11,12,16-19]

3. Research results

3.1 Clinical efficacy of BEAR compared with ACL reconstruction

The strongest comparative evidence comes from prospective and randomized studies in young, active patients. In the first-in-human cohort, BEAR and hamstring autograft ACLR showed similar patient-reported outcomes, anteroposterior knee stability, and functional

performance at 2 years, with no observed failures in either group [1,8]. These outcomes were reinforced in a larger prospective randomized clinical trial involving 100 patients, in which BEAR was found to be non-inferior to autograft ACLR for subjective IKDC scores and anteroposterior laxity at 2 years [2]. A related conference report supported the same conclusion, again showing equivalent subjective outcomes and stability between procedures [7].

Although the overall outcome was similar, several studies identified advantages favoring BEAR during recovery. In the randomized trial, hamstring strength recovery was markedly better after BEAR than after hamstring autograft ACLR [2]. This pattern was also evident in early cohort work and persisted at longer follow-up [1,6,8]. Barnett et al. further reported earlier symptom resolution and faster functional recovery after BEAR, including higher IKDC subjective scores over time, especially at 6 months, and better KOOS symptom scores at 1 year [9]. Clearance to return to sport at 1 year was numerically higher after BEAR, although this difference was not statistically significant [9].

Longer-term follow-up data remain limited but encouraging. At 6 years, BEAR and reconstruction continued to show similar patient-reported outcomes, IKDC grades, KOOS scores, laxity, and functional test performance, while the advantage in hamstring strength remained distinctly in favor of BEAR [6]. Taken together, these data indicate that BEAR provides comparable short- and medium-term efficacy to hamstring autograft ACLR, with a consistent muscle-preserving benefit that may be clinically meaningful for active patients [1,2,6,9].

3.2 Early recovery and psychological readiness

Beyond usual outcome measures, several studies suggest that BEAR may confer early recovery benefits. In comparative assessments, BEAR patients reported improved symptom resolution during the first postoperative year and demonstrated better hamstring function throughout recovery [9]. These early functional gains may be particularly relevant for patients prioritizing rehabilitation experience and return to activity.

Psychological readiness to return to sport has also emerged as an important outcome. In a prospective randomized study, ACL-RSI scores at 6 months were significantly higher after BEAR than after autograft ACLR, suggesting greater confidence and capability during early rehabilitation [10]. However, these differences were no longer present by 12 to 24 months [10].

Higher ACL-RSI scores were associated with stronger muscle performance, less pain, improved subjective knee function, and earlier clearance for sports participation [10]. These data show that BEAR may offer a short-term psychological advantage, although the long-term clinical significance of this effect is still unclear.

3.3 Real-world and post-commercial outcomes

Evidence from post-commercial and registry-based studies suggests that BEAR can be implemented successfully outside controlled trial settings. Among the first 100 patients enrolled in the Bridge registry, the mean age was approximately 31 years, and most were female, showing a wider clinical population than in early trial cohorts. At approximately 15 months of follow-up, adverse event rates were low, reoperation rates were acceptable, and only 2 ACL retears were reported on final follow-up. Objective stability findings were favorable, with most patients demonstrating minimal Lachman side-to-side difference and negative pivot shift, while patient-reported outcomes were similarly positive [11].

A preliminary post-market study in 58 skeletally mature patients with a mean age of 38 years reported full extension and near-full flexion by 6 months, significant gains in patient-reported outcome measures, and no retears, although arthrofibrosis occurred in 5% of patients [12]. The results support the external validity of BEAR and suggest that satisfactory short-term outcomes are achievable in routine practice among adult patients beyond the younger populations represented in earlier trials [11,12].

3.4 Feasibility throughout broader patient groups

Although most comparative data remain concentrated in young, active individuals, emerging studies suggest that BEAR may be feasible among broader patient populations. A published case report described a 47-year-old woman treated 43 days after injury who showed good early clinical recovery and MRI evidence of repair continuity by 3 months, with improved stability at 6 months [13]. While isolated, this case illustrates that BEAR may be applicable in selected middle-aged, non-elite patients when tissue quality and timing criteria are met [13].

Registry and technical reports additionally indicate that procedural modifications, including anchor and suture adaptations, have not resulted in increased complications during early follow-up, supporting procedural flexibility among centers [14]. Surgical technique papers also describe rapid range-of-motion recovery, reduced swelling, and less quadriceps

atrophy relative to reconstruction, although these observations are based primarily on expert experience rather than controlled comparative data [3,4].

3.5 Patient priorities and broader clinical context

Patient preference adds important context to the outcome data. In a discrete choice experiment, return to sport and hamstring strength emerged as the dominant priorities influencing treatment preference between BEAR and hamstring autograft reconstruction among athletes [15]. Reinjury risk was not a significant driver of decision-making, and preferences were broadly consistent across sex, age, activity, and employment groups [15]. These data match the principal observed advantages of BEAR, particularly hamstring preservation and early functional recovery.

The wider epidemiologic and sports medicine literature also stresses the importance of examining BEAR across more varied populations. ACL injuries occur frequently in female athletes and are often non-contact in mechanism, yet high-quality BEAR evidence remains limited in sex-stratified, sport-specific, and occupation-specific analyses [16]. Narrative and review literature place BEAR within a wider movement toward biologically augmented, patient-centered ligament treatment, while stressing that evidence remains limited regarding long-term osteoarthritis prevention, comparative effectiveness relative to other graft options, and fair implementation throughout medical systems [17-20].

In the wider ACL literature, return to sport is increasingly understood as a multidimensional outcome determined by objective knee function, neuromuscular recovery, psychological readiness, and reinjury prevention, which provides important context to understand the potential patient-centered advantages of BEAR [21].

3.6 Summary of findings

Across the included studies, several consistent findings emerged:

- BEAR is non-inferior to hamstring autograft ACLR for subjective knee function and anteroposterior laxity at 2 years [2,7].
- Early human cohort studies and longer-term follow-up data support similar overall functional and clinical outcomes between BEAR and ACLR [1,6,8].
- Hamstring strength recovery is consistently superior after BEAR and remains improved even at 6 years [2,6,9].

- BEAR may provide earlier symptom resolution and greater early psychological readiness to return to sport [9,10].
- Registry and post-market studies show low short-term complication rates and positive outcomes among broader adult populations [11,12].
- Evidence in older adults, diverse racial and occupational groups, and sport-specific populations remains limited, despite growing real-world use [11-19].

4. Discussion

Bridge-enhanced anterior cruciate ligament repair (BEAR) has been established as a credible biologic alternative to conventional hamstring autograft anterior cruciate ligament reconstruction (ACLR) in appropriately selected patients [1,2,6]. Across first-in-human studies, randomized comparative trials, and post-commercial reports, BEAR consistently revealed non-inferior patient-reported outcomes and knee stability compared with reconstruction, whilst preserving hamstring strength to a substantially greater degree [1,2,6,9]. The results are clinically important because they suggest that ligament preservation can achieve functional recovery comparable to that of hamstring grafts without the donor-site morbidity inherent to hamstring graft harvest [2,6,20].

One of the most consistent findings in this review was the superiority of BEAR in hamstring strength recovery [1,2,6,9]. This advantage was evident early after surgery and persisted through 6-year follow-up in the longest available cohort [6]. In practical terms, this may be especially relevant for athletes, physically active patients, and workers whose performance depends on posterior chain strength, sprint mechanics, deceleration control, or dynamic knee stabilization. The discrete choice evidence further reinforces the importance of this finding, as return to sport and hamstring strength were among the most influential factors shaping treatment preferences [15]. Thus, BEAR's muscle-preserving profile may match closely with what many patients value most when choosing among ACL treatment options.

In addition to muscle preservation, BEAR appears to offer advantages during early recovery [9,10]. Patients treated with BEAR showed earlier symptom resolution, better early subjective knee scores, and greater psychological readiness to return to sport during the first postoperative months [9,10]. These differences lessened over time, suggesting that BEAR may not necessarily produce superior long-term global results but may improve the quality and pace of early rehabilitation. This distinction matters because the patient experience during the early

recovery period often shapes satisfaction, adherence to rehabilitation, and confidence in return-to-sport progression. Psychological readiness is increasingly acknowledged as a key determinant of successful return to sport, and the observed short-term advantage in ACL-RSI scores after BEAR may represent a meaningful, patient-centered benefit [10].

At the same time, this review draws attention to the requirement for caution in interpreting the current evidence base. Most of the strongest comparative studies were conducted in young, highly active populations, often under tightly controlled eligibility criteria [1,2,6]. Although registry and post-market studies have expanded the demographic profile of BEAR recipients to include more women and older adults, these reports remain limited by short follow-up, observational design, and incomplete subgroup characterization [11,12]. As a result, generalizability to wider patient groups is still uncertain. Important populations such as older adults, adolescents younger than those represented in trials, heavy manual workers, patients with lower activity demands, and those with comorbidities or delayed presentation remain under-studied [11-13].

The issue of diversity goes beyond age alone. ACL injuries unequally affect female athletes in several sports, and epidemiologic evidence shows important variation in injury mechanisms and exposure patterns by sex, sport, and participation level [16]. However, BEAR studies rarely report outcomes stratified by these variables, and information on race, ethnicity, occupation, and socioeconomic context is largely absent [2,11,12]. This lack of granularity limits the field's ability to determine whether BEAR performs similarly across populations or whether certain groups derive particular benefit or face specific barriers. If BEAR is to become a truly patient-centered innovation, future studies must move beyond proof-of-concept in relatively homogeneous cohorts and examine how clinical effectiveness intersects with demographic, social, and sporting contexts [16-18].

Another key issue is the interpretation of safety and failure risk. The current literature suggests that BEAR has an acceptable short-term safety profile, with low rates of serious adverse events and favorable postoperative stability in both trials and actual conditions [2,11,12]. Nonetheless, some studies have reported numerically higher rates of reoperation or repeat ACL surgery than reconstruction, even when the differences were not statistically significant [2]. Because available cohorts remain relatively small and follow-up remains limited in many reports, definitive conclusions regarding comparative retear risk cannot yet be made.

This is particularly relevant for younger and high-risk athletes, in whom even small differences in failure rate may affect treatment choice. Continued registry surveillance and larger pragmatic comparative studies will therefore be essential.

A major theoretical advantage of BEAR is that it preserves the native ligament and may maintain or restore mechanoreceptor continuity [5]. This concept distinguishes BEAR from reconstruction not only structurally but additionally functionally. If preserved tissue continuity improves proprioception, neuromuscular control, and movement quality, BEAR could potentially affect reinjury risk, long-term joint health, and return-to-sport decisions in ways that conventional outcome measures do not completely capture. However, this proposed mechanism remains largely conceptual in humans [5]. Current studies provide little direct evidence linking mechanoreceptor preservation to clinically measurable differences in sensorimotor recovery, performance, or osteoarthritis prevention. Thus, one of the most promising aspects of BEAR remains one of the least proven.

Long-term joint preservation is another unresolved question. One of the motivations for biologically augmented ligament repair is the possibility that maintaining native tissue and more normal biomechanics could reduce the risk of post-traumatic osteoarthritis [5,6,20]. Yet the present review found no convincing human evidence that BEAR reduces osteoarthritis incidence or structural degeneration beyond medium-term follow-up. Even the 6-year data, while reassuring for maintained function, do not establish chondroprotection [6]. Given that post-traumatic osteoarthritis is one of the most important long-term consequences of ACL injury regardless of treatment, future BEAR research ought to focus on imaging, biochemical, and clinical markers of joint health over longer durations.

This review also places BEAR within a wider shift in sports medicine toward biologically informed, individualized, and less invasive treatment strategies [17-20]. Traditional ACLR remains the standard of care and has a strong evidence base, but it does not fully restore normal knee biology and may be associated with muscle weakness, donor-site morbidity, and incomplete return to pre-injury performance in many patients [17,19]. BEAR addresses some of these drawbacks by attempting to restore the native ligament rather than replace it. However, enthusiasm for innovation needs to be balanced with careful patient selection and realistic expectations. Current evidence supports BEAR primarily in patients with

repairable ACL tissue, acceptable stump quality, and surgery within the indicated timeframe [3,4,13,20]. Its role outside these indications is still unclear.

The findings of the present review should also be interpreted within the wider return-to-sport literature after ACL injury. A recent narrative review emphasized that, although many athletes return to some level of activity after ACL rupture, a substantially smaller proportion regain their preinjury competitive level, and this gap is influenced by reinjury risk, psychological barriers, and the quality of rehabilitation instead than surgical technique alone [21]. This wider context is highly relevant to BEAR, as the apparent early advantages in hamstring strength, symptom recovery, and psychological readiness may extend past standard knee stability measures. Accordingly, future BEAR studies should include criterion-based return-to-sport outcomes, reinjury surveillance, and psychosocial endpoints in addition to conventional PROMs and laxity testing [10,15,21].

The findings of this review also have consequences for shared decision-making. Patients considering ACL surgery may value outcomes differently from clinicians, and the available preference literature suggests that functional recovery and muscle preservation may be more influential than reinjury risk alone [15]. This supports the idea that BEAR should not be framed solely as a technical alternative to reconstruction, but rather as one option within a wider patient-centered decision-making process. Individual anatomy, injury pattern, sport demands, psychological profile, and recovery priorities should all affect treatment selection. For some patients, the possibility of maintaining native tissue and avoiding graft harvest may be highly attractive; for others, the longer-established evidence base for reconstruction may remain more compelling.

Several limitations of this review should be acknowledged. First, the underlying literature is heterogeneous, including randomized trials, observational studies, registry reports, case studies, and narrative contextual papers, which limits direct comparison across studies [1-20]. Second, much of the high-level evidence derives from coinciding research groups and selected patient cohorts, raising the possibility that external validity is more limited than the consistency of results might suggest [1,2,6]. Third, long-term comparative data are sparse, especially beyond 6 years and within real-world populations [6,11,12]. Finally, important outcomes such as sport-specific performance, cost-effectiveness, equity of access, and long-term osteoarthritis risk remain inadequately studied [16-20].

Overall, the evidence synthesized in this review supports BEAR as an encouraging and increasingly evidence-based treatment for selected ACL injuries. Its principal strengths lie in achieving outcomes comparable to hamstring autograft ACLR while protecting hamstring strength and may improve early rehabilitation experience [1,2,6,9,10]. However, the current literature remains too narrow to define its role fully throughout different patient groups and treatment settings. The next phase of BEAR research should therefore focus less on proving that the procedure can work and more on defining for whom it works best, how it compares with a wider range of contemporary treatments, whether it improves long-term joint health, and how it can be implemented equitably in routine practice [11,16-20].

5. Conclusions

BEAR is a biologically informed ACL repair that preserves the native ligament using a collagen scaffold and autologous blood. Across randomized trials, early cohorts, and registry data, it delivers non-inferior knee stability and patient-reported outcomes to hamstring autograft reconstruction through at least 6 years, with consistently superior hamstring strength, earlier symptom relief, and better early psychological readiness. Real-world registry and post-market data in predominantly female, early-middle-aged adults show low retear rates and good function, suggesting feasibility beyond narrow trial populations.

At the same time, evidence remains concentrated in young, largely White, high-activity cohorts, with limited insight into older adults, adolescents, different sports, exposure patterns, or long-term joint health. Patient preference data reveal a strong emphasis on return to sport and hamstring strength—areas where BEAR appears well aligned. Future research needs to therefore expand toward varied populations, compare BEAR with a wider range of treatments, diligently evaluate neuromechanical and osteoarthritis outcomes, and address implementation and equity to fully define BEAR's position in modern, athlete- and patient focused ACL care.

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Declaration of use of artificial intelligent

Artificial intelligence (AI) tools were used exclusively as assistive instruments during manuscript preparation. Their application was restricted to improving clarity, coherence, scholarly style, and manuscript organization. All scientific content, including literature selection, critical analysis, interpretation of findings, and final conclusions, was developed independently by the authors. Human monitoring was maintained throughout the research process.

References

1. Murray M, Kalish L, Fleming B, et al. Bridge-Enhanced Anterior Cruciate Ligament Repair: Two-Year Results of a First-in-Human Study. *Orthopaedic Journal of Sports Medicine.* 2019;7. doi:10.1177/2325967118824356
2. Murray M, Fleming B, Badger G, et al. Bridge-Enhanced Anterior Cruciate Ligament Repair Is Not Inferior to Autograft Anterior Cruciate Ligament Reconstruction at 2 Years: Results of a Prospective Randomized Clinical Trial. *The American Journal of Sports Medicine.* 2020;48:1305 - 1315. doi:10.1177/0363546520913532
3. Bond EC, Wu KA, Mills FB, O'Donnell R, Cochran G, Lau BC. Bridge-Enhanced Anterior Cruciate Ligament Restoration: Surgical Technique. *Video Journal of Sports Medicine.* 2024;4. doi:10.1177/26350254231218749
4. Bond E, Wu KA, Mills FB, O'Donnell R, Cochran G, Lau BC. Bridge-Enhanced Anterior Cruciate Ligament Restoration: Surgical Technique. *Video Journal of Sports Medicine.* 2024. doi:10.1177/26350254231218749
5. Beveridge JE, Zandiyeh P, Owens BD, Kiapour A, Fleming B. Structure and Function Are Not the Same: The Case for Restoring Mechanoreceptor Continuity Following Anterior Cruciate Ligament Injury.. *Rhode Island medical journal.* 2024;107 8:12-17.

6. Fleming B, Baranker BT, Badger GJ, et al. Bridge-Enhanced Anterior Cruciate Ligament Restoration: 6-Year Results From the First-in-Human Cohort Study. *Orthopaedic Journal of Sports Medicine.* 2024;12. doi:10.1177/23259671241260632
7. Fleming B, Badger G, Kramer DE, Micheli L, YenMD Y, Murray M. O'Donoghue Sports Injury Award: Bridge-Enhanced ACL Repair is Non-Inferior to Autograft ACL Reconstruction at 2-Years: Results of a Prospective Randomized Clinical Trial. *Orthopaedic Journal of Sports Medicine.* 2020;8. doi:10.1177/2325967120s00358
8. Murray M, Kalish L, Fleming B, et al. Bridge-Enhanced ACL Repair: Two Year Results of the First In Human Study. *Orthopaedic Journal of Sports Medicine.* 2019;7. doi:10.1177/2325967119s00197
9. Barnett S, Murray M, Badger G, et al. Earlier Resolution of Symptoms and Return of Function After Bridge-Enhanced Anterior Cruciate Ligament Repair As Compared With Anterior Cruciate Ligament Reconstruction. *Orthopaedic Journal of Sports Medicine.* 2021;9. doi:10.1177/23259671211052530
10. Sanborn RM, Badger G, Proffen B, et al. Psychological Readiness to Return to Sport at 6 Months Is Higher After Bridge-Enhanced ACL Restoration Than Autograft ACL Reconstruction: Results of a Prospective Randomized Clinical Trial. *Orthopaedic Journal of Sports Medicine.* 2022;10. doi:10.1177/23259671211070542
11. Wittstein JR, Strickland S, Gomoll AH, et al. Postcommercialisation outcomes of bridge-enhanced anterior cruciate ligament restoration: The first 100 Bridge registry patients. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA.* 2025. doi:10.1002/ksa.12806
12. Shah AK, Rizy ME, Neijna AG, Uppstrom TJ, Gomoll AH, Strickland S. A Preliminary Study of Post-Market Bridge-Enhanced ACL Restoration (BEAR) Suggests Non-Inferior Short-Term Outcomes and Low Complications. *HSS Journal*®. 2024;21:404 - 413. doi:10.1177/15563316241265351
13. Khan A, Aziz R, Reen M, Walker W, Myers P. The First Case of Bridge-Enhanced Anterior Cruciate Ligament (ACL) Repair (BEAR) Procedure in Mississippi. *Cureus.* 2023;15. doi:10.7759/cureus.44218
14. Wittstein JR, Strickland SM, Gomoll AH, et al. Poster 224: Outcomes of Bridge Enhanced ACL Restoration in the first 100 Bridge Registry Patients. *Orthopaedic Journal of Sports Medicine.* 2025;13. doi:10.1177/2325967125s00311
15. Feeley SM, Broome JN, Cherelstein RE, Neubauer BE, Kuenze CM, Chang ES. Evaluating the Importance of Return to Sports and Hamstring Strength in a Discrete Choice

Experiment for Anterior Cruciate Ligament Injury. *Orthopaedic Journal of Sports Medicine.* 2024;12. doi:10.1177/23259671241282657

16. Chia L, De Oliveira Silva D, Whalan M, et al. Non-contact Anterior Cruciate Ligament Injury Epidemiology in Team-Ball Sports: A Systematic Review with Meta-analysis by Sex, Age, Sport, Participation Level, and Exposure Type. *Sports Medicine (Auckland, N.z.).* 2022;52:2447 - 2467. doi:10.1007/s40279-022-01697-w
17. Krzaczkowski A, Barańska O, Chańko M, et al. Bridge-Enhanced ACL Repair: New approach and developing opportunities in anterior cruciate ligament injury management - literature review. *Quality in Sport.* 2025. doi:10.12775/QS.2025.44.62865
18. Wasilewska M, Pietrzak K, Polok S. Advancing Injury Prevention and Athletic Performance: Bridging Biomechanics, Technology, and Rehabilitation in Sports Medicine. *Quality in Sport.* 2025. doi:10.12775/QS.2025.42.60826
19. Dudek S, Koziak W, Makieła M, et al. Reconstruction of the Anterior Cruciate Ligament in Athletes – A Review of Methods and Therapy Results. *Quality in Sport.* 2025. doi:10.12775/QS.2025.39.59286
20. McMillan S, Sigman S, Dougherty C, Ford E. For Your Consideration: Bridge Enhanced ACL Restoration (BEAR): Why, How, and When. *Journal of Orthopaedic Experience & Innovation.* 2022. doi:10.60118/001c.38392
21. Rusiłowicz R, Peszt MJ, Szaryński M, Jakubowska P, Prokopczyk K, Wasilczuk A, et al. The impact of anterior cruciate ligament rupture on athletes return to sport - A literature review. *Quality in Sport*. 2025;48:66870. doi:10.12775/QS.2025.48.66870