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BRIDGE-ENHANCED ACL REPAIR: NOVEL APPROACH AND EMERGING OPPORTUNITIES IN ANTERIOR CRUCIATE LIGAMENT INJURY MANAGEMENT - LITERATURE REVIEW

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Abstract
Anterior cruciate ligament injury is one of the most common trauma in sport. It leads to long-term exclusion from physical activity, poor quality of life and may result in posttraumatic osteoarthritis. The current gold standard in managing ACL rupture is reconstruction procedure but it is associated with complications such as chronic pain of the knee and muscle weakness. Furthermore, a significant number of patients do not regain their pre-injury level of activity. This study examines research on the BEAR method, being the novel approach in ACL injury management. In this technique, a bovine-derived implant is inserted within the patient's native ligament, allowing it to heal properly without being replaced by a graft. This is achieved by preserving blood clot formation within the joint, which was a limitation of primary open repair cases. It was found that patients who have undergone the BEAR procedure presented better hamstring strength compared to the ACL reconstruction group, have earlier resolution of symptoms, faster psychological preparedness for returning to sport, low complication rate and no donor-site morbidity. It was stated that BEAR itself is non-inferior to ACLR in terms of Patient-Reported Outcome Measures. The efficacy of this technique in reducing posttraumatic osteoarthritis remains to be established. However, findings from animal studies indicate promising outcomes. Larger-scale studies are needed to fully evaluate this modern approach.
Methods of research
A comprehensive search strategy was performed to find articles relevant to the topic. The Pubmed, Cochrane and Google Scholar databases were searched using keywords such as “Anterior Cruciate Ligament”, “Bridge-Enhanced ACL Repair”, “BEAR”, “Bridge-Enhanced ACL Restoration”. To ensure accuracy, search filters were applied to only include papers written in English and published in the last 10 years, prioritizing articles published

in the last 5 years. Furthermore, the reference lists from the studies mentioned were also used to find relatable data for the work.

Keywords
Anterior Cruciate Ligament, Bridge-Enhanced ACL Repair, BEAR, Bridge-Enhanced ACL Restoration

Introduction

Anterior Cruciate Ligament (ACL) is one of two cruciate ligaments located intra-articularly within the knee joint. It has an important function of stabilizing the knee in the sagittal plane by preventing excessive forward movement of the tibia relative to the femur, as well as limiting rotational movements in the knee. It is responsible for the proper biomechanics of the abovementioned joint, providing stability and balance during movement (Hassebrock et al., 2020) . Its rupture leads to instability of the knee and constant feeling of giving way during weightlifting, which results in poor quality of life as well as being associated with increased risk of secondary osteoarthritis of the knee (Beard et al., 2024) .

ACL injury is one of the most common trauma in sports, affecting over 200,000 people yearly in the United States, while in Europe, the incidence rate is approximately 1 in 3,000 individuals (Yu et al., 2024) . It leads to long-term exclusion of the athlete from sports competition due to time-consuming rehabilitation process, surgery-related complications and psychological factors. The first surgical procedure for treating ruptured ligament was performed in 1970s and it was primary open repair. It consisted of an arthrotomy, reconnection of the ACL stumps by suturing and finally immobilizing the knee in the cast for the duration of 4 to 6 weeks (Heusdens, 2021) . The initially promising method quickly lost its popularity due to unsatisfactory results in follow-up where re-tear rate was almost 50% in 2 years period (Khan et al., 2023) . The cause of this phenomenon was found in the improper healing process of the sutured ligament within the joint. To allow reconstitution of the torn ACL, the early clot has to form to bridge the wound and serve as temporary scaffold for cell ingrowth. It was determined that intra-articular plasminogen dissolves any initial blood-clot that begins to form thereby depriving the ligament of the necessary scaffolding needed to heal itself (Haggerty et al., 2020) .

The current gold standard in managing ACL rupture is reconstruction procedure. It is estimated that in the United States surgeons perform almost 250,000 ACL reconstructions annually (Perrone et al., 2017) , while in western countries, as other sources report, about 34 to 44 out of 100,000 people undergo this surgery every year (Malahias et al., 2018) . This procedure requires using artificial grafts, allograft tendons harvested from cadavers or autograft tendons, sourced directly from the patient's ipsilateral or contralateral leg to recreate ruptured ligament (Fan et al., 2023) . The most favored choices are patellar tendon or hamstring tendon, rarely the quadriceps tendon find its use in this procedure (Mouarbes et al., 2019) . Despite proper treatment, only 50% to 65% of recreational athletes regain their pre-injury level of sports performance (Heusdens, 2021) . What is important, even those athletes continue to experience weakness in the area from which the autograft was sourced (Murray, 2021) . Moreover, depending on the tendon used for reconstruction procedure, 20% of patients experienced anterior knee pain and 15% experienced pain during kneeling, which are typical issues associated with patellar tendon graft. In instances where hamstring tendon was used for the procedure, 10% of patients suffered from hamstring muscle weakness (Heusdens, 2021) .

Recently, a new method has emerged that targets the reason why repair of the native ACL has failed. It involves the use of an implant that acts as a scaffold between the remnants of the ruptured ACL, allowing blood clot formation process to occur and persist within the joint, not being targeted by the intra-articular plasminogen. Bridge-Enhanced ACL Repair (short-term BEAR), by improving the healing process of the ruptured ligament,

sheds new light on the reconstruction-over-repair dilemma, giving promising results in recent studies. This work collects information available in the literature regarding the BEAR technique, which may be a turning point in the management of ACL ruptures.

Characteristics of BEAR Implant

BEAR implant is a cylindrical material made of bovine-derived extracellular matrix proteins, mostly type 1 collagen. It is 44 mm in length by 22 mm in diameter and due to its hydrophilic properties, it is capable of retaining up to five times of its own weight in liquid (S. Barnett, Murray, et al., 2020) . Application of this property takes place before the implant is positioned within the ligament, precisely in the moment when surgeon injects it with 10ml of autologous blood. This addition is responsible for smoothening the scaffold and allows it to conform to the uneven contour of the space between two ruptured ends of the ACL (Shah et al., 2025) . By immobilizing the blood within, the BEAR implant preserves native fibrin clot and allows growth factors and proteins to start healing process of the torn ligament. What is more, through stimulating cell recruitment to the implant, the tibial stump fibers of the ACL can reconnect with femoral stump fibers (Spindler et al., 2022) . It was shown that when combining collagen-based scaffold with platelet rich plasma, concentrate derived from the blood itself, the copolymer forms that is resistant to plasmin activity, thus preserving healing properties of the clot that forms (L. Proffen et al., 2015) **.** It was questioned whether concentration of specific blood cell types such as platelets in autologous blood, would have an influence on healing potential of the ACL or not. It was found in a 6-month follow-up that higher physiologic platelet counts are in fact not associated with it (Freiberger et al., 2020) . In this context, BEAR implant acts as a shield for growth factors and proteins within the clot, enabling their full therapeutic potential. After 8 weeks from the implantation process, reabsorption of the collagen-based scaffold occurs, leaving no signs of recently placed material within the knee joint (Perrone et al., 2017) . According to the source, the BEAR implant received FDA approval in regard to biocompatibility and sterility (L. Proffen et al., 2015) .

Preoperative indications for BEAR implant

Multiple studies have been conducted to determine which patients can undergo and benefit from BEAR instead of classic ACL reconstruction. Inclusion and exclusion criteria have varied during the clinical trials leading up to the launch of BEAR.

In the first-in-human trial, which was performed by Murray et al. and enrolled 10 patients in the BEAR group, criteria were the most stringent. The patient had to be between 18 to 35 years old, had a complete ACL tear which occurred less than 1 month prior to the operation and had been preoperatively assessed by magnetic resonance imaging to ensure that they have at least 50% of the length of the ACL connected to the tibia.
Candidates were deemed ineligible for the procedure if they have met at least one of the following criteria: presence of a partial ACL tear, a history of prior knee surgery, a previous knee infection, risk factors that can contribute to improper healing process such as nicotine or tobacco use, corticosteroids use in the last 6 months, chemotherapy history, diabetes or inflammatory arthritis. Moreover, the patients were excluded if they have a displaced bucket-handle tear of the medial meniscus with the requirement of repair procedure, have a full-thickness chondral injury, a grade 3 medial collateral ligament injury, a concurrent complete patellar dislocation or an operative posterolateral corner injury (Murray et al., 2016; Shah et al., 2025) .

Since then, a more liberal approach has been applied, and inclusion criteria have widened with a reduction in the exclusion criteria. In the recent trial called BEAR III, a prospective multicenter cohort study, the patients age could differ from 12 to 80 years, and acceptable time from injury to surgery has increased, enrolling patients with the accident occurring within 50 days prior to the BEAR procedure. Patients with any meniscal and collateral ligament injuries were included and the ones with the partial ACL tear with positive pivot shift were accepted as suitable for the trial. Some of the exclusion criteria persisted, such as ipsilateral knee surgery in the past, history of knee infections, chemotherapy, diabetes, inflammatory arthritis and nicotine/tobacco use whereas some of them softened, for example corticosteroid-free period became 3 months prior to surgery (Sanborn et al., 2023) .

In one of the most recent works, which is a retrospective cohort study, a group of skeletally mature patients with a midsubstance or proximal ACL tear that occurred and had been treated with BEAR between March 2022 and August 2023 were analyzed. No age-related, demographic or other exclusion criteria were applied. Having those

in mind, the results of this preliminary paper of post-market BEAR are hard to extrapolate and imply study generalizability of which patient would benefit the most from BEAR because of the small sample size, consisting of 58 patients and some of them are still yet to achieve 6 months follow-up period (Shah et al., 2024) .

It is yet to determine the perfect candidate for BEAR implant as more data is being collected.

BEAR surgical implantation techniques

Since the BEAR implant was approved by the FDA and considered a viable treatment option for ACL rupture, surgeons have tried various approaches to perform the implant placement surgery.

The original surgical technique involved putting the patient under general anesthesia. Then, arthroscopy was performed to assess meniscal injuries. The tibial aimer was utilized to place guide pin within the tibial ACL footprint, which was subsequently over-drilled with a reamer. The same technique was used on the femoral side, ensuring correct tunnel positioning. The 2-inch arthrotomy was performed at the medial patellar tendon border to provide suture passage. A No. 2 Vicryl suture was introduced into the tibial stump of the torn ACL and two No. 2 Ethibond sutures were looped through a cortical button for femoral fixation. The button, Vicryl suture and two Ethibond sutures were then passed through the femoral tunnel and secured against the lateral femoral complex. Finally, the BEAR scaffold was introduced with both Ethibond sutures passing through it. It was then saturated with 10ml of autologous blood and placed between torn ACL stumps, with Ethibond sutures internally bracing it, thanks to additional tibial cortical button and femoral button. The Vicryl suture was tied over the femoral cortical button to pull the ACL stump into the scaffold and arthrotomy was closed in a typical manner (Murray et al., 2016) .

Since then, new techniques have begun to emerge with the intention of simplifying the procedure learning process, making it risk-free and with the best possible outcome for the patient. Firstly, modifications to the necessary materials were applied with introduction of high strength sutures to maintain necessary tension of the ACL. Sutures were passed via arthroscopic tunnels and femoral incision has been enlarged to make sure that tension is preserved throughout the knotting procedure (Fortier et al., 2022) .

Later, a modified technique was presented, introducing adjustable-loop cortical suspensory femoral fixation system, which aimed to overcome the limitations of the original procedure, mainly the need for a larger incision on the femoral side to ensure the proper tension of sutures and risk of knot slippage while securing ACL repair suture. Through that system, the tension was maintained by an adjustable loop and the tensioning sutures were tied percutaneously at the last step of the procedure, ensuring knot stability. What is more, that procedure no longer necessitated over-drilling the guide pin on both the femoral and tibial sides, as was done in the original surgery. The disadvantages which were pointed out have included higher costs of the procedure and increased complexity compared to the approach described by Murray et al. (Wu, 2024) .

The suture anchor technique was proposed, involving suture anchors for the femoral fixation in comparison to suspensory fixation methods described in previous approaches. Some advantages of this method involve efficiency, simplicity and potential fast learning curve because of its similarities with well-known patellar tendon autograft reconstruction procedure. Moreover, it is said that the gap formation and tunnel widening are less likely to happen and the need for making excessive incision is avoided. The technique itself allows the surgeon to use 4 fully independent sutures for ACL repair whereas in suspensory techniques there is possibility to use only one running suture. The disadvantage of this method is found in the situation where revision surgery is needed, making it more difficult to perform compared to the suspensory method (Gao & Wang, 2024) .

Rehabilitation process after BEAR

After the procedure was performed, patients had to undergo a strict rehabilitation process to later assess valid procedure outcomes. The process itself varied in different studies.

Murray et al. in their paper, which assessed two-year results of first BEAR trial, described standardized rehabilitation protocol that consisted of applying a locking hinged brace for all patients to limit their range of motion from 0 to 50 degrees of flexion of the knee for 2-week period with increase to 90 degrees for the next 4 weeks. If any meniscal repair was performed during surgery, the restriction to 40 degrees of flexion was introduced for the duration of 4 weeks postoperatively and after that the brace was open to 90 degrees of range.

A cold therapy unit was provided for recovery, and physical therapy was administered, including partial weight-bearing for 2 weeks, followed by progressive weight-bearing with crutches until week 4. It was recommended to use a functional ACL brace from 6 to 12 weeks after surgery and during high impact sport activities even for up to 2 years. Running was permitted if 3 months had passed from the operation, with a gradual return to sports at 6 months (Murray et al., 2019) .

Different postoperative rehabilitation protocol was introduced after modified Bridge-Enhanced ACL Repair procedure described by Kantrowitz et al. Through first 2 weeks the patients were allowed to partial weight bearing at 50%, in the next 2 weeks at 75%, and after that patients could bear weight as tolerated. The limitations in range of motion have also gradually mellowed, starting at 0 to 45 degrees in weeks 0 to 2, moving to 0 to 90 degrees in next two-weeks period, finishing at full range of motion 4 weeks postoperatively (Kantrowitz et al., 2024) .

Due to observed limited healing process of the ACL in the early post-operative period, the BEAR-MOON Design Group proposed a more time-consuming rehabilitation strategy. It was found in the prior BEAR study that patients who had undergone slower rehabilitation protocol, as a result, had greater ACL strength. What is more, excessive movement restriction after procedure can lead to loss of motion and may contribute to the development of arthrofibrosis. Taking all the above into consideration, a new BEAR-specific protocol was presented. Weightbearing was restricted in the brace for 6 weeks after the procedure and range of motion was limited to 30 degrees in the first two weeks postoperatively. For weeks 2 to 4 the range of motion was extended, yet still limited to 60 degrees, and for the next two weeks the restriction ranged between 0 to 90 degrees. After 6 weeks there were no limitations to the range of motion. Patients could start quadriceps strengthening 3 to 4 weeks postoperatively and jogging could be introduced 3 to 6 months after the surgery (Spindler et al., 2022) .

In the study conducted by Barnett et al. it was found that female patients had greater functional outcomes and muscle strength at 6 months after BEAR surgery in comparison to male participants. Males demonstrated slower hamstring and quadriceps strength recovery than females, with deficits of 12% and 9%, respectively, at six months postoperatively. They also showed significantly poorer single-leg hop performance, a known indicator of quadriceps weakness, at 6 months (78% vs. 91%, $p < 0.001$) and 12 months (87% vs. 97%, $p < 0.01$) after the surgery. There were no significant differences in recovery process between sexes after 2 years' time. Taking all that into consideration, because of a delayed functional muscle recovery after BEAR procedure, male patients may require some changes in rehabilitation protocol to ensure adequate restoration of lower extremity muscle function by the 6 months period (S. Barnett, Badger, et al., 2020) .

Results

The outcomes of BEAR were evaluated through different criteria, starting directly after first in-human study to 6 years postoperatively, and were compared to the ACL reconstruction procedure outcomes.

- **Functional Outcomes and Return to Activity**

Range of motion (ROM) was measured to assess how quickly patients would return to their pre-injury mobility levels. Shah et al. defined Full ROM as achieving movement from 0 to 135 degrees. Based on the 6-month follow-up results, 51 out of 58 patients (88%) - representing 100% patients eligible for evaluation at that time - had recovered and reached the expected level of ROM. At the time of the analysis, the remaining part of the sample had not yet completed the follow-up (Shah et al., 2024) .

Assessment of muscle strength and function were conducted by measuring isometric hamstring, quadriceps, hip abductor, hip adductor and hip extensor muscle strengths and by performing single-hop, triple-hop, 6-m timed hop, and crossover hop tests (S. C. Barnett et al., 2021) .

It was found that the patients who had undergone BEAR had significantly higher hamstring muscle strength through all the observed periods ($P < 0.001$). After 6-months, compared to the contralateral knee, the hamstring strength was a mean 93% in the BEAR group and 59% in the ACLR group (S. C. Barnett et al., 2021) **.** This trend has been maintained after 2 years ($p < 0.00001$, mean difference = 35.84; 95% CI: 28.22 to 43.46) (Mansour et al., 2023) . Regarding hip extensor strength, the BEAR group had better results after 6 months. There was no significant difference in quadriceps strength at any time. Hip adductor strength was generally higher in the ACLR group ($P = .027$), with the most noticeable differences observed at 6 months and 1-year post-surgery (S. C. Barnett et al., 2021) .

Performed hop tests have shown no significant differences at any postoperative period, except 6-m timed hop after 2 years, where one study reported that the BEAR group was considerably slower than the ACLR group ($P = .017$) (S. C. Barnett et al., 2021.) whereas other paper pointed out that the BEAR group had performed that test

significantly better ($p < 0.0001$, mean difference = 8.64; 95% CI: 4.51 to 12.77) (Mansour et al., 2023) .
In 6-years follow-up the only observed difference between treatment groups was mean hamstring strength, scoring >100% in BEAR patients to 56% in ACLR group. Other functional outcomes showed no statistical significance (Fleming et al., 2024) .
Patients were asked to complete the return to activity survey in the preliminary post-market approval study. Out of 30 patients who completed the questionnaire, there was only one (3%) who was able to participate in an activity on a higher level than before the surgery. Three of them (10%) resumed their previous level, while 26 (87%) returned to a reduced level of activity (Shah et al., 2024) **.** It has been stated that even though BEAR patients experienced faster resolution of symptoms and return of function in comparison to the ACLR group, it did not translate into earlier medical clearance or impact the postoperative activity level (S. C. Barnett et al., 2021) .
In terms of psychological readiness of patients to return to sport after ACL injury, Sanborn et al. conducted a study, where ACL-RSI scale was assessed 6, 12 and 24 months after surgery to find out whether the procedure type would make an impact in that area or not. The BEAR group received significantly higher ACL-RSI scores 6 months postoperatively in comparison to the ACLR group, which would represent better psychological preparedness of that sample. The results after 12 and 24 months were similar between cohorts (Sanborn et al., 2022) .

- **Patient-Reported Outcome Measures (PROMs) and Satisfaction**

The questionnaires used in studies to assess the outcomes of BEAR procedure were International Knee Documentation Committee Subjective Knee Form (IKDC) and Knee injury and Osteoarthritis Outcome Score (KOOS) with all its subscales included, such as KOOS-Pain, KOOS-Symptoms, KOOS-ADL, KOOS-Sport and KOOS-QoL What is more, Lachman test was conducted and anteroposterior knee laxity was measured to fully evaluate the BEAR technique.
All 58 patients in Shah et al. study got IA grade in Lachman test 6 weeks after surgery and out of 51 patients who finished 6-month follow-up visit, only one scored lower on clinical examination. A notable improvement in PROMs was observed when comparing assessments before and after surgery. What is more, 52% of patients who finished PROM questionnaires reached the 2-year ACLR minimal clinically important difference (MCID) values in each subsequent PROM before that period was achieved (Shah et al., 2024) .
It was stated that patients after BEAR had better IKDC and KOOS results in early postoperative period compared with ACLR group, especially after 6 months where IKDC was significantly higher ($P = .001$) and 1 year, where KOOS-Symptoms subscale also presented better, statistically important data ($P = .009$). There was also no significant difference in instrumented anteroposterior knee laxity between BEAR and ACLR groups in 2 years period (S. C. Barnett et al., 2021) . Moreover, a higher ACL-RSI score that was achieved after 6 months by BEAR patients in a study conducted by Sanborn et al. was closely linked to higher IKDC score 6-months postoperatively (Sanborn et al., 2022) .
In longer observation period, BEAR patients have met the non-inferiority criteria in terms of IKDC score and anteroposterior knee laxity 2 years after surgery, compared with autograft ACLR patients (Murray et al., 2020) **.** The 2-year results of the first-in-human study regarding BEAR also showed no difference in IKDC subjective scores, KOOS or knee laxity, with improvement over time in both groups. That said, the difference was found in IKDC objective scores after 24 months, where the IKDC objective grade of A (normal) was achieved by 44% and 29% of patients in BEAR and ACLR cohorts, successively (Murray et al., 2019) **.** After 6 years, both groups demonstrated comparable results in terms of PROM as in a 2-year period (Fleming et al., 2024) .
In the satisfaction-related part of the survey conducted in the group of 29 participants, 17% were very satisfied with the result, 24% were satisfied, 24% were neutral to the outcome and 31% and 3% were dissatisfied and very dissatisfied, successively. The reason for such results was found in the patients' high initial expectations of the new procedure, which resulted in disappointment after the actual level of performance after surgery was achieved (Shah et al., 2024) .

- **Surgical and Procedural Aspects**

Early safety studies demonstrated immunologic tolerance for the BEAR scaffold. As it was shown in a porcine model, the MRI variables, such as T2* and volume, have found their use in predicting structural properties of the healing ligament (Biercevicz et al., 2015) .
The 3-month postoperative MRI assessment showed continuous tissue at the ACL site in the BEAR group. Compared to the patients who undergone ACL reconstruction procedure, there was no significant difference in

synovial fluid levels and increased synovium presence. In the BEAR group, the regenerated ACL tissue spanned directly between the original femoral and tibial insertion points, instead of following the path created by the suture tunnels (Murray et al., 2016) .

In BEAR procedure there is no need for graft harvesting therefore more advantages in comparison to the autograft ACL reconstruction may be found. The most important one is no donor-site morbidity associated with collecting the tissue to recreate torn ligament such as knee pain or hamstring muscle weakness, depending on tendon used for that purpose. It may result in a faster alleviation of knee-related symptoms, enhanced satisfaction of the patients and less symptoms after operation, especially within the first few months following surgery (S. C. Barnett et al., 2021; Heusdens, 2021) .
There is a possibility that by preserving the native ACL, proprioceptive fibers that go along with it could be maintained too. It may benefit in less post-traumatic osteoarthritis cases and significant improvement in sensorimotor control of the knee joint (Fortier et al., 2022; Murray et al., 2019) .

- **Long-term joint health potential**

Patients who have undergone ACL reconstruction procedure frequently develop substantial posttraumatic osteoarthritis 10 to 20 years postoperatively, with rates reaching up to 50% at 10 years when broader diagnostic criteria are applied (Spindler et al., 2022) .
Karamdechu et al. tested 36 minipigs, some of which were randomly assigned to receive the BEAR procedure. After 52 weeks, this group exhibited reduced macroscopic cartilage damage compared to the ACL reconstruction group (Karamchedu et al., 2021) .

Spindler et al. pointed out that there is a possibility in the future to use quantitative MRI after 2 years postoperatively and fixed-flexion radiographs 5 to 6 years after surgery to evaluate changes in articular cartilage and assess, whether BEAR would slow down the development of posttraumatic osteoarthritis in humans (Spindler et al., 2022) . More time and larger studies are needed to clarify the BEAR chondroprotection effect in patients (Fleming et al., 2024) .

- **Post-surgery Complications and Reoperations**

In the early feasibility cohort study conducted by Murray et al., within the first three months following surgery no patient experienced a notable inflammatory response, readmission due to pain or superficial or deep infections in neither BEAR nor ACLR group. Observed adverse events were similar between the samples and included nausea, pain requiring oral medications, joint effusion, localized temporary paresthesia involving lower extremity and necessity to use crutch (Murray et al., 2016) . 2-year follow-up of the first BEAR trial has shown no difference in terms of number and severity of adverse events in both the BEAR and ACLR groups (Murray et al., 2019) so as the 6-year post-surgery data. The subsequent surgeries after 6 years included 2 ipsilateral procedures, one in each group, and 1 case of contralateral ACL surgery in the BEAR group. The 11% revision rate for the BEAR and 14% for the ACLR sample in that follow-up were similar to the previously reported results regarding ACLR. (Fleming et al., 2024) .
It is important to mention that those findings are hard to extrapolate due to the low number of patients enrolled in pointed studies.
The BEAR II trial in terms of revision ACL surgery rates showed no significant difference between BEAR group (14%) and ACLR group (6%) in 2 years after surgery. All the mentioned patients from the BEAR sample, who had converted to the ACLR, had similar outcomes 2 years postoperatively as the ones with primary ACLR procedure. What is more, no significant differences were observed between the groups regarding additional surgical procedures on either the same or the contralateral knee (Murray et al., 2020) .
A preliminary study showed that the BEAR procedure presents a low complication rate in selected patients. Out of 58 people enrolled in a study conducted by Shah et al., there were 5 cases of complications, 3 of which were arthrofibrosis that needed lysis of adhesions 64 to 78 days postoperatively, 1 case of meniscal body reatear at 8 months after procedure and 1 case of lateral tibial subchondral fracture after span of 16 months due to sport-related accident. What is worth mentioning, there was not a single case of any complications commonly linked to

ACL reconstruction, such as persistent effusion, knee instability, quadriceps atrophy, surgical site infection or deep vein thrombosis. The arthrofibrosis cases represented 5% of BEAR patients in comparison to reported incidence of 2% to 35% after ACL reconstruction surgery, depending on the study. No retear or instability cases were observed during follow-up (Shah et al., 2024) .

Rilk et al. compared reoperation rates between different approaches for treating ACL ruptures in regards of the patients' age. No significant difference in reoperation rates was found between ACLR and BEAR. It was stated that there is still not enough data to stratify the outcomes of BEAR by age but at the same time, it was pointed out that revision rates in younger cohorts were significantly higher than in patients aged over 22. There is a need to study the correlation between age, revision risk and higher activity levels in adolescent patients as the animal models have shown improvement in migration, proliferation and ACL healing in younger species, so there is a possibility that those differences stem from greater propensity for engaging in risky behavior and participation in more intense physical activities (Rilk et al., 2025) .

Discussion

Bridge-enhanced ACL Repair is a new, promising approach for treating anterior cruciate ligament ruptures. Until now it was considered ineffective to repair native ACL because of improper healing and significant re-tear rate. Since the introduction of the BEAR implant, preservation of the aforementioned ligament has become an option to consider when addressing an ACL injury.

This review collects the available literature on BEAR and information presented within, starting from the implant description, followed through the indications, implantation techniques, rehabilitation protocols and finishing on the benefits to the patient in comparison to the current gold standard, ACL reconstruction surgery. The short-term results are promising, stating that the BEAR is not inferior to the ACLR technique and can lead to better hamstring strength postoperatively. What is more, earlier resolution of symptoms and low complication rate after BEAR proves efficiency of that approach. Having that in mind, lack of long-term follow-up and small sample sizes in conducted studies limits the evaluation of the collected data. For example, influence on posttraumatic osteoarthritis rate, indications for choosing BEAR over ACLR and complications such as revision surgeries, retears etc. in longer observation period and larger groups of patients are yet to be established. More studies are needed to address those subjects.

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The authors confirm contribution to the manuscript as follows:

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- **Methodology:** MR
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- **Check:** MC, EN, JD
- **Formal Analysis:** ZS
- **Investigation:** EN
- **Resources:** JD
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