FLEX CEUs

Bridge-Enhanced Anterior Cruciate Ligament Repair

Introduction

This course provides an in-depth exploration of Bridge-Enhanced Anterior Cruciate Ligament Repair (BEAR) and its applications in physical therapy. As a cutting-edge approach to treating ACL injuries, BEAR offers a regenerative alternative to traditional ACL reconstruction by eliminating the need for grafts. Through the use of a collagen scaffold positioned between the torn ligament ends, BEAR promotes natural healing and regeneration, preserving the ligament's proprioceptive and biomechanical functions. This course will cover the core principles of BEAR, including the underlying physiological mechanisms, anticipated outcomes, and specialized rehabilitation protocols for patients undergoing this procedure. With an emphasis on evidence-based practices, this course equips physical therapists and physical therapist assistants to support patient recovery with techniques specifically designed for the BEAR approach.

BEAR Procedure Background

References: 1

The Bridge-Enhanced Anterior Cruciate Ligament Repair (BEAR) procedure is a groundbreaking approach to treating ACL injuries. Unlike traditional methods that replace the damaged ligament with a graft, the BEAR procedure preserves the patient's natural ligament. It uses a collagen scaffold placed between the torn ends of the ligament to support natural healing and regrowth. This innovative technique aims to restore the ligament's original function, including its strength and ability to sense movement. This section provides an overview of the BEAR procedure, its development, how it differs from traditional ACL reconstruction methods, and criteria for consideration. Understanding this background will help physical therapists appreciate the unique benefits and challenges of this new approach to ACL repair.

Bridge-Enhanced ACL Repair Explanation

References: 1, 2

The Bridge-Enhanced Anterior Cruciate Ligament Repair (BEAR) procedure is a revolutionary approach in ACL repair, utilizing the body's healing potential instead of replacing the torn ligament with a graft. Traditional ACL reconstruction often requires either autografts (tissue from the patient's own body) or allografts (tissue from a donor), which can carry risks such as prolonged healing times or donor-site morbidity. In contrast, BEAR preserves the native ACL tissue, aiming to regenerate and repair the ligament naturally. This regenerative approach has shown promising outcomes in terms of restoring both strength and proprioceptive function, key to a stable and responsive knee.

The BEAR procedure is based on stimulating the body's natural healing mechanisms to regenerate ligament tissue, a concept known as ligamentization. The blood-soaked scaffold provides a rich supply of nutrients, oxygen, and cellular building blocks needed for tissue growth. Cells from the torn ligament migrate onto the scaffold and begin proliferating, forming new collagen fibers that gradually replace the original scaffold structure. Throughout the healing process, the body reshapes and strengthens the newly formed tissue, integrating it into the knee joint. This gradual transformation from scaffold-supported tissue to fully regenerated ligament restores both the strength and sensory function of the ACL, which is essential for maintaining balance, stability, and proprioception in the knee.

BEAR Scaffold

References: 1

The Bridge-Enhanced ACL Repair (BEAR) scaffold is an innovative device designed to promote natural healing of the anterior cruciate ligament (ACL) following a tear. Unlike traditional ACL reconstruction, which relies on grafts to replace the torn ligament, the BEAR scaffold facilitates the repair of the native ligament. Made from a biodegradable, biocompatible material, the scaffold features a porous matrix that supports cellular infiltration and tissue regeneration. During the surgical procedure, it is infused with the patient's blood to create a biologically enriched environment rich in platelets and growth factors essential for healing.

Once positioned between the torn ends of the ACL, the scaffold provides mechanical support and stimulates healing by enhancing cell migration, collagen deposition, and vascularization. The surgeon secures the torn ligament to the scaffold, which stabilizes the repair while enabling natural tissue regeneration. Over time, the scaffold is absorbed by the body, leaving behind healed ligament tissue. By preserving the native ACL, the BEAR scaffold eliminates the need for grafts, reducing donor site morbidity and potentially improving proprioception. Early clinical outcomes show promising results for ligament stability, strength, and functional recovery, particularly in patients with acute ACL tears and high-quality ligament tissue. As a groundbreaking approach, the BEAR scaffold offers a less invasive and physiologically harmonious alternative to traditional ACL reconstruction, with long-term studies continuing to evaluate its efficacy.

Differences of BEAR from other ACL Surgeries

References: 1, 3

The Bridge-Enhanced Anterior Cruciate Ligament Repair (BEAR) procedure offers a distinctive approach to ACL repair that contrasts with traditional techniques like autograft, allograft, and synthetic grafts. This section offers a breakdown of the key differences between BEAR and these other methods.

Tissue Preservation vs. Replacement

One of the primary differences between BEAR and traditional ACL reconstruction techniques is the method of dealing with the torn ligament. BEAR does not replace the torn ACL with a graft but instead uses a collagen scaffold to bridge the torn ligament ends, allowing the body to regenerate the native ACL tissue. This regenerative approach aims to preserve the ligament's natural properties, including its proprioceptive functions.

In contrast, autograft and allograft techniques involve replacing the torn ACL with a graft—either from the patient's own tissue (autograft) or from a donor (allograft). These methods require the graft to undergo a process as mentioned previously called ligamentization, where it is transformed over time into a structure that mimics the native ACL. However, unlike BEAR, these techniques completely replace the torn ligament, which may not fully restore its original function, particularly proprioception.

Biological Scaffolding

Another key difference is the use of a biological scaffold in BEAR. The BEAR procedure uses a specially designed collagen scaffold, which is placed between the torn ACL ends. This scaffold acts as a bridge to promote natural healing by providing a matrix for cells to migrate and regenerate the ligament tissue. The scaffold is bioabsorbable, meaning it dissolves as the ligament heals, leaving behind newly formed tissue that resembles the original ACL.

In contrast, traditional ACL reconstruction techniques do not use a scaffold. Instead, the graft serves as the structure for healing. The graft undergoes remodeling as the body works to integrate it into the knee, but it does not involve the regenerative scaffold used in BEAR.

Proprioceptive Preservation

Proprioception, the ligament's ability to sense joint movement and position, is crucial for knee stability and function. BEAR preserves the native ACL tissue, which allows it to maintain its proprioceptive properties. This could potentially result in a more natural recovery and better overall knee function compared to traditional graft-based methods.

Autograft and allograft procedures, on the other hand, completely replace the ACL, and the new graft lacks the proprioceptive nerve endings of the original ligament. While the graft eventually provides stability, it may not restore proprioception to the same degree as BEAR's regenerative approach.

Graft Harvesting and Donor Site Morbidity

The BEAR procedure eliminates the need for graft harvesting, which is required in autograft techniques. Harvesting tissue from the patient's own body, usually from the hamstring, quadriceps, or patellar tendon, can result in additional pain, weakness, and potential complications at the donor site. By avoiding graft harvesting, BEAR reduces the risk of donor-site morbidity and minimizes the trauma involved in the procedure.

In contrast, autograft ACL reconstruction involves harvesting tissue from the patient, which can lead to pain, scarring, and long-term functional limitations at the donor site. Allograft procedures eliminate the need for harvesting from the patient but still carry the risk of tissue rejection and disease transmission.

Less Invasive with Potentially Faster Recovery

BEAR is considered less invasive than traditional ACL reconstruction methods because it does not require graft harvesting. This can result in a quick recovery, reduced post-operative pain, and fewer complications from additional incisions. The healing process focuses on regenerating the ligament using the patient's own cells and blood, which may also lead to less trauma and a more natural healing environment.

Traditional ACL reconstruction methods may involve longer recovery times due to the additional surgical steps required for graft harvesting and the adaptation of the graft tissue. Although recovery times can vary, graft-based reconstructions typically take longer to heal compared to the BEAR procedure, particularly due to the need for the graft to undergo ligamentization.

Healing Mechanism

The healing mechanism in BEAR is regenerative, utilizing the scaffold to support the body's natural ability to repair and regenerate tissue. The scaffold provides a framework for the torn ligament ends, helping cells migrate into the area to create new ligament tissue. Over time, the scaffold is absorbed, leaving behind a regenerated ACL that is biologically similar to the original.

In graft-based procedures, the healing mechanism is reconstructive. The body remodels the graft over time, but it does not regenerate the original ligament tissue. The graft undergoes ligamentization, a process where the body slowly turns the graft tissue into something that functions similarly to the native ACL. This process, while effective, can result in a graft that differs in structure from the original ligament.

The BEAR procedure offers a regenerative, scaffold-based approach that aims to preserve native ACL tissue and potentially restores proprioception and knee function more naturally. Traditional graft-based techniques, while effective, involve replacing the torn ACL with a graft and may have longer recovery times, more invasive procedures, and less restoration of proprioception. BEAR's focus on natural healing and tissue regeneration makes it an appealing alternative for select patients, while traditional methods remain the go-to for a broader range of ACL injuries.

Criteria for BEAR Consideration

References: 1, 4

The Bridge-Enhanced Anterior Cruciate Ligament Repair (BEAR) procedure is an innovative approach to treating ACL injuries and is considered an alternative to traditional reconstruction. Candidates for BEAR are typically younger individuals, often under the age of 40, with moderate to high activity levels, as the procedure aims to restore more natural ACL function.

BEAR is most suitable for specific types of ACL tears, especially proximal tears that are fresh or have occurred within a few weeks. It is typically recommended for patients with certain injury profiles where the body's natural healing abilities can be harnessed. The procedure may not be appropriate for patients with chronic tears or extensive damage to the ACL or other knee structures.

The procedure is most suitable for complete mid-substance ACL tears where the ligament ends are not severely retracted or frayed, as these conditions are essential for healing. Timing is critical, with the best outcomes seen when the procedure is performed within 50 days of the injury, allowing for better preservation of the ligament's integrity. BEAR is generally recommended for skeletally mature patients with closed growth plates and no significant arthritis or additional ligamentous injuries, such as severe collateral ligament damage, which might require other surgical approaches. Successful outcomes also depend on the patient's commitment to a structured rehabilitation program, as post-operative physiotherapy is integral to recovery. However, patients with conditions that impair healing, such as severe infections or systemic illnesses, are not suitable candidates. As BEAR is still an emerging procedure, access may be limited to specialized centers or clinical trials, with ongoing research continuing to refine patient selection criteria.

Autograft and allograft techniques are more widely applicable, with these methods used for a broader range of ACL injuries, including chronic tears. These procedures can be performed at various stages after injury, even for patients who have delayed surgery or have more complex damage to the ACL.

Section 1 Key Words

BEAR Procedure – The Bridge-Enhanced ACL Repair (BEAR) procedure is a surgical technique used to repair a torn anterior cruciate ligament by promoting the natural healing of the native ligament rather than replacing it with a graft

BEAR Scaffold - A biodegradable medical device designed to facilitate the natural healing of a torn anterior cruciate ligament

Ligamentization - The biological process by which a graft or repaired ligament undergoes structural and functional transformation to resemble a native ligament

Section 1 Summary

The Bridge-Enhanced Anterior Cruciate Ligament Repair procedure represents a revolutionary advancement in the treatment of ACL injuries. By preserving the patient's native ligament and utilizing a collagen scaffold to support natural healing, BEAR offers a regenerative alternative to traditional ACL reconstruction methods. This approach aims to restore the ligament's strength and proprioceptive function, offering a more natural recovery process. With a focus on the development and unique characteristics of BEAR, this section highlights how it differs from traditional ACL repair techniques and outlines the criteria for its application. Understanding these aspects will equip physical therapists with valuable insights into the benefits and challenges of this innovative procedure.

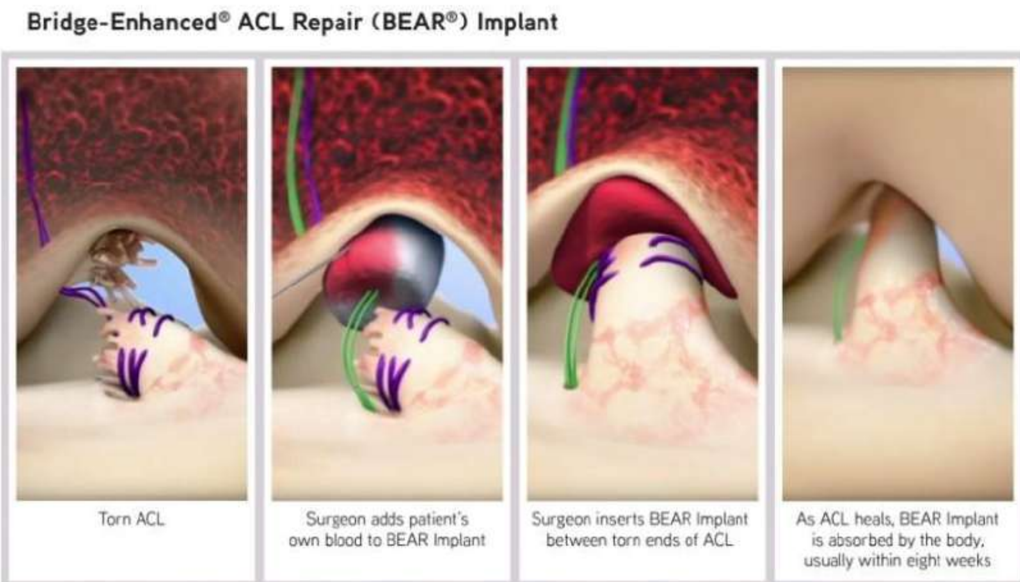
Details of BEAR Procedure

The Bridge-Enhanced ACL Repair (BEAR) procedure represents a novel approach to treating anterior cruciate ligament (ACL) tears, shifting from traditional reconstruction techniques to a method focused on repairing and preserving the native ligament. ACL injuries are among the most common orthopedic injuries, particularly in athletes and active individuals, and historically have been managed by reconstructing the ligament using grafts from autologous or allogeneic sources. The innovative BEAR procedure not only eliminates the need for grafts but also aims to restore the native ligament's structure and function, offering the potential for improved outcomes in stability, proprioception, and long-term knee health. This section will cover the BEAR procedure in detail, the outcome comparisons of BEAR vs other procedures, healing timelines, MRI findings that indicate success, and functional outcome measures.

BEAR Procedure in Detail

References: 1, 4

The BEAR procedure is a groundbreaking surgical technique designed to repair ACL tears by leveraging the body's natural healing processes. Unlike traditional ACL reconstruction, which involves replacing the torn ligament with a graft, the BEAR procedure preserves the native ligament. Central to this approach is the use of the BEAR scaffold, a biodegradable and biocompatible device that bridges the gap between the torn ligament ends. The scaffold features a porous matrix that supports cellular infiltration and tissue regeneration, and it is infused with the patient's blood during surgery to create a biologically enriched environment. This infusion introduces platelets and growth factors that stimulate healing, promote vascularization, and encourage collagen deposition.



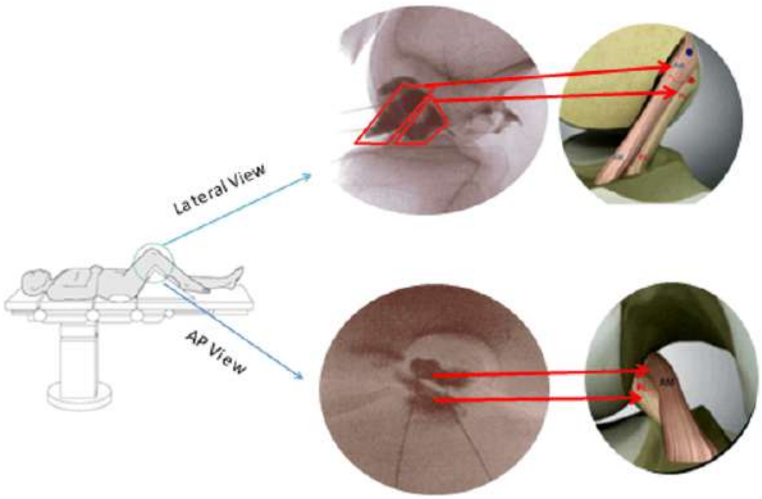
https://www.cosportsmedicine.com/blog/dr-logan-discusses-acl-repair-all-about-the-bear-to-restore-the-acl

The surgical process begins with the preparation of the torn ligament. The surgeon arthroscopically cleans the damaged ends to expose healthy fibers and places sutures in the ligament stumps for secure fixation. The BEAR scaffold is then hydrated with the patient's blood, which is obtained through venipuncture, activating the scaffold and optimizing it for integration. Once prepared, the scaffold is positioned within the knee joint between the torn ligament ends. The previously placed sutures are passed through the scaffold to anchor it securely and align the ligament ends. After confirming proper placement and stability through a range-of-motion assessment, the incisions are closed, and the knee is bandaged.

https://www.pinnacle-ortho.com/bridge-enhanced-acl-restoration-bear-implant

The BEAR scaffold plays a critical role during the healing process by providing a temporary bridge that connects the torn ligament ends while supporting cellular activities essential for tissue repair. Fibroblasts and other cells migrate into the scaffold, initiating the production of Type I and Type III collagen, which form the foundation of the repaired ligament. Simultaneously, the scaffold promotes angiogenesis, ensuring a robust blood supply for nutrient delivery and waste removal. Over several months, the scaffold gradually degrades and is absorbed by the body, leaving behind a fully regenerated ligament.

Postoperative rehabilitation following the BEAR procedure is carefully structured to protect the repair and facilitate a gradual return to function. Early stages focus on minimizing swelling, maintaining range of motion, and protecting the healing ligament. As the ligament strengthens, weight-bearing and strengthening exercises are introduced, eventually progressing to sport-specific training. This rehabilitation protocol mirrors the gradual healing process of the repaired ligament, which can take several months to fully mature.



https://regenexx.com/blog/the-bear-implant-for-acl-tears/

The BEAR procedure offers several advantages over traditional ACL reconstruction. It preserves the native ligament, potentially improving proprioception and natural knee kinematics. By avoiding the need for grafts, it eliminates donor site morbidity and reduces the surgical trauma associated with autograft or allograft harvest. The biological healing promoted by the scaffold may also reduce the risk of osteoarthritis and other complications in the long term. However, the procedure is currently best suited for acute ACL injuries with high-quality ligament remnants, as it requires healthy tissue for successful repair. While early clinical studies have demonstrated promising outcomes in terms of stability and function, further research is needed to validate its long-term efficacy and durability compared to traditional methods. The BEAR procedure represents a significant step forward in ACL injury management, prioritizing tissue preservation and biological healing in a way that aligns with the body's natural processes.

Outcome Comparisons of BEAR vs Others

References: 2, 5

The Bridge-Enhanced ACL Repair procedure provides a novel alternative to traditional ACL reconstruction, offering distinct advantages in certain outcomes while posing unique challenges compared to autograft and allograft approaches. In terms of knee stability, the BEAR procedure has shown outcomes comparable to autografts and allografts. Objective assessments such as the Lachman test and KT-1000 arthrometer measurements demonstrate that the BEAR repair achieves similar levels of anterior tibial stability, particularly in younger patients with acute ACL injuries and good ligament quality. Autografts, particularly patellar tendon grafts, are known for their excellent stability and low failure rates, while allografts generally provide satisfactory stability but have slightly higher failure rates, especially in younger, active individuals due to slower biological incorporation and remodeling.

When evaluating functional outcomes, studies report similar recovery in scores such as the International Knee Documentation Committee (IKDC) and Lysholm scales among BEAR, autograft, and allograft procedures. The BEAR technique may have an edge in proprioception, as it preserves the native ACL fibers responsible for sensory feedback, potentially improving knee biomechanics. Conversely, autografts require the remodeling of harvested tissue into ligament-like structures, which lack the native ligament's proprioceptive qualities, though they still result in robust functional outcomes when paired with comprehensive rehabilitation. Allografts, while effective, may lead to slower recovery timelines due to delayed graft incorporation and lower initial mechanical strength.

From a healing and biological integration perspective, the BEAR procedure emphasizes natural regeneration of the native ACL by leveraging the body's intrinsic healing capacity. The BEAR scaffold, infused with the patient's blood, promotes cell migration, collagen deposition, and angiogenesis to restore ligament integrity. This approach potentially results in a repaired ligament more aligned with the natural anatomy and function of the knee. In contrast, autografts and allografts rely on the body to remodel transplanted tissue, which can take 12 to 24 months, with allografts typically experiencing slower integration due to reduced cellular activity in donor tissue. Additionally, the BEAR procedure avoids donor site morbidity, a significant advantage over autografts, which may cause anterior knee pain (patellar tendon grafts) or hamstring weakness (hamstring grafts). Allografts eliminate donor site complications entirely but carry a slightly elevated risk of immune response or infection, though modern sterilization practices have mitigated these risks.

The return-to-sport timeline for the BEAR procedure is similar to traditional reconstruction, with most patients returning to activity within 9 to 12 months. However, long-term data on high-performance athletes are still emerging. Autografts, particularly patellar tendon grafts, remain the gold standard for athletes due to their durability and high rates of return to pre-injury activity levels. Allografts, while suitable for older or less active patients, often result in slower return-to-sport timelines and increased failure rates in high-demand settings.

Regarding long-term joint health, the BEAR procedure offers potential advantages. By preserving the native ACL, it may reduce the risk of post-traumatic osteoarthritis and better maintain long-term knee function. Conversely, graft-based reconstructions, while effective in stabilizing the knee, do not restore the natural biology of the ACL, which may contribute to cartilage degeneration over time. Allografts, in particular, may be associated with a slightly higher incidence of long-term joint degeneration due to slower biological remodeling and integration.

In terms of graft failure, early studies suggest that the BEAR procedure has comparable or slightly higher failure rates than autografts, particularly in younger and more active patients, though ongoing refinements in surgical technique and patient selection are likely to improve these outcomes. Autografts, particularly patellar tendon grafts, remain the most durable option, with consistently low failure rates, while hamstring grafts have slightly higher failure rates in young athletes. Allografts, although convenient and less invasive, show the highest failure rates among the three techniques, particularly in individuals under 25 years old engaging in high-demand sports.

The BEAR procedure holds great promise as a biologically harmonious alternative to ACL reconstruction, offering comparable functional and stability outcomes while preserving the native ligament and avoiding donor site morbidity. However, its long-term durability and efficacy, particularly in high-performance athletes, require further investigation. Autografts remain the gold standard for young, active patients due to their proven durability, while allografts provide a viable option for older or less active individuals. As advancements in surgical techniques and technology continue, the BEAR procedure may redefine the approach to ACL injuries, particularly for patients prioritizing native tissue preservation and natural healing.

Healing Timeline

References: 1, 6

The healing process following the BEAR procedure involves several distinct biological and functional phases, leveraging the body's natural tissue repair mechanisms. As mentioned, the BEAR procedure supports native ligament regeneration through the BEAR scaffold, which is specially designed to bridge the torn ends of the ACL and promote healing by creating an optimal environment for cellular growth and collagen deposition. Below is a detailed timeline that highlights the phases of healing, along with the corresponding biological processes and rehabilitation goals.

Immediate Postoperative Phase (0–6 Weeks)

During the first six weeks following the BEAR procedure, the focus is on initiating biological healing and protecting the repair. The BEAR scaffold, infused with the patient's blood, acts as a matrix to support the migration of fibroblasts and other reparative cells to the injury site. Platelets from the blood release critical growth factors, such as vascular endothelial growth factor and platelet-derived growth factor, which stimulate angiogenesis and facilitate the deposition of extracellular matrix. These processes begin the formation of a new ligament by producing Type III collagen, which serves as an initial, less-structured framework for tissue regeneration.

Functionally, this phase focuses on minimizing stress on the healing ligament while maintaining controlled range of motion. Patients typically wear a hinged locking knee brace and engage in partial weight-bearing with crutches to protect the repair. A hinged locking knee brace provides advanced stabilization and controlled motion due to rigid side bars and an integrated hinge system. This brace allows precise regulation of the knee's range of motion while protecting the healing ligament from excessive forces. The locking mechanism can immobilize the knee at specific angles or permit incremental adjustments to ROM, ensuring the joint remains in a biomechanically safe position during each phase of rehabilitation. Rehabilitation involves gentle exercises, such as passive and active-assisted ROM activities, with an emphasis on restoring knee extension to prevent contractures. Quadriceps activation exercises are introduced to maintain muscle strength and prevent atrophy, while swelling and pain management are prioritized through modalities like icing and elevation.

https://orthotape.com/products/post-op-rom-acl-knee-brace

Early Healing and Remodeling Phase (6–12 Weeks)

Between six and twelve weeks, significant biological and structural changes occur in the healing ligament. The Type III collagen initially laid down begins to be replaced by the stronger and more organized Type I collagen. Angiogenesis continues, and new blood vessels support increased vascularization, improving nutrient delivery and waste removal at the repair site. The scaffold gradually degrades during this period as the body transitions to relying on the regenerated native tissue for structural integrity.

Rehabilitation progresses as patients achieve full weight-bearing and gradually discontinue the use of a knee brace. Strengthening exercises are advanced to include closed-chain activities, such as mini squats and step-ups, which reduce stress on the knee joint. Balance and proprioceptive training begin to enhance neuromuscular coordination, a critical factor in regaining functional stability. The goals during this phase are to improve ROM, reduce swelling, and establish a strong foundation for later strengthening.

Intermediate Phase (3–6 Months)

During the intermediate phase, the ligament undergoes further remodeling, with collagen fibers becoming more organized and aligned to withstand mechanical stresses placed on the knee during activity. Vascular remodeling ensures that the ligament receives adequate blood supply, supporting its maturation. By the end of this phase, the scaffold has been almost entirely absorbed, leaving a regenerated ligament composed predominantly of native tissue.

Functional goals during this phase shift toward restoring full ROM, increasing muscle strength, and improving knee stability. Rehabilitation includes progressive resistance training, focusing on the quadriceps, hamstrings, and hip stabilizers. Cardiovascular conditioning through low-impact activities like cycling and swimming is also introduced. Patients may begin light agility drills, such as lateral movements or controlled pivoting, under the guidance of a physical therapist. These exercises prepare the patient for the demands of high-impact activities while minimizing the risk of reinjury.

Late Remodeling Phase (6–12 Months)

The late remodeling phase is marked by the ligament gaining significant tensile strength as collagen fibers fully align with the knee's natural biomechanical demands. The vascular network stabilizes, and the newly formed ACL increasingly resembles its native counterpart in both structure and function. While the ligament may not be fully mature by the end of this phase, it is sufficiently robust to support a return to more advanced activities.

Rehabilitation during this phase intensifies with the introduction of dynamic and plyometric exercises, such as jumping, cutting, and sport-specific drills. Advanced proprioceptive training helps refine balance and neuromuscular control. Patients undergo return-to-sport testing, including single-leg hop tests and isokinetic strength assessments, to evaluate their readiness for athletic participation. Most patients can return to high-impact activities and sports around 9–12 months post-surgery, provided they demonstrate adequate strength, stability, and control.

Maturation Phase (12–24 Months)

The final phase of healing extends over the first two years post-surgery, during which the ligament reaches full biological maturity. Collagen remodeling continues, resulting in a structure that closely mimics the native ACL in both tensile strength and elasticity. By this stage, vascularity stabilizes, and the ligament integrates seamlessly with surrounding knee structures, completing the regeneration process.

Functional goals during this phase include achieving pre-injury performance levels, maintaining long-term knee health, and preventing reinjury. Patients are encouraged to continue strength training, flexibility exercises, and neuromuscular conditioning to ensure knee stability. Ongoing injury prevention strategies, such as ACL-specific training programs focusing on proper landing mechanics and strength imbalances, are essential to reduce the risk of future injuries.

Factors Influencing Healing Timeline

The healing timeline for the BEAR procedure can vary based on several factors. Younger patients often heal faster due to higher cellular activity and vascularity, while the severity of the initial injury, including the size of the ligament gap, may extend recovery time. Compliance with rehabilitation protocols is critical, as consistent engagement in therapy significantly improves outcomes. Athletes and active individuals may require more intensive rehabilitation to safely return to pre-injury performance levels. Finally, surgical technique, including precise placement of the BEAR scaffold, plays a pivotal role in optimizing the healing environment.

MRI Findings that Indicate Success

References: 7, 8

Magnetic Resonance Imaging (MRI) is an invaluable tool for assessing the success of the Bridge-Enhanced ACL Repair procedure. It allows clinicians to evaluate the structural integrity, biological healing, and functional recovery of the ligament over time. Several key findings on MRI can indicate a successful outcome, including evidence of a continuous ligament structure, proper signal intensity changes, scaffold integration, vascularization, collagen organization, and the absence of complications.

One of the most critical MRI findings in a successful BEAR procedure is the formation of a continuous ligament structure. On T2-weighted images, the repaired ACL should exhibit a clear, uninterrupted fiber bridge connecting the femoral and tibial insertions. In the early postoperative phase, the ligament may appear disorganized due to surgical manipulation and the incorporation of the BEAR scaffold. Over time, as the ligament regenerates and remodels, the fibers should align in a parallel, organized configuration, reflecting the restoration of structural integrity.

The evolution of signal intensity within the repaired ACL is another hallmark of successful healing. In the early postoperative phase (0–3 months), T2-weighted images typically show increased signal intensity, which reflects normal edema, inflammation, and the initial incorporation of the scaffold. By the intermediate phase (3–6 months), the ligament should show a gradual reduction in signal intensity, indicating reduced inflammation and ongoing remodeling. By the late phase (6–12 months), the ligament should exhibit low signal intensity similar to that of native ACL tissue, signifying advanced maturation and integration of the repaired ligament.

Scaffold integration with bone is also a vital indicator of success. MRI should demonstrate the scaffold merging seamlessly with the femoral and tibial bone attachments, creating continuity between the ligament and surrounding structures. Bone tunnels, if used during the procedure, should exhibit progressive filling with new bone, indicating stability at the attachment sites. The absence of cystic changes, tunnel widening, or loosening further supports a successful outcome.

Vascularization plays a pivotal role in ligament healing, and MRI findings can provide insight into this process. In the early stages of recovery, T1-weighted contrast-enhanced imaging may reveal hyperintensity around the scaffold, which reflects robust vascularization necessary for tissue regeneration. As healing progresses, the vascular signal diminishes, leaving behind a well-vascularized ligament capable of sustaining normal perfusion. This transition is a positive indicator of biological recovery.

Collagen organization within the repaired ligament can also be assessed using MRI. As the ligament heals, it transitions from an amorphous, heterogeneous tissue structure to a well-organized fibrillar pattern. Advanced imaging techniques such as diffusion tensor imaging (DTI) can provide detailed information on fiber orientation and density, offering insights into the biomechanical competence of the newly regenerated ACL.

Finally, the absence of complications on MRI is a critical indicator of procedural success. A successful BEAR repair should show no signs of excessive joint effusion, synovitis, cystic changes at the insertion sites, scaffold degradation without ligament replacement, or evidence of re-tear or mechanical failure. Normal ACL orientation, aligning parallel to Blumensaat's line on sagittal imaging, further supports a positive outcome. Additionally, restoration of the ligament's expected length, thickness, and cross-sectional area compared to the contralateral ACL confirms the recovery of both structure and function.

In summary, a successful BEAR procedure is characterized on MRI by a continuous and organized ligament structure, proper signal intensity changes over time, effective scaffold integration, adequate vascularization, and the absence of complications. These findings reflect the biological and mechanical restoration of the ACL, providing critical benchmarks for tracking recovery and guiding rehabilitation protocols. Serial MRI assessments allow clinicians to monitor healing progress and optimize long-term outcomes.

Recommended Functional Outcome Measure Testing

References: 9-11

To comprehensively evaluate recovery after the Bridge-Enhanced ACL Repair procedure, clinicians use a variety of functional outcome measures that assess range of motion, strength, stability, neuromuscular control, and overall functionality. These measures provide critical data to guide rehabilitation progress, address deficits, and ensure a safe return to activity.

Knee range of motion testing is one of the primary measures used in the early stages of recovery. This assessment ensures the knee regains its natural flexibility and joint mechanics, preventing stiffness and contractures. Using a goniometer, clinicians measure both passive and active ROM, with the goal of achieving full extension by six weeks postoperatively to support normal gait. Progressive flexion, reaching approximately 120–135 degrees by three months, is also targeted to restore functional mobility. Achieving these benchmarks is essential for transitioning to more advanced rehabilitation activities and maintaining proper joint function.

Quadriceps and hamstring strength testing is another critical measure, as muscle strength is vital for knee stability and performance. Isokinetic dynamometry, the gold standard for strength evaluation, measures torque across a range of motion, while handheld dynamometry offers a portable alternative for isometric strength testing. Strength comparisons between the affected and contralateral limbs are expressed as the Limb Symmetry Index (LSI), with a goal of greater than 90% symmetry by six to nine months. Quadriceps strength, in particular, is a key determinant of successful functional outcomes, as deficits in this muscle group are associated with increased re-injury risk.

Dynamic power and control are evaluated through single-leg hop tests, which simulate functional activities like running and jumping. These tests include the single-leg hop for distance, triple hop for distance, crossover hop, and timed hop tests, each assessing aspects of lower-limb power and symmetry. Success is typically defined as achieving greater than 90% symmetry between limbs by nine to twelve months. These tests are particularly important for assessing readiness for high-impact activities and sport-specific movements.

Balance and proprioception testing is crucial for evaluating neuromuscular control and stability. Tests such as the single-leg balance test, Y-Balance Test, and Star Excursion Balance Test (SEBT) measure the patient's ability to maintain balance and control dynamic movements.

The Star Excursion Balance Test is comprehensive and evaluates dynamic balance by testing eight different reach directions: anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anteromedial. Participants stand at the center of a star-shaped pattern and perform reach movements with one leg while maintaining balance on the other. Reach distances are recorded for each direction, and asymmetries or reduced reach distances may highlight deficits in balance, strength, or proprioception. While more detailed than the YBT, the SEBT requires additional time and precision for administration, making it well-suited for detailed assessments in clinical or rehabilitation settings. The Y Balance Test is a simplified and time-efficient version of the SEBT. It uses a Y-shaped pattern with three reach directions: anterior, posteromedial, and posterolateral. During the test, the participant stands on one leg at the center of the "Y" and uses the opposite leg to reach as far as possible in each direction without losing balance or moving the stance foot. The distances reached are measured, normalized to leg length, and analyzed for asymmetries between the limbs. Poor scores or significant differences between limbs may indicate instability, neuromuscular deficits, or an increased risk of injury. The YBT is commonly used for return-to-sport testing due to its simplicity and ability to detect subtle imbalances. Restoring balance symmetry and proprioceptive function to levels comparable to the contralateral limb is essential for reducing re-injury risk and enhancing functional capacity. These assessments are particularly valuable during the early and mid-phases of rehabilitation.

Patient-reported outcome measures (PROMs) provide insights into the patient's subjective experience of recovery, including pain levels, functionality, and quality of life. Tools such as the Knee Injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC) form, and Lysholm Knee Scoring Scale are commonly used to evaluate knee function. The KOOS is a comprehensive PROM that evaluates both short- and long-term outcomes of knee injuries and osteoarthritis. It consists of 42 items divided into five subscales: pain, symptoms, activities of daily living, sports and recreation, and quality of life (QoL). Each subscale score ranges from 0 to 100, with higher scores indicating better function and less impairment. The KOOS is especially useful for tracking recovery over time and comparing treatment effectiveness, offering a detailed picture of how knee problems affect daily activities, athletic performance, and overall quality of life.

The IKDC Subjective Knee Form is a standardized PROM that focuses on overall knee function and symptoms, including pain, swelling, stiffness, and instability. Patients also rate their ability to perform basic and advanced activities and provide an overall assessment of their knee function on a scale from 0 to 10. The IKDC generates a composite score from 0 to 100, with higher scores representing better knee function. This tool is commonly used for evaluating knee injuries in active individuals, particularly athletes, due to its simplicity and broad applicability across a range of knee conditions.

The Lysholm Knee Scoring Scale is specifically designed for assessing ligament injuries, particularly anterior cruciate ligament injuries. It evaluates eight key aspects of knee function, including limping, pain, swelling, stability, and the ability to perform activities like squatting and climbing stairs. Scores range from 0 to 100, with higher scores reflecting better knee function; scores above 84 generally indicate good to excellent outcomes. While originally developed for ACL injuries, the Lysholm scale is also applicable to other knee-related conditions and surgical outcomes. These PROMs are supplemented by the Tegner Activity Scale, which assesses the patient's activity levels and readiness for return to sports. Improved scores over time indicate positive progress and restoration of confidence in knee performance.

Later in rehabilitation, functional movement screening (FMS) identifies compensatory movement patterns, imbalances, or weaknesses. Movements like the deep squat, hurdle step, and inline lunge are assessed to address deficits that may predispose the patient to future injury. Timed agility and performance tests, including the T-Test, Illinois Agility Test, and single-leg box drop test, are also used to evaluate dynamic control and readiness for high-level activities. These tests simulate real-life scenarios and sport-specific demands, offering valuable information for return-to-sport decision-making.

Additional assessments include strength ratio testing, focusing on the quadriceps-to-hamstring strength balance, and instrumented knee laxity testing, which evaluates the stability of the repaired ligament. A target quadriceps-to-hamstring ratio of 60:40 ensures proper dynamic stability, while knee laxity tests, such as those using the KT-1000 or KT-2000 arthrometer, measure anterior tibial translation. Side-to-side differences of less than or equal to 3 mm are indicative of adequate ligament stability and biomechanical success.

These functional outcome measures are applied systematically throughout the rehabilitation timeline. Early-phase testing emphasizes ROM, balance, and initial strength recovery, while mid- and late-phase assessments focus on power, agility, and return-to-sport readiness. By utilizing these detailed and structured evaluations, clinicians can ensure optimal recovery and successful outcomes following the BEAR procedure.

Section 2 Key Words

Lachman Test – A clinical diagnostic maneuver used to assess the integrity of the anterior cruciate ligament

Return to Sport Timeline - The estimated period it takes for a patient to recover sufficiently from their surgery to resume participation in their previous sports or athletic activities

Maturation Phase - Begins around 3 to 6 months post-surgery and extends up to 12 months or longer; focus on the remodeling and strengthening of the repaired ligament and surrounding tissues as they mature and become more functional

Section 2 Summary

The BEAR procedure represents a groundbreaking advancement in the treatment of anterior cruciate ligament (ACL) injuries. By prioritizing the repair and preservation of the native ligament rather than traditional reconstruction with autografts or allografts, the BEAR technique offers a promising alternative that may improve long-term outcomes. This innovative approach has the potential to enhance knee stability, proprioception, and overall joint health, marking a significant shift in ACL injury management, particularly for athletes and active individuals. This section has explored the details of the BEAR procedure, compared its outcomes to traditional techniques, examined healing timelines, reviewed MRI findings that signify success, and outlined functional outcome measures that track recovery and rehabilitation progress. Together, these insights highlight the potential of the BEAR procedure to transform ACL treatment and improve patient outcomes.

Physical Therapy Protocol

The BEAR procedure introduces unique considerations for rehabilitation, as the repaired native ligament requires a carefully structured recovery plan to promote tissue healing, restore knee function, and ensure long-term stability. Physical therapy plays a critical role in achieving these goals by balancing protection of the healing ligament with gradual progression toward functional recovery. Throughout rehabilitation, physical therapy interventions are guided by key milestones, including restoring full extension, achieving functional range of motion, improving strength, and regaining neuromuscular control. Close collaboration between the patient, physical therapist, and surgical team is essential to optimize outcomes and ensure a safe return to activities and sports. By adhering to this protocol, clinicians can effectively guide patients through the recovery process, fostering confidence, functionality, and long-term knee health.

Physical Therapy Examination Findings

References: 4, 12

The physical therapy examination following the Bridge-Enhanced ACL Repair procedure focuses on assessing the patient's progress through the healing phases, identifying impairments, and tailoring the rehabilitation plan to meet individual needs. This examination includes evaluations of pain, range of motion (ROM), swelling, strength, neuromuscular control, functional performance, and psychological readiness. These findings are critical for monitoring recovery and guiding progression through the rehabilitation protocol.

Pain and Swelling Assessment

References: 13

Pain and swelling are common in the early phases post-surgery and are carefully monitored during each evaluation. Persistent or excessive swelling/effusion may indicate inflammation or overloading of the healing ligament, while uncontrolled pain may hinder functional recovery. Therapists use subjective pain scales (Numeric Pain Rating Scale) and effusion grading tests (stroke test) to evaluate these symptoms and adjust the rehabilitation intensity accordingly.

The stroke test, also known as the sweep test, is a straightforward and reliable method to grade the severity of effusion. The patient is positioned supine with the knee slightly flexed and relaxed. The examiner begins by stroking fluid from the medial side of the joint upward toward the suprapatellar pouch using the palm or fingers. Then, the examiner strokes downward along the lateral joint line to push fluid back to the medial compartment. The return of a visible wave of fluid to the medial side indicates the presence of effusion. The stroke test is graded on a scale from 0 (no fluid wave observed) to 3+ (significant fluid accumulation that prevents full stroke testing). This grading system helps quantify the level of effusion, providing a useful indicator of inflammation and joint irritation.

Range of Motion (ROM)

Restoration of ROM is a key focus of the examination, particularly achieving full knee extension early in recovery to prevent contractures. Flexion is gradually increased, with specific targets depending on the recovery phase. ROM is assessed using a goniometer, with attention paid to any restrictions, compensatory patterns, or pain during movement. By the end of the initial rehabilitation phase, patients should achieve 0–90° of flexion, progressing to full ROM in later stages.

Strength and Muscle Activation

Quadriceps strength and activation are commonly impaired following ACL injury and surgery. Therapists evaluate quadriceps activation using tests like the straight leg raise (SLR) for extensor lag and isometric quad sets. Manual muscle testing or hand-held dynamometry may be used to assess strength in key muscle groups, including the quadriceps, hamstrings, glutes, and calf muscles. Weakness or asymmetry between limbs is documented to guide strengthening exercises.

Neuromuscular Control and Proprioception

Neuromuscular control and proprioception are essential for joint stability, particularly after ACL repair. Functional assessments such as balance tests (Single-leg stance, Y Balance Test) and dynamic movement evaluations help identify deficits in coordination, postural control, and limb symmetry. These findings inform interventions targeting proprioceptive retraining and motor control.

Functional Performance

Functional tests are introduced in the later stages of recovery to assess readiness for higher-level activities. These include hop tests (Single-leg hop for distance, triple hop, or timed hop), which measure strength, stability, and limb symmetry. The results provide a benchmark for progression toward sports-specific training and eventual return to activity.

Psychological Readiness

ACL injuries and subsequent surgical interventions can impact psychological readiness for activity. Tools such as the Anterior Cruciate Ligament-Return to Sport after Injury (ACL-RSI) scale can be used to evaluate confidence, fear of re-injury, and mental preparedness for physical activity. These findings are critical for addressing psychological barriers to recovery.

The ACL-RSI scale consists of 12 questions, each rated on a visual analog scale from 0 to 100. A score of 0 represents the least favorable response (e.g., "not confident at all"), while a score of 100 represents the most favorable response (e.g., "completely confident"). The final score is calculated as the average of all responses, with higher scores indicating greater psychological readiness to resume sports and physical activities. This scoring system provides valuable insights into the patient's psychological state and helps guide the focus of rehabilitation interventions.

By conducting a comprehensive examination that includes these domains, physical therapists can identify areas of progress, target specific impairments, and optimize the rehabilitation process. Regular re-assessments allow for adjustments to the treatment plan, ensuring safe and effective progression toward functional recovery and return to activity following the BEAR procedure.

Weekly Restriction Outline

References: 1, 14

This section will outline the weekly restrictions to optimize healing after a BEAR procedure. It will include brace usage, range of motion restrictions and weight bearing status.

First 24 Hours

Initially, the brace is often locked in full extension (0°) to protect the repair site and prevent strain on the graft, especially during weight-bearing activities. The patient will need to be partial weight bearing (PWB) or not bear more than 50 percent of their weight on the surgical limb.

Week 0 to Week 2

As recovery progresses, the hinge system allows controlled increases in flexion, typically starting from 0°–30° and advancing incrementally based on clinical milestones. From 0-4 weeks, the brace should be locked at 0 degrees for ambulation. The brace should also be locked at 0 degrees for the first 6 weeks for sleeping. The patient should still be partial weight bearing.

Week 2 to Week 4

After 2 weeks, the brace may be unlocked to progressively to 60 degrees for range of motion exercises and while seated. Range of motion should not exceed 90 degrees until at least 4 weeks post-operative. The patient should still be partial weight bearing.

Week 4 to Week 6

During this time period the brace can be unlocked to 90 degrees for exercises and ambulation if the patient has adequate quadriceps control. Range of motion for exercises nonweightbearing can progress to beyond 90 degrees after 4 weeks. The patient may start progressing during this period to weight bearing as tolerated when cleared by the PT and surgeon. They must have no pain, no extensor lag, ambulate with a normal gait, and have adequate quadriceps control to avoid injury. PT should train the patient with crutches weaning from partial weight bearing to weight bearing as tolerated. They should then progress to no crutches when the gait pattern is stable and the patient can negotiate stairs without increased pain and adequate stability.

After 6 Weeks

From 6 weeks onward, the brace should be worn progressing range of motion as tolerated. This is when range of motion can be progressed past 90 degrees toward a normal flexion of around 150 degrees. After 6 weeks all patients are typically cleared for full weight bearing. They must exhibit adequate quadriceps control, no extensor lag, normal ambulation pattern, and no pain.

Range of Motion Exercise Progression

References: 9, 12

Progressing through range of motion exercises are a large part of the physical therapy protocol post BEAR procedure. Throughout the rehabilitation phases, it is crucial to monitor pain and swelling to avoid overloading the repair. Progression through each phase should be based on individual recovery milestones and adhere to the BEAR rehabilitation protocol. By following this structured approach, patients can achieve full functional ROM while supporting ligament healing and long-term joint health.

Early Phase (Weeks 0–2)

The early phase of range of motion after the BEAR procedure focuses on protecting the repaired ligament while introducing gentle mobility exercises to prevent stiffness and maintain joint health. The primary goals during this phase are to achieve full knee extension, limit flexion to approximately 60° to safeguard the repair, and minimize swelling. Specific exercises include heel slides, which involve slowly sliding the heel toward the buttocks, assisted with a towel if needed, to gently increase flexion. Patients are also instructed to perform passive knee extension stretches by placing a rolled towel under the heel and allowing gravity to push the knee into full extension. This exercise helps prevent contractures. Additionally, quadriceps sets, where the quadriceps muscle is contracted to press the back of the knee into the floor, are used to maintain muscle activation without joint movement. These exercises are performed with minimal strain to protect the healing tissue during this critical period.

Intermediate Phase (Weeks 3–6)

In the intermediate phase, ROM goals expand to include increasing flexion to 90° at 4 weeks and beyond after 4 weeks, while maintaining full extension. The focus shifts toward controlled active motion to support joint mobility and improve muscle activation. Gradual progression ensures safety while promoting recovery. Key exercises include seated assisted knee flexion, where the patient uses their opposite leg or a strap to gently bend the knee toward 120° flexion holding the position briefly before releasing. Stationary cycling with no resistance is also introduced, allowing the patient to pedal within their available ROM to promote circulation and reduce stiffness. To further encourage full extension, prone hangs are performed by lying face down with the affected leg hanging off a surface, letting gravity gently assist with extension. These exercises are essential for progressing ROM while maintaining joint integrity.

Late Phase (Weeks 6–12)

The late phase focuses on achieving full ROM while integrating strength and functional exercises. By this stage, patients work toward a range of motion from 0–135° or more. Dynamic activities are introduced to prepare the joint for higher demands. Exercises such as wall slides are used to combine ROM improvement with strength. During wall slides, the patient stands with their back against a wall and performs a controlled descent into a mini-squat, ensuring the knee does not exceed 90° flexion. Active knee flexion with resistance bands is also incorporated, where a resistance band is used to pull the heel toward the body to enhance controlled knee flexion. Additionally, step-ups on a small step allow patients to practice functional movement patterns while gradually loading the knee. These exercises help improve ROM, strength, and neuromuscular control, paving the way for more advanced activities.

Advanced Phase (Weeks 12+)

The advanced phase prioritizes maintaining full ROM and integrating mobility into sport-specific and high-demand activities. Patients now transition to exercises that enhance movement quality for everyday and athletic tasks. Dynamic lunges are introduced, where patients perform forward lunges with proper alignment, gradually increasing depth as ROM and strength allow. This exercise strengthens the knee while ensuring functional ROM. Hamstring stretches with a resistance band are also used to improve posterior chain flexibility and knee mobility, with the patient lying supine and pulling the leg upward until a stretch is felt. Finally, full-ROM bodyweight squats are performed to build strength and ensure that the knee can function across its entire range. These exercises prepare the patient for the physical demands of their daily and athletic activities, completing the rehabilitation process.

Strength Expectations and Management

References: 15-17

Strength training is a crucial part of rehabilitation following the BEAR procedure for ACL repair, as it helps restore muscle strength, stability, and neuromuscular control, ultimately preparing the knee for functional activities and sports. Below is a detailed outline of the key strength training goals and exercises for each phase of recovery, progressing from post-operative to advanced rehabilitation.

Early Phase (Weeks 0–2)

In the early phase, the focus is on preventing muscle atrophy and initiating muscle activation without stressing the healing ligament. Strengthening is primarily isometric, with exercises designed to maintain muscle engagement, promote circulation, and avoid strain on the ACL repair. Key exercises include quadriceps sets, where patients contract the quadriceps to press the knee into the surface, and hamstring sets, which activate the hamstrings without movement. Straight leg raises and glute sets are also included to maintain muscle tone and stability around the knee. These exercises are performed without joint movement, protecting the healing ligament while engaging the surrounding muscles to prevent weakness. Therapists may use neuromuscular electrical stimulation (NMES) and biofeedback to increase the recruitment of the quadriceps during this stage. This is especially important if tactile cueing is not sufficient in achieving muscle activation.

NMES is used to combat quadriceps inhibition, which often occurs due to pain, swelling, and joint instability. By delivering electrical impulses directly to the quadriceps muscle, NMES facilitates muscle activation and helps restore strength and control during a period when voluntary contraction may be limited. In early rehabilitation, NMES is typically applied during isometric exercises, such as quad sets or straight leg raises, to enhance muscle engagement and promote motor unit recruitment. Regular use of NMES during therapy sessions can accelerate recovery by reducing atrophy, improving neuromuscular control, and facilitating faster progression to weight-bearing and functional activities. Proper placement of electrodes and adjustment of intensity to achieve a strong, visible contraction are essential for optimal outcomes.

Intermediate Phase (Weeks 3–6)

The intermediate phase shifts toward increasing muscle strength and control. As knee flexion is safely increased, strength training focuses on strengthening the quadriceps, hamstrings, and hip muscles to support joint stability. Exercises such as mini-squats (to about 45° knee flexion), step-ups onto a low step, and lateral leg raises target these muscle groups. Bridges are also incorporated to strengthen the glutes, hamstrings, and core. These exercises are designed to promote muscle endurance and coordination, preparing the knee for more functional movements in subsequent phases.

Late Phase (Weeks 6–12)

In the late phase, the emphasis is on increasing resistance and introducing more dynamic, functional strength exercises. Patients progress to more challenging exercises like goblet squats, which strengthen the quadriceps, hamstrings, and glutes while preparing for more complex movements. Lunges, both forward and reverse, are introduced to enhance dynamic strength and improve knee function. Leg press exercises build strength in the quadriceps and hamstrings with controlled resistance. Single-leg deadlifts are also performed to target the hamstrings, glutes, and core, improving balance and stability. These exercises prepare the patient for higher-demand activities like walking, climbing stairs, and more complex movements.

Advanced Phase (Weeks 12+)

During the advanced phase, strength training is focused on high-demand activities and sport-specific movements. The goal is to restore power, explosiveness, and neuromuscular control, ensuring that the knee can handle the stresses of sports and dynamic activities. Exercises such as squat jumps and box jumps improve power and explosiveness in the quadriceps and hamstrings, while plyometric lunges build strength and stability for quick, reactive movements. Resistance band agility drills strengthen the hip abductors and improve lateral stability, which is essential for sports that require cutting or side-to-side movement. These exercises help prepare the knee for the dynamic demands of sports and high-impact activities.

Throughout each phase of rehabilitation, strength training exercises should be gradually progressed in intensity and volume to avoid overloading the healing tissue. Close monitoring for pain or swelling is necessary to ensure the exercises are not stressing the healing ligament. Rehabilitation should be individualized, with adjustments made based on the patient's progress and goals. By following a structured progression of strength training, patients can restore muscle function, improve knee stability, and safely return to sports and daily activities after the BEAR procedure.

Proprioception and Neuromuscular Control

References: 9, 16

Proprioception and neuromuscular control are critical components of rehabilitation following the Bridge-Enhanced ACL Repair procedure. The native ACL is essential for maintaining knee stability and proprioceptive feedback. After repair, the rehabilitation program must emphasize restoring these functions to ensure a successful recovery and reduce the risk of reinjury.

Proprioception refers to the body's ability to sense joint position, movement, and force. After an ACL injury and subsequent BEAR procedure, proprioceptive feedback mechanisms are often impaired due to ligament damage and disrupted sensory input. A structured rehabilitation plan focuses on progressively retraining the sensory-motor pathways to restore this awareness. In the initial phase of rehabilitation, proprioceptive training begins with low-impact exercises to reintroduce joint awareness without compromising the healing ligament. Early interventions include weight-shifting drills and static balance training, such as standing on one or both legs on a flat surface. As healing progresses, dynamic proprioception exercises are introduced, including balance boards, foam pads, single-leg activities, and perturbation training, which mimic real-life scenarios by challenging the knee's adaptability to external forces.

As rehabilitation progresses, mid-phase neuromuscular training incorporates closed-chain exercises like mini-squats and leg presses, which enhance joint stability while protecting the healing ligament. Functional movement patterns, such as step-ups or controlled lunges, are also included to mimic everyday activities. In advanced phases, dynamic stabilization drills, such as lateral step-overs, hopping, and agility ladder drills, are introduced to improve both strength and coordination. Reactive neuromuscular training, involving rapid changes in direction or speed, prepares patients for sport-specific movements, ensuring readiness for more demanding physical activities.

Combining proprioceptive and neuromuscular exercises creates a comprehensive approach to rehabilitation. Balance activities can be paired with resistance exercises, such as single-leg stance with resistance bands or weights, to improve joint stability and muscle strength simultaneously. Functional drills, including controlled plyometric movements and agility exercises, reinforce both proprioceptive and neuromuscular adaptations needed for sports and other high-demand activities.

The ultimate goal of proprioceptive and neuromuscular rehabilitation is to restore functional stability, reduce the risk of reinjury, and prepare the patient for a safe return to sport or activity. Success is measured through functional tests, such as the Y-Balance Test and hop tests, which demonstrate improved joint awareness, muscle coordination, and dynamic knee stability. A carefully guided rehabilitation program ensures that the repaired ACL regains its role in maintaining knee function, while patients build the confidence to perform at their desired activity level.

Effusion and Ligament Instability

References: 12, 18

Effusion and ligament instability are critical considerations in the rehabilitation and post-operative care of patients undergoing the BEAR procedure. These two factors are indicators of how well the knee is healing and can influence the approach to rehabilitation.

Effusion in BEAR ACL Procedure

Effusion, or the accumulation of fluid in the knee joint, is a common occurrence after ACL surgery, including the BEAR procedure. It is often caused by inflammation or irritation in the joint following surgery. Effusion can manifest as swelling around the knee and may be accompanied by pain or stiffness. It is important to monitor effusion during the recovery process because excessive fluid accumulation can impede range of motion, disrupt normal movement patterns, and delay the healing process.

In the context of the BEAR procedure, effusion is expected in the initial post-operative phase, particularly during the first few weeks. However, as the healing progresses, the goal is to minimize effusion to optimize recovery. Patients may need to apply ice, elevate the leg, and engage in gentle range-of-motion exercises to reduce swelling and promote fluid drainage. Persistent or severe effusion may signal complications or overexertion, and further intervention or adjustment in rehabilitation may be required.

Ligament Instability Post-BEAR Procedure

Ligament instability following ACL surgery, including the BEAR procedure, refers to the inability of the ligament to provide adequate stability to the knee joint, often due to incomplete healing, weakness in surrounding muscles, or excessive stress on the ligament during rehabilitation. Instability can lead to abnormal joint movement, pain, and a higher risk of re-injury.

The BEAR procedure is unique because it aims to repair the native ACL ligament, as opposed to using a graft (autograft or allograft), and relies on biological healing with the help of a scaffold. During the initial phases of rehabilitation, the healing ligament will be weaker and less stable than a fully reconstructed or grafted ligament. As such, it is important to protect the ligament during early recovery through the use of a hinged knee brace and gradual progression of weight-bearing activities.

In the early rehabilitation phase, the focus is on protecting the ligament and avoiding stress that could lead to instability. This includes avoiding deep knee bends and high-impact activities and using a knee brace to restrict movement during the healing process. As the patient moves through the intermediate and late phases of rehabilitation, the ligament will gradually strengthen, and dynamic stability will improve through controlled exercises and neuromuscular re-education.

During the advanced rehabilitation phase, once stability is restored, patients are encouraged to engage in more challenging exercises that simulate sport-specific movements. However, it is crucial to monitor for signs of instability, such as giving way or difficulty with balance, as these could indicate insufficient healing or overloading of the ligament.

Management of Effusion and Ligament Instability

Both effusion and ligament instability require careful monitoring and management during rehabilitation after the BEAR procedure. Early intervention with ice, elevation, and anti-inflammatory measures can help control effusion, while a progressive rehabilitation protocol focusing on strength, stability, and functional control helps address ligament instability. A customized approach that gradually increases load while protecting the healing tissue is key to optimizing outcomes and ensuring long-term knee stability.

Considerations with Medial Meniscus Damage

References: 16, 19, 20

When managing rehabilitation following the BEAR procedure with medial meniscus damage, several critical considerations must be addressed. These considerations stem from the complex nature of managing both ACL repair and meniscal healing simultaneously, as the two structures have different healing timelines and requirements. The goal is to optimize the rehabilitation process while preventing further injury to the meniscus and supporting the healing ACL.

Surgical Vs. Conservative Management

The first consideration of meniscus involvement is management. The rehabilitation approach may differ depending on whether the meniscus is treated conservatively or surgically. Surgical intervention will either be a repair or a partial removal (meniscectomy). Meniscus repair requires a more conservative approach to rehabilitation, as the meniscus needs time to heal and reattach to the knee joint. A slower and more cautious approach is required for those with meniscus repairs, particularly during the first 8–12 weeks, as the repaired tissue needs time to heal and reintegrate with the knee. Flexion and weight-bearing activities should be limited during this phase. Meniscectomy, where part of the meniscus is removed, may allow for a more aggressive rehabilitation protocol but places the joint at higher risk of future degeneration. With a partial meniscectomy, there is less concern about restricting motion, and the patient may progress more quickly in rehabilitation. However, the loss of meniscal tissue can result in long-term concerns, such as an increased risk of osteoarthritis, which must be factored into rehabilitation and long-term management. Physical therapists must coordinate a post-surgical meniscus protocol with the BEAR ACL protocol if it is repaired or removed surgically.

Conservative Meniscus Management and BEAR ACL Considerations

In the early phases of rehabilitation, the most important consideration is protecting both the repaired ACL and the damaged medial meniscus. The BEAR procedure aims to preserve the native ACL, and the presence of meniscal damage can compromise joint stability. The rehabilitation protocol must strike a delicate balance between early protection and gradually loading the knee to promote healing. The initial protocol with meniscus damage requires partial weight bearing and the same range of motion restrictions and bracing restrictions as if the meniscus were not involved.

In the intermediate to late phases of rehabilitation, having the consideration of meniscus healing in addition to the ACL requires a few different considerations. It is likely that more joint effusion and stiffness will be present in the knee with a meniscus tear. This may or may not require a slower approach to range of motion and more focus on clearing the joint effusion with strategies like elevation, ice, and effusion massage. This progression depends on the specific clinical presentation of the patient at hand. The meniscus contributes greatly to stability in the knee and should heal along with the repaired ACL, especially if the tear is within the outer one-third of the meniscus. The inner portion of the meniscus has less blood supply and healing times are lengthened beyond 6-8 weeks (how long the outer third takes to heal). In these phases, it is crucial to watch closely for signs of joint instability as single leg and resistive exercises are added. It is likely that exercise progression will be a bit slower than without damage to the meniscus as the body works to heal both the meniscus and ACL. This may result in longer time spent working on bilateral close chain exercises before progressing to single leg and dynamic movements. More time will focus on balance and neuromuscular rehabilitation as well to ensure stability is restored in the mid to late phases of rehabilitation.

Return to Sport Considerations[12,21]

References: 12, 21

Returning to sport after the BEAR procedure requires adherence to a carefully structured progression that prioritizes tissue healing, functional recovery, and minimizing the risk of reinjury. Unlike traditional ACL reconstruction, the BEAR procedure preserves the native ligament, necessitating specific considerations during rehabilitation. Each phase of return-to-sport (RTS) is determined by meeting established clinical and functional milestones rather than relying solely on a predefined timeline.

In the early phase (0-12 weeks post-operative), the focus is on protecting the repaired ligament while gradually restoring range of motion, strength, and neuromuscular control. Specific considerations during this phase include achieving near-full extension by two weeks and gradually progressing flexion to prevent stiffness without overstressing the healing tissue. Early weight-bearing with a hinged brace set to a safe range of motion (0-90 degrees) and low-load quadriceps activation exercises are introduced to prevent muscle atrophy. Patients continue using a hinged knee brace during weight-bearing activities for added stability. At this stage, no sport-specific activities are allowed, as the focus is strictly on controlled movement patterns and early functional recovery.

The mid-phase (12-24 weeks post-operative) introduces more dynamic exercises and emphasizes the development of strength, balance, and controlled movement patterns. Strengthening progresses to closed-chain exercises, such as leg presses and controlled squats, to improve lower extremity strength. Proprioceptive training, including single-leg balance drills, unstable surface work (with the use of foam pads, BOSU balls), and perturbation training, is used to enhance joint stability and proprioceptive feedback. Low-impact cardiovascular activities like cycling, swimming, or walking may be introduced to build endurance without placing undue stress on the knee. Sport-specific activities, such as running, are not initiated until patients demonstrate sufficient quadriceps strength (at least 60-70% of the non-operative leg), appropriate neuromuscular control, and absence of effusion or instability.

During the late phase (24-36 weeks post-operative), progression to light sport-specific activities begins, with a focus on agility, power, and functional skills. Running is gradually introduced, starting on a treadmill or outdoors with controlled increases in duration and intensity, ensuring a symmetrical gait and absence of pain or swelling. Agility drills, such as lateral shuffles, forward-backward runs, and controlled cutting or pivoting drills, replicate sport-specific movements. Plyometric exercises begin with low-impact jumping and landing drills, advancing to higher-demand activities based on individual tolerance and functional testing results. Patients must demonstrate at least 80% symmetry in quadriceps and hamstring strength and neuromuscular control, as measured by hop tests or balance assessments, before progressing to unrestricted training.

The return-to-sport phase (36-52 weeks post-operative) focuses on preparing the patient for full participation in their chosen activity, ensuring both physical and psychological readiness. Functional testing, such as the Y-Balance Test, single-leg hop tests, and isokinetic strength assessments, confirms readiness, with passing criteria typically requiring >90% symmetry between limbs and appropriate biomechanics during dynamic movements. Gradual reintroduction to sport begins with non-contact drills and controlled scrimmages before advancing to full contact or competitive play. Psychological readiness is also addressed using tools like the ACL-RSI scale, ensuring patients feel confident and mentally prepared for RTS.

Key considerations throughout the RTS process include individualized progression based on objective criteria and the patient's functional status, rather than rigid timelines. Monitoring for symptoms such as effusion, pain, or instability is crucial, as these may signal the need to delay progression. Close communication between the patient, physical therapist, and surgeon ensures the recovery aligns with the ligament's healing timeline and the patient's goals. By following these structured guidelines, clinicians can optimize recovery, minimize reinjury risks, and support a safe return to sport for individuals undergoing the BEAR procedure.

Section 3 Key Words

Stroke Test – A clinical assessment where clinicians quantify the presence and severity of effusion, often as part of the diagnostic and monitoring process for knee injuries or conditions such as ligament tears, osteoarthritis, or post-operative swelling

Anterior Cruciate Ligament-Return to Sport after Injury (ACL-RSI) - A validated tool designed to assess the psychological readiness of individuals recovering from an ACL injury or surgery to return to sports and high-demand physical activities

Section 3 Summary

The BEAR procedure presents unique challenges and considerations in rehabilitation, as the goal is to repair the native ACL rather than reconstruct it. A carefully structured recovery plan is essential to promote tissue healing, restore knee function, and maintain long-term knee stability. Physical therapy is critical in this process, as it strikes a balance between protecting the healing ligament and gradually progressing toward functional recovery. Key rehabilitation milestones, such as restoring full knee extension, improving range of motion, strengthening muscles, and regaining neuromuscular control, guide the rehabilitation process. Successful outcomes rely on close collaboration between the patient, physical therapist, and surgical team to ensure a safe return to activities and sports. By following a structured rehabilitation protocol, clinicians can effectively support patients through recovery, fostering confidence and ensuring long-term knee health and function.

Case Study 1

Beth, a 28-year-old recreational soccer player, sustained a complete tear of her anterior cruciate ligament during a non-contact pivoting injury. After a thorough discussion with her orthopedic surgeon about treatment options, Beth opted for the Bridge-Enhanced ACL Repair (BEAR) procedure to preserve her native ACL tissue and potentially improve proprioception and long-term joint health. Post-operatively, Beth was placed in a hinged knee brace set to limit range of motion (ROM) to 0-90 degrees and was instructed to use crutches for partial weight-bearing. Her physical therapy program began two weeks after surgery.

Reflection Questions

1. What are the key considerations for rehabilitation after the BEAR procedure compared to traditional ACL reconstruction?
2. What is the goal of rehabilitation by week six post operatively?
3. How could the physical therapist address the lack of recruitment of Beth's quadricep at week 3 during quadriceps sets?

Responses

1. The BEAR procedure requires protecting the native ligament to promote healing while avoiding overstress. Early ROM and weight-bearing are cautiously progressed, focusing on milestones rather than timelines. Attention to effusion, ligament integrity, and psychological readiness is critical for guiding rehabilitation.
2. The goals should be to achieve full knee extension and 90 degrees of flexion, minimal pain, to be transitioning from partial weight bearing to weight bearing as tolerated and transitioning out of the hinge brace at 6 weeks.
3. The PT could use techniques like biofeedback and neuromuscular electrical stimulation (NMES) to achieve muscle activation in the correct patterns and timing. These are crucial strategies to implement early on because recruitment of the quadriceps will allow terminal knee extension and support of knee extension during the gait cycle. The therapist should always work on muscle cueing with tactile feedback at first and progress to NMES and biofeedback if needed.

Case Study 2

Tiffany, a 24-year-old collegiate basketball player, sustained a complete ACL tear during a non-contact pivot while attempting a layup. She experienced immediate swelling, instability, and an inability to continue playing. After a comprehensive evaluation and discussion with her orthopedic surgeon, Tiffany opted for the Bridge-Enhanced ACL Repair (BEAR) procedure. She was motivated by the potential benefits of preserving her native ACL tissue, including improved proprioception and long-term knee health, and her primary goal was to return to competitive basketball by the following season. Post-operatively, Tiffany's rehabilitation was carefully structured, with an emphasis on gradual progression to protect the healing ligament while addressing her specific needs as an athlete. By week 12 following her procedure, Tiffany was at full range of motion in flexion and extension and had 85% symmetry in weight bearing.

Reflection Questions

1. What should Tiffany's physical therapy plan of care focus on next?
2. When may Tiffany be cleared to run again?
3. If everything progresses according to plan, when may Tiffany return to collegiate basketball?

Responses

1. Tiffany is a collegiate athlete trying to return to her sport, so the next phase of her rehabilitation should be the return to sport phase. Because she is at 85% symmetry bilaterally with weight bearing exercises, she is ready to progress to dynamic movements that mimic the movements in basketball. This includes progressing from double leg stability and balance drills to

single leg stability and dynamic balance with plyometrics. She should continue to regain muscle mass by progressing major muscle group lower extremity exercises like dead lifts and squats to 8-12 repetition maximums.

2. Once Tiffany achieves the 80-85% symmetry in bilateral closed chain exercises and returns to normal balance levels from outcome measures, she should be able to jog on even, predictable surfaces. This includes a treadmill and an indoor track and should progress in 5-10 minute increments or so weekly (depending on her baseline conditioning). To return to sport, she will need to build her aerobic conditioning back up. Tiffany should have a decent baseline of aerobic conditioning from prior phases of rehabilitation involving a stationary bicycle and elliptical.
3. Decision on return to sport readiness should be based on strength and functional testing results, psychological readiness, and sport-specific capabilities. Collaboration among the patient, therapist, and surgeon ensures a safe and individualized return. Tiffany should be able to return anywhere from 9-12 months post operatively.

Conclusion

Bridge-Enhanced Anterior Cruciate Ligament Repair (BEAR) represents an innovative, regenerative approach to ACL injury treatment that offers a promising alternative to traditional reconstruction methods. By utilizing a collagen scaffold to promote natural healing between the torn ligament ends, BEAR preserves the ligament’s proprioceptive and biomechanical functions, potentially improving long-term outcomes. This course has covered the fundamental principles of BEAR, including its physiological mechanisms, anticipated recovery milestones, and the specialized rehabilitation protocols tailored to this procedure. Equipped with evidence-based practices, physical therapists and physical therapist assistants can confidently guide patients through their recovery, using techniques that align with the unique characteristics of the BEAR approach and foster optimal patient outcomes.

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