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Case Report

Bone- Patellar Tendon- Bone Augmentation as a Treatment for Partial Anterior Cruciate Ligament Injury

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Abstract

Anterior cruciate ligament (ACL) rupture is one of the most common knee injuries in young active patients, negatively impacting their sports activity. Clinical presentation typically includes a history of trauma accompanied by edema, pain, functional limitation, and sense of joint instability. There are various clinical signs and MRI findings suggestive of the injury, although arthroscopy remains the definitive diagnostic method. Treatment goals aim to achieve optimal rehabilitation and functional recovery, early return to sports and prevention of joint damage that could lead to premature knee degeneration. In the context of partial tears, there is no consensus on whether to preserve the remaining bundle or perform total ligament reconstruction. Regarding the choice of surgical technique, anatomical reconstruction has been preferred, and for graft selection, autograft has been chosen, although there are different valid therapeutic options based on each patient's characteristics. This review presents the case of a 36-year-old male diagnosed with a partial ACL tear with an intact posterolateral bundle, following an axial load injury mechanism with the knee in flexion, clinically presenting with pain, limited mobility, and joint instability of the knee. Due to the patient's clinical and imaging characteristics, arthroscopy was chosen as the diagnostic and therapeutic method. Based on arthroscopic findings, ligament augmentation with a bone-patellar tendon-bone autograft was performed, due to the mechanical advantages of the anatomical positioning of the bone tunnels offered by the surgical technique, as well as the biological advantages, such as preservation of joint proprioception, bone integration, and functional benefits of graft selection.

Key Words: anterior cruciate ligament; ligament augmentation; autograft; bone-tendon-bone graft; arthroscopy

Abbreviations

ACL: Anterior cruciate ligament

AMB: Anteromedial bundle

PLB: Posterolateral bundle

MRI: Magnetic resonance imaging

BTB: Bone- patellar tendon - bone

Introduction

The anterior cruciate ligament (ACL) is one of the two most important intra-articular fibrous ligaments of the knee, whose main function is to provide rotational and translational stability. Its structure consists primarily of fibroblasts located in type I and type III collagen, with smaller amounts of type IV collagen at its insertion sites [1]. The ACL originates in the posteromedial region of the lateral femoral condyle and extends distally and anteriorly to insert immediately anterior to the intercondylar eminence on the tibia. The ACL is divided into two bundles: the anteromedial bundle (AMB) and the posterolateral bundle (PLB), with distinct footprints in their femoral and tibial portions, the latter of which gives them their names [2]. The two bundles vary in function. The AMB is mostly isometric, while the PLB is anisometric. In extension, the AMB appears as a flat band, and the PLB is tense. With progressive flexion, the AMB tightens, and the PLB begins to loosen. The AMB is mainly responsible for resisting anterior tibial translation in flexion, while the PLB resists rotation, hyperextension, and anterior tibial translation in extension [3].

Partial ACL injuries may occur following a cutting or pivoting movement injury, but they differ in presentation from a complete tear. Patients often associate an injury event with the onset of symptoms; however, they may experience vague symptoms and perceive the injured knee as "feeling different" compared to the contralateral side [4]. Alternatively, the patient may describe an injury followed by obvious symptoms of instability and inability to cut and turn, more consistent with a complete ACL tear [5,6]. In terms of diagnostic approach, magnetic resonance imaging (MRI) is the most useful study to differentiate the morphology between a normal and abnormal ACL, although it is less reliable for determining and categorizing partial injury characteristics [7]. On T2-weighted images, diffuse thickening and disorganization within the ACL suggest a partial tear. Oblique images in coronal, sagittal, and axial projections can better delineate the nature of the injury. Recently, two easily identifiable signs have been described on routine MRI sequences that help diagnose an isolated PLB tear: the "gap" sign and the "footprint" sign. The "gap" sign is described as an increase in signal on water-sensitive sequences between the lateral femoral condyle and the proximal part of the ACL. The "footprint" sign is seen on coronal images as an increased signal correlating with an avulsion or compromise of the PLB's tibial insertion area [8]. Even when suspected, MRI accuracy for partial ACL tears ranges from 25 to 53%, making it a challenging task for radiologists [7]. The diagnostic standard remains intraoperative confirmation in the context of a stable knee on physical examination [9].

The primary determinant for selecting appropriate treatment for partial ACL tears depends on whether the ACL is competent and functional. A functional partial ACL tear would be defined as one where the athlete can return to their usual sports activity with confidence in their knee and with minimal or no sensation of laxity on physical examination after an appropriate rehabilitation period. On the other hand, a non-functional partial tear would be one where the athlete is unable to return to their usual sports activity due to instability symptoms during demanding sports activities or evident laxity on physical examination. ACL reconstruction or augmentation is recommended for patients unable to return to their desired activity level with symptoms and physical findings associated with a non-functional partial ACL tear. Contact sports involving pivoting movements (e.g., soccer, rugby, basketball, and American football) and an age of 20 years or younger have been notable factors described as increasing the risk of progression to a complete ACL tear [10]. The typical candidate for non-surgical treatment is a patient with a negative pivot shift maneuver and anterior tibial translation less than 5 mm, as quantified by an arthrometer compared to the contralateral knee, in addition to the ability to participate at the same sports level [10].

As part of conservative treatment, protocols with a duration of 3 months have been proposed, consisting of immobilization and rehabilitation in patients with a laxity difference of <4 mm, with reassessment of laxity at 3 months. If the patient remains stable, they may return to sports at that time [11]. A short period of immobilization is recommended to reduce edema and pain, followed by a functional rehabilitation program focused on maintaining mobility and strength before progressing to specific sports activities [9]. When surgical treatment is chosen, it should be based on arthroscopic findings and a decision on whether to perform selective debridement and augmentation or opt for a standard ACL reconstruction.

The decision is based on the amount and quality of remaining fibers after debridement, as well as the surgeon's preference [12]. Several techniques have been described for selective reconstruction of the AMB or PLB. Selective reconstruction follows the anatomical principles of double-bundle reconstruction, which aims to restore the anatomy and individual function of one bundle without damaging the intact bundle. Femoral tunnel drilling has been described using various techniques such as all-inside, "over-the-top," transtibial, and anteromedial, all with good clinical and functional outcomes [13].

The aim of the article is to establish ligament augmentation as an effective therapeutic option in partial anterior cruciate ligament injury using a bone-patellar tendon-bone autograft, due to its anatomical, functional, and biomechanical advantages.

Case presentation

A male patient, 36 years old, with no relevant medical or surgical history. One month prior to evaluation, he sustained an injury to the right knee during contact sports, with a mechanism of axial load on a flexed knee. Currently, he reports pain along the medial joint line, swelling, and a sensation of joint instability, with episodes of symptom exacerbation during physical activity.

On physical examination, pain, range of motion, muscle strength by group, and joint stability of the knee were assessed. The patient presented localized pain in the anterior surface at the medial parapatellar level along the joint line. Knee mobility arcs showed active flexion of 75º, passive flexion of 130º, with full extension, both passive and active. Muscle group strength was decreased (4/5 on the Daniels scale) with the knee flexed beyond 45º, while strength was 5/5 with the knee extended. Special maneuvers were performed to assess the meniscal-ligamentous structures of the knee, with negative results for both valgus stress and meniscal tests. Anteroposterior ligament stability was evaluated with the Lachman test, which was negative, and the anterior drawer test at 30º, 60º, and 90º, revealing anterior tibial translation compared to the contralateral limb at 60º and 90º.

As part of the diagnosis, a simple MRI of the knee was performed to assess ligament injuries. Among the findings, thinning of the anterior cruciate ligament (ACL) and periligamentous inflammatory fluid with increased intensity were observed, consistent with an ACL injury (Figure 1). The rest of the intra-articular anatomical structures were found to be intact.

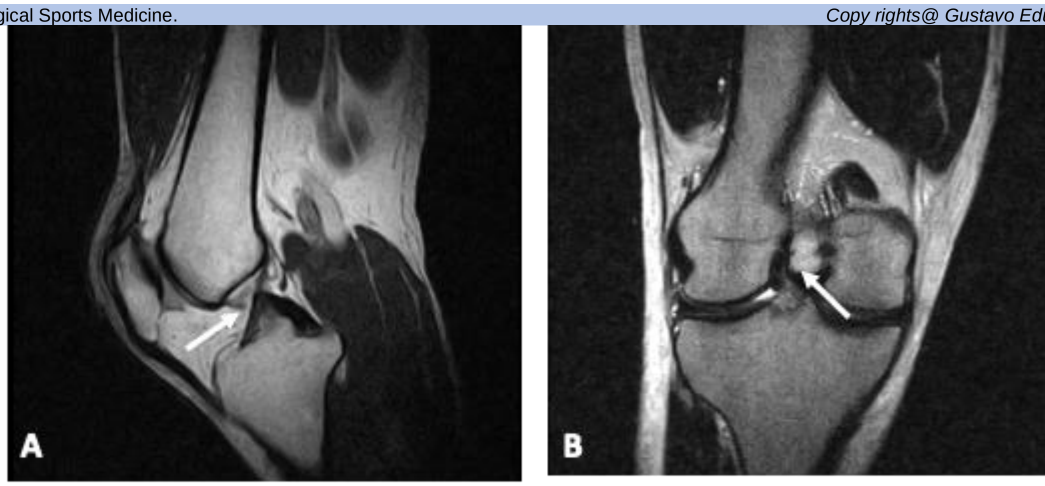

Figure 1: MRI of the right knee in T2 sequence. **A**: sagittal view; **B**: coronal view. Thinning of the anterior cruciate ligament is observed.

Based on the clinical and imaging findings, the diagnosis of right knee anterior cruciate ligament rupture was made. Due to the patient's symptoms and joint instability, a diagnostic and therapeutic arthroscopy was proposed to confirm the ACL rupture, with the possibility of reconstructing it using a patellar tendon autograft.

In the operating room, the patient was re-examined under balanced general anesthesia. The pivot shift maneuver was positive. The surgical phase of the arthroscopy proceeded, revealing a partial tear of the ACL with involvement of the posterolateral bundle (Figure 2). The tension and stability of the anteromedial bundle were evaluated, showing competence, so it was decided to perform ligament augmentation with a patellar tendon autograft, and the graft was obtained.

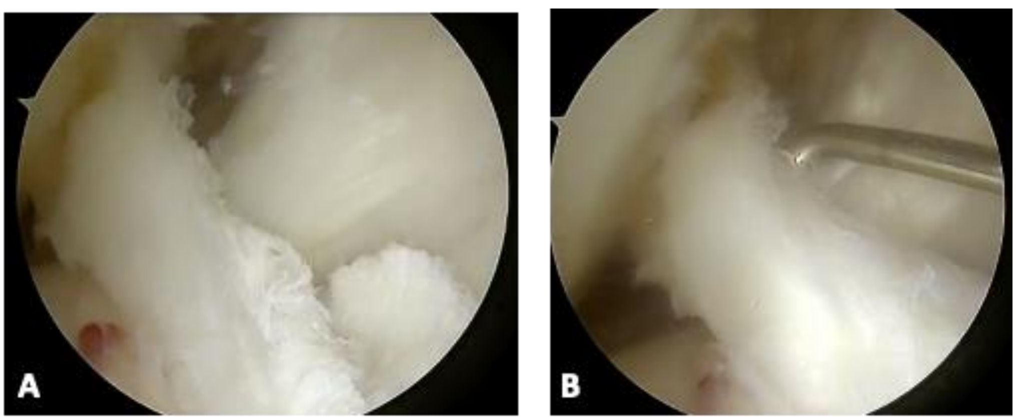

Figure 2: Arthroscopic image of the knee. **A**: Partial rupture of the anterior cruciate ligament with integrity of the posterolateral bundle is observed. **B**: The anatomical and functional competence of the posterolateral bundle is confirmed.

The anterior tibial tuberosity was located, a longitudinal incision was made, the insertion site of the patellar tendon was identified, and a 3 cm long by 1 cm wide section was marked distally. The graft was harvested using an oscillating saw, making 1 cm deep cuts. A second horizontal incision was made between the arthroscopic portals, the distal edge of the patella was located, the peritendon was incised, and the origin of the patellar tendon was identified, with a 2.5 cm long by 1 cm wide and 1 cm deep section marked on the patella. The graft was harvested using a saw. A bone-tendon-bone (BTB) graft with two bone blocks (proximal and distal) and the patellar tendon was obtained, prepared with vancomycin, and configured to 9 mm in width, with bone blocks measuring 25 mm at the femoral end and 30 mm at the tibial end.

The arthroscopic procedure continued, verifying the integrity of the menisci, ruling out meniscal and articular cartilage injury, and observing adequate patellar tracking. The lateral condylar notch was measured at 26 mm, a microfracture was performed 12 mm from the posterior cortex, and a retrograde femoral guide was placed at 105º. A 25 mm bone socket was drilled retrogradely. The tibial tunnel guide was set at 55º, drilling from outside in at the tibial footprint using a 10 mm drill.

The BTB graft was passed by pulling sutures from the external femoral and tibial surfaces, inserting the bone blocks into the previously made bone tunnels (Figure 3). An 8 x 26 mm biocomposite screw was inserted in the femur (Figure 3). The knee was cycled, and with full extension, the tibia was fixed using an 8 x 30 mm biocomposite screw. The anatomical position of the ACL graft was observed, verifying adequate tension and stability of the ligament (Figure 4).

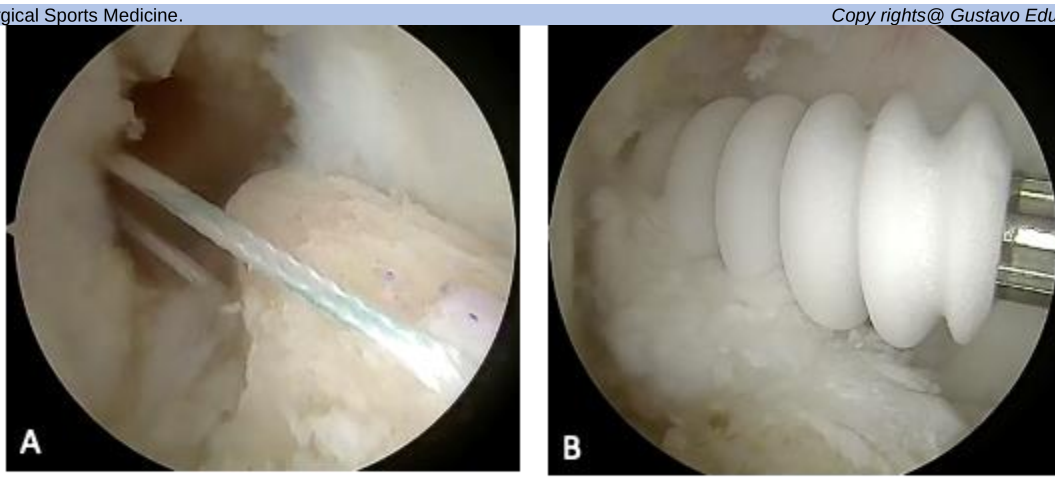

Figure 3: Arthroscopic image of the knee. **A**: Femoral bone tunnel created with retroconstruction, showing the passage of the bone block from the graft. **B**: Fixation of the bone block in the femoral tunnel with a biocomposite screw.

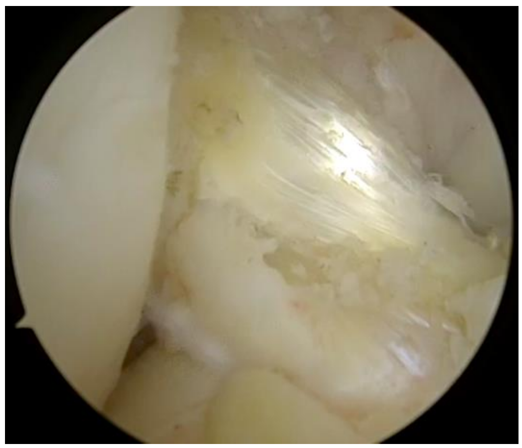

Figure 4: Arthroscopic image of the knee. HTH ligament graft of the anteromedial bundle, placed in an anatomical position.

The patient was discharged from the operating room in stable condition, with cryotherapy and compression systems, along with an analgesic and anti-inflammatory regimen. Passive movements were initiated in the immediate postoperative period, as well as weight-bearing as tolerated on the limb. He was discharged home 12 hours after surgery. At 2 weeks, the stitches were removed, and physiotherapy and rehabilitation began, focusing on regaining range of motion, quadriceps strengthening, and gait re-education. Currently, at 3 months post-surgery, the patient is asymptomatic, with active range of motion showing 115º flexion, full extension, 5/5 strength, and clinical stability of the anterior cruciate ligament.

Discussion

Anterior cruciate ligament (ACL) rupture is one of the most common sports injuries in young athletes. Partial ACL injuries account for 9 to 28% of all ACL injuries [7]. A definitive diagnosis for these partial injuries has not yet been concisely established, but suggestive diagnostic criteria include clinical, imaging, and arthroscopic findings [7]. In the case of our patient, the criterion for performing surgery in the context of a partial ACL tear was joint instability [14].

Once the arthroscopic diagnosis was confirmed and the integrity of the remaining bundle was observed, it was decided to preserve it. Preserving the remaining ACL bundle has been described to offer biological, clinical, and functional benefits. Preserving the remaining ACL bundle maintains a cellular and vascular environment that promotes graft integration while retaining the ligament's cellular properties, such as proprioception, promoting a faster recovery of range of motion and an earlier start of physical rehabilitation [15, 16].

Two of the most commonly used methods for obtaining autografts are the bone-patellar tendon-bone (BPTB) graft and the hamstring graft. The BPTB graft offers biological advantages over the hamstring graft. The integration seen with BPTB, due to the bone tunnels and bone plugs, provides faster and stronger bone integration at the fixation sites compared to hamstring grafts, which require soft tissue-to-bone biointegration [17]. This advantage in integration results in faster recovery of knee stability, which is crucial for athletes and active individuals aiming to return to their previous level of physical activity as quickly as possible [18]. The BPTB graft has shown greater resistance to elongation and higher initial fixation strength compared to hamstring grafts. This resistance to elongation may translate into less postoperative laxity and greater joint stability, which is essential for sports activities that require quick direction changes and high-intensity movements [18]. Long-term studies have indicated that patients with BPTB grafts have lower graft failure rates and fewer complications related to residual knee laxity. Although both graft types have good short-term outcomes, evidence suggests that BPTB grafts may offer advantages in terms of lasting joint stability and lower reoperation rates [17].

The use of hamstring grafts can compromise muscle strength in the knee flexor muscle group, which could negatively impact athletic performance and overall knee stability [19]. In contrast, using the BPTB graft avoids this complication since the donor site is the patellar tendon, which has less impact on overall muscle function compared to the hamstrings [19].

Although the BPTB graft may be associated with more postoperative pain and a higher incidence of donor site morbidity, such as patellar tendinitis and anterior knee pain, careful patient selection and appropriate postoperative management can mitigate these effects [18].

The femoral retro-reconstruction technique allows for more anatomical positioning of the bone tunnel and graft in the femur. This translates to better restoration of knee biomechanics and greater postoperative stability. Additionally, it offers the advantage of preserving more bone stock and maintaining femoral cortical integrity [20].

Conclusions

In conclusion, arthroscopic augmentation of the anterior cruciate ligament (ACL) through the preservation of the remaining bundle as a therapeutic option in the context of partial tears offers biological, clinical, and functional advantages compared to complete anatomical reconstruction. When selecting the autograft (BPTB or hamstring), both are viable options for ACL reconstruction. The BPTB graft offers functional advantages both in the short and long term, as well as a lower rate of reoperations. Graft selection should be personalized, considering both the biomechanical and clinical advantages as well as the potential complications associated with each graft type. The choice of technique and graft can improve surgical outcomes and patient satisfaction in the treatment of partial ACL tears, as well as facilitate a quicker return to sports or recreational activities.

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