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Research Article

Quadrupled Semitendinosus Tendon with Hybrid Tibial Fixation for Anatomic ACL Reconstruction: Surgical Technique Description

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Abstract

The incidence of Anterior cruciate ligament (ACL) tear is increasing, with an even more prominent increase in female athletes due to predisposing factors. The objective of this study is to present steps to perform a surgical technique for anatomic ACL reconstruction (AACLR) that takes advantage of the clinical and biomechanical benefits of the use of a quadruple semitendinosus graft (ST4) combined with the use of a hybrid tibial fixation. A technique which adapts to the current needs for early and safe rehabilitation and with the ability to overcome anatomical and physiological limitations such as small intercondylar notch and low Bone Mineral Density (BMD) for its application to a further range of adult population. A series of systematized steps are used based on clinical and biomechanical studies, consensus, and international guidelines, which have individually demonstrated good biomechanical and clinical properties for the AACLR.

Keywords: ACL; Reconstruction; Four Bands; Semitendinosus; Graft; Hybrid Tibial Fixation; Anatomic

Introduction

The rupture of the Anterior Cruciate Ligament (ACL) is one of the most common orthopedic injuries worldwide, and its incidence continues to increase due to the rise in physical activities in the general population [1-3]. In a study evaluating 1145 consecutive patients with traumatic hemarthrosis, 52% had ACL injuries (1 in every 2 knees). This injury can lead to a deterioration in functionality and a decrease in the quality of life [4,5]. Arthroscopic Anterior Cruciate Ligament Reconstruction (ACLR) surgery has become one of the most performed procedures in orthopedics, being the standard management for this injury in active individuals and athletes [5,6]. Given its growing importance, ACLR techniques are required to restore the previous anatomy and stability, limit secondary damages, reduce the risk of failures, and withstand early postoperative forces to meet the current needs of early return to sports and daily activities [3,4,7,8].

In orthopedics, it is our obligation to devise techniques that increasingly allow for their safe use across the same age groups, surpassing limitations that restrict the safe application to all patients undergoing an Anatomical Anterior Cruciate Ligament Reconstruction (An-ACLR). Such limitations may include factors like the size of the intercondylar notch or a decrease in bone mineral density [9,10].

For An-ACLR, there are various grafts and fixation techniques. The most commonly used autograft options include hamstring grafts, typically the Semitendinosus and Gracilis four-strand (ST/G 4) graft, followed by bone-tendon-bone (H-T-H) grafts, and patellar tendon (T-P) grafts. There is an increasing use of hamstring grafts due to lower morbidity at the harvesting site, a reduced rate of complications, and a lower risk of post-surgical residual pain [6,11,12]. This translates to a higher perceived postoperative safety for the patient and greater potential for early rehabilitation.

However, with the combined harvesting of the Semitendinosus and Gracilis tendons, there is a decrease in flexion and internal tibial rotation strength, along with an increase in anterior tibial translation. This contributes to a deficit in postoperative athletic performance [5,12,13].

Methods

A single-harvest approach and the application of the four-strand Semitendinosus graft (ST4) have been implemented for ACL reconstruction (RaLCA). This method provides a graft with sufficient dimensions for safe ACL reconstruction, [13-20] clinically yielding results similar to the use of ST/G 4 [21,22].

Biomechanically, it achieves greater strength, stiffness, less posterior elongation after cycling [23], and a reduction in side-to-side deficits in maximum isokinetic flexion torque compared to ST/G 4 [5]. Additionally, by preserving the gracilis, it limits the loss of flexion strength [11,24] and postoperative internal rotation [5], maintaining its integrity if needed for use in multiligament injuries or future interventions [5,24].

On the other hand, the selection of the fixation method also remains a topic of discussion for arthroscopists. Graft fixation, especially on the tibial side, has been recognized as a weak point in the immediate postoperative period, at least since 1987, with the study by Kurosaka., *et al*. [25,26].

Tibial fixation has been identified as the cause of complications related to early graft integration failure, tunnel widening, late anteroposterior laxity, which may promote the development of premature arthritis on the tibial and femoral surfaces in patients undergoing ACLR [8,26-29]. This issue has driven the development of techniques in search of optimal tibial fixation for ACLR. Following the description of techniques such as the one performed by Lubowitz., *et al*. involving all-inside ACL reconstruction, [30] where tenosuspension methods were developed, tibial fixation techniques have been classified as intratunnel (IT) or opening and extra-tunnel (ET) or suspensory.

In IT fixation, interference fixation is performed in the cancellous bone located within a complete tunnel, which relies on adequate bone stock. The fixation is close to the joint level, reducing the working length and increasing construct stiffness [20,26]. Meanwhile, in ET fixation, incomplete tunnels are usually drilled, minimizing trauma and preserving the outer cortex, for the implementation of a suspensory fixation, providing a more secure fixation with greater primary stability but increasing the working length, giving rise to longitudinal and sagittal micro-slippages that hinder integration and result in tunnel and graft elongation [26-28].

To counteract the limitations of implementing IT and ET techniques separately, the combination of both methods in hybrid or supplementary fixation has been proposed. Biomechanically, hybrid fixation results in a significant decrease in graft elongation, increased construct stiffness, and increased resistance to loads, allowing for an increase in early postoperative rehabilitation strength. Clinically, hybrid fixation allows for a reduction in displacement and anterior laxity without sacrificing the range of motion [26,27].

The aim of this study is to describe a surgical technique for ACL reconstruction (RaLCA) that takes advantage of the benefits of the single-graft application of ST4, combined with hybrid tibial fixation. This technique aims to provide acceptable conditions for early rehabilitation with a reduced risk of failures and can be implemented across a wide range of the population. A series of systematic steps are used, based on clinical studies, biomechanics, consensus, and international guidelines, which have individually demonstrated good biomechanical and clinical properties for RaLCA [3,4,7,8,11,13,14,16,18-20,30-38]. These steps are extensively explained for easy reproduction and minimal room for interpretation.

Surgical technique

For the implementation of the technique, the patient is positioned on the operating table in a supine position, with the operative leg free. A tourniquet is applied, and a lateral thigh post is used to allow knee valgus. The following equipment will be used

- A Graft Pro® graft preparation system (Arthrex®), Graft sizing block with holes from 4.5 to 12 mm in increments of 0.5 mm (Arthrex®).
- Arthroscope with a 30° angulation.
- For femoral tunnel creation, a retrograde drilling system (Flipcutter Arthrex®) is used, along with an ACL femoral footprint guide (Arthrex®) positioned at 100° on the Drill guide handle for Retro Construction, lateral release (Arthrex®), FlipCutter guide sleeve with a 10 mm step, 3.5 mm (Arthrex®).
- For tibial tunnel drilling: cannulated drill bit from 8 mm, 55° ACL tibial drilling guide (Arthrex®) placed in the Ring-C adapter for the drilling guide (Arthrex®), Guide sleeve for 2.4 mm pin, 3.5 mm (Arthrex®), 2.4 mm pin. Both Flipcutter and cannulated drill systems should have a diameter matching the ST4 graft diameter.
- For graft passage and fixation in the femoral tunnel, use a FiberStick (Arthrex®) and an adjustable button system (TightRope Arthrex®).
- Finally, for double tibial fixation, use a connectable button system (ABS Arthrex®) and a BioComposite biodegradable interference screw (Arthrex®) matching the graft dimensions and not smaller than 1mm than the tibial tunnel dimensions. (Lubowitz, Silva AL, Van Eck, Flury)

Harvesting of ST graft, quadruplication, and preparation

The harvesting of the semitendinosus (ST) tendon is performed on the anteromedial aspect of the tibia, over the insertion site of the pes anserinus, using a 3 cm oblique incision. Adipose tissue is dissected down to the sartorius fascia, and an inverted "L" incision is made. The ST is dissected, released from adhesions, and detached using a closed tenotome to collect the tendon. Care is taken to avoid excessive manipulation, and any adhering muscular tissue is removed [11,14,31,32].

The obtained semitendinosus tendon is symmetrically folded over the loop of the adjustable button system (ABS Arthrex®) and again symmetrically folded over the loop of the adjustable button system (TightRope Arthrex®), resulting in a 4-strand construct. (Figure 1) The loops and systems at each end are placed in the Graft Pro® graft preparation system (Arthrex®). A high-strength No. 2 suture is passed through each strand of the tibial end, knotted in a figure-eight configuration, and continued with knots more directed toward the femoral side to increase graft stiffness and strength [13,14,33].

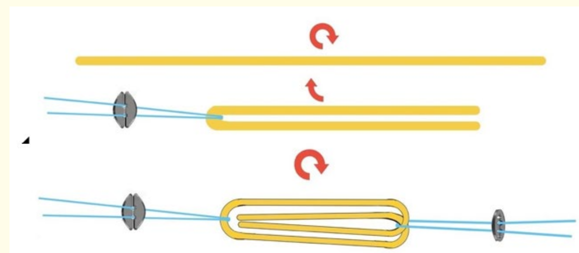

Figure 1: Graft preparation technique with a 4-strand construct using a double tenosuspension system.

The graft is subjected to a pretension force of 40 N for one minute. Afterward, it is measured using the graft sizing block to determine the length and diameter of the bone tunnel perforations. Following pretensioning, the intraosseous femoral distance is marked on the adjustable button loop. On the graft, the distance within the femoral tunnel, the intra-articular distance, and the distance within the tibial tunnel are marked. In the loop of the toggle button system, the intraosseous tibial distance is marked [14,33].

The measurements will vary depending on the obtained graft and the dimensions of the knees to be operated on, but generally, for this technique, the expectation is to obtain a tendon of 280 mm, which will provide a construct of around 8 mm in diameter and 4 equidistant bands of approximately 70 mm each. After pretensioning, these bands will result in a length of around 75-80 mm. Ideally, there should be 20 mm of graft in the femoral tunnel, 30 to 35 mm of graft in the intra-articular region, and 20 to 30 mm of graft in the tibial tunnel [13-20,33].

Femoral tunnel drilling

With the knee flexed at 90°, arthroscopy is initiated, and the standard anterolateral portal and medial

portal on the medial edge of the patellar tendon over the joint line are established [13]. The standard arthroscopic procedure is followed to confirm the ACL injury. The diameter of the femoral insertion footprint of the ACL is delineated, located below the lateral intercondylar ridge, in the posterior third of the lateral wall of the medial femoral condyle, and its center is identified, over the lateral bifurcated ridge. To ensure the creation of an anatomical femoral tunnel, the location of the site to be drilled is confirmed by placing the arthroscope in the medial portal and marking the desired site with radiofrequency [3,4,7,8,33,35].

Introduction of the femoral guide

The Femoral Guide for ACL footprint (Arthrex®), placed at 100° in the drill guide handle for Retro Construction, lateral release (Arthrex®), is introduced through the lateral portal. On the outer side of the guide, the Cam Guide for FlipCutter with a 10 mm step, 3.5 mm (Arthrex®), is inserted and brought close to the skin. Its location is suggested to be anterior to the posterior edge of the iliotibial band, 2.5 cm proximal to the lateral femoral condyle, with an approximate inclination of the guide in relation to the femoral diaphysis greater than 35° [8,33]. After confirming that the placement of the femoral guide ends is as desired, an incision is made with a scalpel. The guide sleeve is advanced to the bone and the Retrograde Drilling System (FlipCutter Arthrex®) is introduced, activated until it passes into the joint.

Upon observing the free tip of the FlipCutter above the joint surface, it is flipped perpendicular, the guide sleeve is percussed until advancing 10mm. The femoral tunnel is drilled retrograde to the required distance measured by laser marks (the marked distance of the graft calculated inside the femoral tunnel plus 10 mm to avoid it colliding with the end of the created tunnel, to allow tension during fixation) [33].

The FlipCutter is reintroduced into the joint, the tip is returned to the initial position, and it is completely removed. The Drill Guide Handle is released and removed along with the ACL Footprint Guide. Direct visualization of the created tunnel is performed with the arthroscope. The loop of a high-strength suture mounted on a FiberStickTM (Arthrex) is introduced through the guide sleeve and pulled out of the joint through the lateral portal. The guide sleeve is removed. The suture ends are intertwined and secured with atraumatic forceps. The arthroscope is returned to the lateral portal and directed to the lateral gutter to debride the synovial tissue located between the lateral femoral cortex and the fascia lata [33,36].

Tibial tunnel drilling

The footprint of the tibial insertion of the ACL is delineated, located posterior to the anterior horn of the lateral meniscus, and 5 to 7 mm anterior to the tibial insertion of the posterior cruciate ligament. The center is marked with electrocautery. Through the medial portal, the ACL Tibial Drill Guide (Arthrex®) is introduced, placed in the Ring-C Adapter for the drill guide (Arthrex®), and positioned over the marked site on the tibial surface. A 2.4 mm to 3.5 mm Guide Sleeve for a 2.4 mm Pin (Arthrex®) is passed through the outer part of the guide, introduced through the incision created for the semitendinosus harvest, and brought into contact with the tibia, taking care to protect the gracilis tendon. A 2.4 mm pin is inserted into the sleeve and drilled until passing through the intra-articular tibial cortex. After confirming the desired placement within the articular surface, the sleeve is removed, and a complete tunnel is drilled with a cannulated drill of the same diameter as the graft [3,4,7,8,33,35].

Graft passage

In this step, the sutures' clamps introduced through the femoral tunnel are removed, and the loop is retrieved through the tibial tunnel. The loops of the adjustable button system, attached to the graft's femoral end, are passed through this loop. The suture is pulled proximally to recover the loops through the femoral tunnel. With the adjustable button oriented parallel to the graft, the loop is pulled until the marking of the intraosseous femoral distance reaches the femoral tunnel (indicating the complete passage of the adjustable button through the femoral tunnel). At this point, the loop that turns the adjustable button perpendicularly to the femoral cortex can be pulled. To confirm the perpendicular deployment of the button on the femoral cortex, its positioning in the lateral groove is directly observed with the arthroscope [7,33,36].

Graft fixation

The visualization and working instruments are removed from the portals, and the knee is flexed to 20°.

The loop that brings the graft towards the end of the femoral tunnel is pulled [14,28,29]. The nitinol guide is concentrically introduced through the tibial tunnel, and an approximate tension of 90N is applied to both loops of the ST4 graft [28,29]. The BioComposite biodegradable interference screw (Arthrex®)

is introduced, and its positioning is observed by inserting the arthroscope into the tibial tunnel (Figure 2). The attachable button (ABS Arthrex®) approaches the tibial cortex, and the system is adjusted, locking the tibial loop. Square knots are tied over the button to secure it. Finally, the placement of the ACL reconstruction is observed with the arthroscope, and the incisions are closed [3,4,7,8,13,26,30,35,37] (Figure 3).

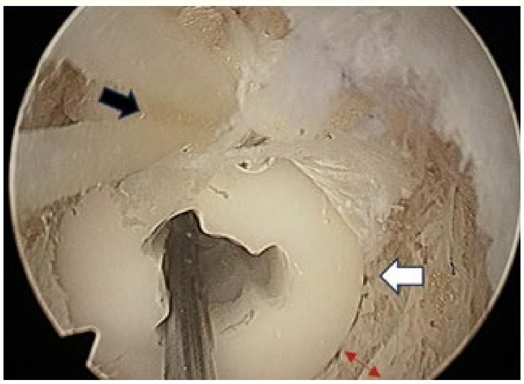

Figure 2: Arthroscopic image of the tibial tunnel. The systems for dual graft fixation are visible. White arrow indicates the BioComposite interference screw. Black arrow indicates the sutures from the suspensory system of the attachable button (ABS Arthrex®). A clear space around the graft and screw is observed in the tunnel to allow proper suspensory function.

Figure 3: Lateral knee X-ray of a patient undergoing ACL reconstruction (RaLCA) with dual tibial fixation, showing graft fixation materials. 1 Arrow: adjustable button (TightRope Arthrex®). 2 Arrows: biodegradable interference screw. 3 Arrows: attachable button (ABS Arthrex®).

Results and Discussion

Choice of ST4 graft

The choice of graft should be individualized by arthroscopists, considering the physical characteristics and post-surgical physical performance expectations of patients. Despite the good clinical and biomechanical results reported with the use of autologous grafts, [5,12,16,35]. graft harvesting is not a completely innocuous process. It can lead to donor site morbidity and complications, as classified by Runer., *et al*. Major complications include graft rupture or contralateral ACL injury, patellar fracture, extensor apparatus rupture, infection, as well as kneeling pain. They define minor morbidities and complications as unaesthetic scarring, areas with changes in sensitivity in the leg, persistent pain in the anterior region of the knee, and tendonitis at the donor site [12].

The harvesting of the patellar tendon graft (T-P) involves risks such as patellar fracture and quadriceps tendon rupture, and its collection is associated with a decrease in knee extension strength. On the other hand, harvesting the hamstring tendon graft (H-T-H), like the quadriceps tendon graft, poses the risk of patellar fracture, quadriceps rupture, and reduced extension strength. Additionally, it is linked to a higher rate of pain at the harvest site, presents a heightened risk of progressing to osteoarthritis in the reconstructed knee, and increases the risk of contralateral ACL injury [12,35].

Finally, the harvesting of hamstring tendon grafts (IS) is associated with a decrease in flexion and internal rotation strength, linked to an increase in anterior tibial translation, and poses a higher risk of infection [5,12,13]. Recently, the technique of preparing IS grafts using the ST tendon in four bands was developed to reduce morbidity and complications associated with the combined extraction of IS [5,13,14,20,24].

It has been noted that there is a significant decrease in flexion strength in knees undergoing ACL reconstruction using autologous hamstring tendon grafts (IS). Despite this, in the vast majority of studies, these results have been obtained by measuring flexion strength after the combined extraction of ST and G. However, there is little information directly comparing postoperative flexion strength with the singletendon harvest of ST. Ardern., *et al*. conducted a systematic review, revealing that the deficit in flexion strength at deep flexion angles after the harvest of semitendinosus-gracilis is greater compared to singletendon harvest of ST [24].

On the other hand, preserving the gracilis avoids the suppression of its function as the primary internal rotator. Therefore, the single-tendon harvest of the semitendinosus for ACL reconstruction should be considered as a method that allows avoiding major risks and complications at the donor site, without compromising postoperative extension strength. At the same time, this method reduces the deficit in flexion strength and internal rotation compared to harvesting both hamstring tendons (IS) [5,11,12,23,24].

In this technique, the collection of the ST tendon is favored with the anteromedial tibial approach. With this method, a graft up to 20 mm longer can be obtained compared to the posterolateral approach, translating to an approximately 5 mm increase in the total graft length when performing the 4-band preparation technique. Moreover, from an aesthetic standpoint, this collection method utilizes a single skin incision for graft extraction, tibial tunnel creation, and the placement of the button system. Making the incision oblique is suggested, considering that it presents a lower risk of injury to the infrapatellar branch of the saphenous nerve (IBSN). Henry., *et al*. conducted a cadaveric study on 200 lower limbs, simulating oblique, transverse, and longitudinal incisions, and found that the oblique anteromedial incision presents a lower risk of IBSN injury (27.6% nerves injured in oblique incisions, compared to 64.7% in vertical incisions and 50% in horizontal ones) [32]. In another study, Albishi., *et al*. compiled a table of 6 studies comparing vertical and oblique incisions, demonstrating a higher prevalence of IBSN injuries as well as a greater area of hypoesthesia with vertical incisions [11].

Dimensions of ST4 and Tunnels.

An obstacle in deciding to use the ST tendon as a single graft is to be certain whether its dimensions can be consistently and safely obtained to achieve the necessary length and diameter for its proper application in ACL reconstruction (RLCA).

The graft diameter size of the IS is directly related to failure. However, there is currently no consensus on the recommended ideal diameter to avoid failure in ACL reconstruction, as the accuracy of this measure remains a topic of debate [16].

In the anthropometric study by Asif., *et al*, they mention that the minimum graft diameter to avoid the risk of failure should be up to 7 mm [39]. However, in the literature review on IS size in ACL surgery by Figueroa., *et al*, they state that this caliber is associated with a higher incidence of failures compared to the use of grafts of 8 mm or more. They further mention that increases of 0.5 mm in grafts from 7 mm onwards are beneficial in reducing the likelihood of revision, although it is also described that from 8 mm onwards, there are no changes in laxity and failures [16].

On the other hand, Schlumberger., *et al*. analyzed 2467 consecutive cases of ACL reconstruction from 2007 to 2010, with a 5-year follow-up, of which there was an incidence of 3% traumatic graft rupture. In this study, no significant differences were found when comparing graft diameters. On the contrary, they identified male gender and age under 25 as risk factors for graft rupture [17]. Thus, it is reaffirmed that it is important to individualize patients and have surgical descriptions that define the steps for an anatomical reconstruction to reduce the risk of failure.

When using IS grafts, constructs with different numbers of bands can be employed, and higher numbers of bands result in larger diameters. Grafts with fewer than 4 bands seldom achieve sufficient diameters to limit the risk of failure. It has been theorized that a higher number of bands would lead to a lower risk of failures. However, Attia., *et al*. conducted a study with 413 patients who underwent ACL reconstruction with autologous IS grafts. They divided the groups into 4, 5, and 6 bands, obtaining mean diameters of 8.25 mm, 9.14 mm, and 8.95 mm, respectively. The study demonstrated that regardless of the number of bands, IS grafts with a diameter above 8.0 mm showed no significant difference in failure rates [18].

For an ACL reconstruction surgery to be considered successful, it requires a graft with a total length that covers the previous extension of the native ACL, and at its ends, there should be sufficient tissue for proper integration. The usual length of the native ACL is 27 to 38 mm [40]. For the femoral side, it is described as necessary to have at least 20 mm of graft within the tunnel; however, the use of a tenosuspension technique allows for a minimum length of 10 mm for graft healing within the femoral tunnel [13]. Guglielmetti., *et al*. conducted an observational study of 71 patients with a 2-year follow-up, in which no significant differences were found in physical examination results (except for the Lachman test), re-rupture rates, KT100 arthrometry, and IKDC and Lysholm scale scores after reconstruction with femoral tunnels >20 mm and ≤20 mm [19].

The ideal length of the graft within the tibial tunnel to reduce revision rates is still controversial. A minimum graft length of 15 mm within the tibial tunnel has been described with the ET fixation method to avoid the risk of failure [13]. On the other hand, 20 mm is described as the minimum length for proper integration with IT fixation [20]. Additionally, when performing hybrid tibial fixation that requires a complete tibial tunnel, its estimated length should be known when using the 55° guide for drilling to prevent the use of a screw that exceeds the dimensions to provide free space in the tunnel for proper tenosuspension. In a study of 27 patients who underwent tibial tunnel drilling with a 55° guide, the average length obtained was 43.3 mm (40 to 48 mm) [30].

Sufficient information was not found regarding the appropriate graft diameter within the tibial tunnel when performing hybrid fixation. Therefore, it is established that, for this technique, a minimum graft length of 20 mm is required for screw fixation and integration, and a maximum length of 30 mm for both graft and screw to maintain at least 10 mm of free space in the tunnel to simultaneously perform ET fixation [20,38].

In 2012, Xie., *et al*. demonstrated the feasibility of obtaining semitendinosus grafts with the required dimensions for successful ACL reconstruction. They conducted an anthropometric study of 235 patients in China, with an average height of 171 cm and an average weight of 71 kg, in which semitendinosus grafts were harvested and quadruplicated. They obtained an average construct diameter of four-banded semitendinosus of 7.4 mm (+- 0.7) and a length of 279.9 (+/- 20.8 mm). Additionally, this study considered weight and height as predictive factors for graft dimensions [15].

Although it is difficult to estimate accurately, there are currently anthropometric calculations to predict the approximate graft length. Colombet and Graveleau combined anthropometric correlations from two studies in a table where it is estimated that from patients between 166 and 170 cm in height, grafts with an average length of 28.1 cm can be obtained (a range between 27.9 and 28.4 cm) [14].

For this technique, it is recommended to use an ST graft with a minimum length of approximately 280 mm, which, when prepared as a four-banded graft, can yield around 70 mm in length. After pretensioning, this will result in an approximate length of 75 to 80 mm. This allows obtaining a 20 mm graft in the femoral tunnel, 30-35 mm in the intra-articular region, and at least 20 mm in the tibial tunnel. In case of obtaining a longer graft, the excess can be used in the tibial tunnel up to 30 mm. A graft of up to 60 mm can be used, reducing it to no less than 10 mm in the femoral tunnel. (Table 1) The suggested ideal diameter is 8 mm to 9 mm, with a suggested lower limit of no less than 7.5 mm.

If the calculated dimensions are not favorable, consider planning another surgical technique. In the case of having already performed the ST graft harvest with measurements smaller than suggested, consider taking a graft from the gracilis to complement it.

Graft size ST4	TF	IA	TT
≥ 60 mm	≥10 mm	≥30 mm	≥20 mm
75mm-80mm (ideal)	20 mm	30-35 mm	20-25 mm
≤ 80 mm	20-25 mm	30-35 mm	Hasta 30 mm

Table 1: Suggested lengths of the ST4 graft for the application of the RaLCA technique with ST4 and hybrid tibial fixation.

TF Graft length in femoral tunnel. IA Graft length in intra-articular space. TT Graft length in tibial tunnel. Tibial IT fixation, either with a biodegradable or metallic screw, is widely used [20,28] and has the advantage of a short working length. However, it relies on adequate mineralization within the bone tunnel [9,20]. It has been demonstrated that this method alone has fallen behind in comparison to advances in new fixation methods in ACL reconstruction [11,20,26,28,41]. On the other hand, ET tibial fixation with tenosuspension has the advantage of using an incomplete tunnel, preserving bone for graft integration, but initially causing slight sagittal micromovements, creating a windshield wiper effect resulting in widening of the tibial tunnel [26,28]. For this technique, hybrid or supplementary tibial fixation is used. This involves a BioComposite biodegradable interference screw (Arthrex®) IT, which should be 20 to 30 mm in length and have a diameter no less than 1 mm of the tibial tunnel diameter, placed concentrically to reduce the likelihood of tibial tunnel widening [42]. Additionally, a tenosuspension system with an adjustable button (ABS Arthrex®) is employed [20,26,28,37,41]. With this technique, an attempt is made to address the issue of deficiency in tibial fixation in ACL reconstruction [1,2].

Hybrid tibial fixation As mentioned earlier, hybrid tibial fixation provides the advantages of IT fixation, immediately offering a significantly stronger and stiffer reconstruction [20,26] (balazs) by reducing the working length. It combines with greater primary stability due to the button attachment of the ET suspensory fixation to the tibial cortex, without the disadvantage of sagittal micromovements [26,28].

Additionally, hybrid tibial fixation can alleviate one of the drawbacks of using an IS graft, anterior tibial translation. In the systematic review of hybrid tibial fixation conducted by Balazs., *et al*, a significant reduction in laxity or anterior tibial translation is described when using supplementary fixation [26]. Moreover, hybrid tibial fixation allows for initial load-sharing strength of the construct. It provides fixation not only in the less dense cancellous bone but also, with supplementary ET fixation, in the denser outer cortex. This is more critical in patients with decreased bone mineral density (BMD). In a biomechanical *in vitro* study comparing the efficacy of supplementary fixation in tibiae with low BMD, Waltz., *et al*. found that the group with supplementary fixation exhibited 25% more resistance to failure compared to the group without supplementary fixation (312.7 ± 67.5 N vs. 235.0 ± 47.6 N) [9]. Hybrid fixation could have a positive impact on the increasingly growing population of recreational athletes with ACL injury who have decreased BMD. This surgical technique description aims to approach providing similar recovery opportunities in the same age group wishing to return to sports activities.

Anatomic reconstruction

The described procedure outlines the steps for performing an anatomical ACL reconstruction (RLCA) surgical technique. To define this technique as such, the criteria from Van Eck., *et al*. were considered, where anatomical reconstruction is defined as the functional restoration of the ACL to its native dimensions, collagen orientation, and insertion sites [7]. Additionally, in the article by the same author with different collaborators, they created a checklist for the use and interpretation in anatomical ACL reconstruction [34].

Meeting the following checklist criteria: the use of a 30° arthroscopy lens, direct visualization of the femoral insertion site of the ACL and measurement of its dimensions, visualization of the lateral intercondylar crest and lateral bifurcate crest, placement of the femoral tunnel over the ACL insertion site with a transportal drilling; direct visualization and measurement of the tibial insertion, placement of the tibial tunnel over this native insertion; documentation of the graft type to be used, its tension during fixation, description of femoral fixation, double tibial fixation, and knee flexion degrees during fixation [34].

Anterior Cruciate Ligament Reconstruction (ACL) techniques should aim to approximate a restoration of the native anatomy and the previous stability of the injured knee. It has been described that the method that comes closest to this goal is the use of two grafts to separately restore the anteromedial and posterolateral fascicles [4,7,8]. However, the use of a single-graft technique with an anatomical method has shown similar clinical results. The latest clinical practice guideline from the Japanese Orthopaedic. Association for the treatment of ACL injuries (GPC-JOA-LCA) describes a meta-analysis of five other meta-analyses comparing clinical outcomes between these two techniques. The analysis found no significant difference in Lysholm score, KOOS (4 items), KOOS pain, KOOS sports, knee arthrometer measurements (KT-1000), or re-rupture rates. The only significantly better results were found in the decrease in postoperative pivot test, although the positivity rates of this test equalized between both techniques over the course of 5 years [35].

Furthermore, when comparing these procedures, those involving the repair of both fascicles are associated with a higher degree of complexity, a steeper learning curve, and often higher costs, requiring two grafts and at least four fixation systems (two femoral and two tibial). Additionally, this technique necessitates a knee with an intercondylar notch size above 12-14 mm for its application, as short intercondylar spaces may hinder the anatomical placement of tunnels and increase the risk of ACL re-rupture [3,7,8,28].

This last point becomes relevant since not all population groups have intercondylar spaces of these dimensions. In a cohort conducted by Shelbourne., *et al*. the intercondylar space of 517 patients was measured using knee radiographs. The study found that white individuals had significantly smaller intercondylar spaces compared to African Americans of the same gender. Among white women, the mean intercondylar space was found to be the smallest, measuring 14.1 mm (8-21 mm) [10]. This average in the white female population represents the lower limit of the intercondylar notch diameter for the performance of double-bundle ACL reconstruction without presenting a challenge for its execution [7].

Given that there are increasingly more female athletes who also have a higher predisposition to ACL injuries (35), the focus should be on developing techniques that are increasingly safe, have low failure risk, are easy to reproduce, and can be useful for the majority of the adult population. This technique outlines the steps for a single-bundle reconstruction with a ST4 graft, which can be easily applied in patients with small intercondylar spaces. This approach may offer broader applicability across all adult population groups with ACL injuries seeking surgery.

Conclusion

- The ST4 graft allows obtaining suitable dimensions for safe Single-Bundle Anterior Cruciate Ligament Reconstruction (RaLCA), with the advantage of reducing comorbidities and risks associated with other types of grafts.
- Performing RaLCA with a single bundle yields clinical outcomes similar to double-bundle techniques, offering the advantage of applicability to a broader range of the adult population.
- Hybrid tibial fixation in RaLCA provides adequate clinical and biomechanical results, reducing the risk of failure. It combines the benefits of intra-tibial fixation (IT) while incorporating extra-tibial (ET) cortical fixation, making it safer for adults with ACL injuries and decreased bone mineral density (BMD).
- This proposed technique of single-bundle RaLCA with ST4 graft and hybrid tibial fixation stands as a surgical alternative. It allows for early and safe return to low or moderate-demand sports activities, making it applicable to a wider range of non-elite female patients or recreational athletes who may have started the process of bone demineralization.

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