**Benha Journal of Applied Sciences (BJAS)** **print: ISSN 2356–9751**
**Vol. (8) Issue (7) (2023), (51-62)** **online: ISSN 2356–976x**
**http://bjas.journals.ekb.eg**

# Minimally Invasive Quadriceps vs Hamstring Tendon Autografts in Arthroscopic ACL Reconstruction: A Comparative Review

**Mohammed.A.Gharib, Mohamed.S.Shawky and Elsayed.M.Bayomy**
Orthopedic surgery Dept., Faculty of Medicine, Benha University
**E-mail:** doctorgharib84@gmail.com

**Abstract**
**Background:** Arthroscopic anterior cruciate ligament (ACL) reconstruction is a commonly performed procedure for individuals with ACL injuries. The choice of graft material is crucial for the success of the surgery, with minimally invasive quadriceps tendon autografts and hamstring tendon autografts being the most frequently used options. **Objective:** This comparative review aims to analyze and compare the outcomes of arthroscopic ACL reconstruction using minimally invasive quadriceps tendon autografts and hamstring tendon autografts. The objective is to provide valuable insights into the advantages, limitations, and clinical efficacy of each graft option. **Conclusions:** Both minimally invasive quadriceps tendon autografts and hamstring tendon autografts have demonstrated positive outcomes in arthroscopic ACL reconstruction. Each graft option has its own advantages and limitations, such as graft strength, harvest site morbidity, postoperative pain, and recovery time. Surgeons and patients can use this information to make informed decisions regarding graft selection in ACL reconstruction.

**Keywords:** Arthroscopic ACL Reconstruction; Minimally Invasive; Quadriceps Tendon Autograft; Hamstring Tendon Autograft; Outcomes.

## Introduction

ACL reconstruction is a vital surgical procedure aimed at restoring knee stability and function in individuals with anterior cruciate ligament (ACL) injuries. The ACL is a major ligament in the knee joint that provides stability by preventing anterior translation of the tibia in relation to the femur. However, ACL injuries are common, especially among active individuals participating in sports that involve sudden stops, changes in direction, or pivoting movements [1].

The prevalence of ACL injuries has been a cause for concern, with numerous studies reporting a significant incidence among athletes and non-athletes alike. ACL tears often result from sports-related activities such as soccer, basketball, football, and skiing, but they can also occur during non-contact situations involving sudden twists or turns. Additionally, female athletes have shown a higher susceptibility to ACL injuries compared to their male counterparts [2].

The importance of ACL reconstruction lies in the potential consequences of leaving the injury untreated. A torn ACL can lead to knee joint instability, which hampers normal daily activities and sports participation. Furthermore, the absence of surgical intervention may accelerate joint degeneration, resulting in long-term complications such as meniscal tears, cartilage damage, and an increased risk of developing osteoarthritis [3].

The primary goals of ACL reconstruction are to restore knee stability, enable a return to previous levels of activity, and minimize the risk of future knee injuries. Achieving these goals requires careful consideration of several factors during the surgical procedure. The surgical approach plays a crucial role in accessing the knee joint and performing the necessary repairs. Arthroscopic techniques, which involve smaller incisions and the use of a camera and specialized instruments, have become the standard approach due to their minimally invasive nature, reduced postoperative pain, faster recovery, and improved cosmetic outcomes [4].

In addition to the surgical approach, the choice of graft type, graft placement, and fixation method are pivotal in determining the success of ACL reconstruction. Graft selection involves using a suitable tissue substitute to reconstruct the torn ACL. Common graft options include autografts, which are harvested from the patient's own body, and allografts, which are obtained from a donor. Autografts are generally preferred due to their better healing potential and lower risk of disease transmission. The most commonly used autografts for ACL reconstruction are hamstring tendon autografts and bone-patellar tendon-bone autografts [4].

Graft placement refers to the accurate positioning of the graft within the knee joint to restore the native ACL's biomechanical function. The proper placement of the graft ensures stability and optimal load transmission throughout the knee joint. Fixation methods are employed to secure the graft in its anatomical position during the healing process. Various techniques are available, including

interference screws, suspensory devices, and cortical fixation methods. The choice of fixation method depends on factors such as graft type, surgeon preference, and patient-specific considerations [5].

The type of graft used in ACL reconstruction has a significant impact on surgical outcomes and patient satisfaction. The biomechanical properties, healing potential, and potential complications associated with each graft type should be carefully considered. Hamstring tendon autografts are widely used due to their availability, ease of harvest, and satisfactory clinical outcomes. On the other hand, bone-patellar tendon-bone autografts are considered the gold standard graft due to their excellent potential for bone-to-bone healing. However, these grafts may be associated with complications such as anterior knee pain and patellofemoral arthritis [6].

Recently, minimally invasive quadriceps tendon autografts have gained attention as a viable alternative for ACL reconstruction. The quadriceps tendon has shown comparable biomechanical properties to hamstring tendon and bone-patellar tendon-bone grafts, with similar stability, patient-reported outcomes, and strength. Quadriceps tendon autografts have also demonstrated a lower failure rate compared to patellar tendon autografts and reduced incidence of anterior knee pain. These advantages, along with decreased donor site morbidity, make quadriceps tendon autografts an attractive option for primary ACL reconstruction [7].

This review aims to compare the outcomes of arthroscopic ACL reconstruction using minimally invasive quadriceps tendon autografts and hamstring tendon autografts, providing valuable insights into their respective advantages, limitations, and clinical efficacy.

**1. Anatomy and Biomechanics of the ACL:**

The anterior cruciate ligament (ACL) is one of the two major ligaments within the knee joint that plays a crucial role in providing stability. It is located deep within the knee, connecting the femur (thighbone) to the tibia (shinbone). The ACL runs diagonally in the center of the knee, crossing over the posterior cruciate ligament (PCL) to form an "X" shape. The ACL's primary function is to prevent excessive forward movement (anterior translation) of the tibia in relation to the femur, as well as to control rotational forces [8].

The ACL consists of two bundles: the anteromedial bundle (AM) and the posterolateral bundle (PL). The AM bundle is taut during knee flexion and is primarily responsible for preventing excessive anterior translation of the tibia. It also plays a role in resisting rotational forces. The PL bundle, on the other hand, becomes taut during knee extension and contributes to overall knee stability [9].

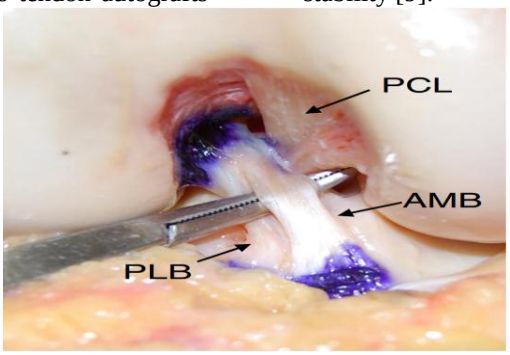


**Fig. (1)** The photograph of the AMB and PLB of the ACL in the axial view. The ACL was bluntly separated into the two bundles. Note that the AM bundle attaches on the cylindrical surface of the femoral intercondylar notch around its proximal/ posterior outlet [9].

Biomechanically, the ACL acts as a primary restraint against anterior tibial translation and rotational instability of the knee joint. It helps maintain the integrity of the joint by resisting forces that could potentially cause the tibia to move excessively forward or rotate abnormally. During activities involving jumping, pivoting, or changing direction, the ACL undergoes significant stress and must withstand substantial loads to maintain knee stability [10].

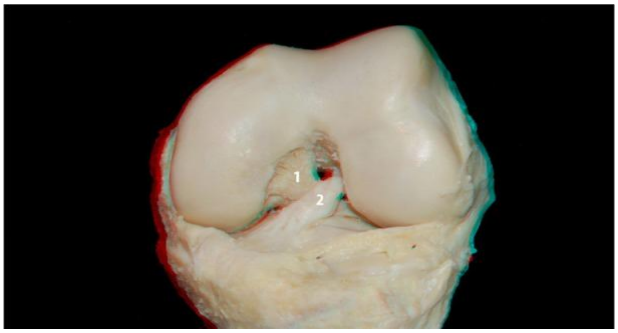


**Fig. (2)** PCL (1) and ACL (2) in knee flexion [11].

When the ACL is torn, the knee becomes unstable, leading to feelings of giving way, impaired joint function, and increased stress on other structures within the knee. ACL injuries often occur during sports activities that involve sudden deceleration, landing from a jump, or twisting motions. The injury can range from a partial tear to a complete rupture of the ligament [12].

ACL reconstruction surgery aims to restore knee stability by replacing the damaged or torn ACL with a graft. Grafts can be obtained from the patient's own body (autograft) or from a donor (allograft). The choice of graft depends on various factors, including the patient's age, activity level, and surgeon preference [13].

The role of grafts in ACL reconstruction is to serve as a biological scaffold that eventually transforms into a functional ligament. Grafts are positioned within the knee joint to replicate the anatomical location and function of the native ACL. The graft acts as a substitute ligament and gradually undergoes a healing process called ligamentization, where it integrates with the surrounding tissues and assumes the biomechanical properties of a normal ACL [14].

Restoring knee stability with a graft involves mimicking the biomechanics of the native ACL. The graft must be tensioned appropriately to provide stability in both anterior-posterior and rotational directions. It should also have sufficient strength and stiffness to withstand the forces encountered during activities like running, jumping, and cutting maneuvers [12].

The choice of graft type can influence the biomechanical properties of the reconstructed ACL. Hamstring tendon autografts and quadriceps tendon autografts, for example, are more pliable and exhibit greater elongation compared to bone-patellar tendon-bone autografts. This pliability allows for better adaptation to knee motion and may contribute to improved functional outcomes. However, it is important to strike a balance between graft pliability and stability to prevent overconstraint or laxity in the reconstructed knee [13].

Graft fixation is another critical aspect in ACL reconstruction. The graft must be securely fixed in place to allow healing and integration with the bone tunnels created during surgery. Various fixation methods, such as interference screws, suspensory devices, and cortical fixation, are utilized to ensure stable graft fixation. The choice of fixation method depends on factors such as graft type, surgeon preference, and patient-specific considerations [15].

## 2. Graft Options for ACL Reconstruction:

ACL reconstruction surgery involves the use of grafts to replace the torn or damaged anterior cruciate ligament (ACL) and restore knee stability. Various graft options are available, with the choice depending on factors such as patient characteristics, surgeon preference, and desired postoperative outcomes. The three commonly used graft options for ACL reconstruction are hamstring autografts, bone-patellar tendon-bone (BPTB) autografts, and quadriceps tendon autografts [16].

### A. Hamstring Autografts:

Hamstring autografts are harvested from the patient's own hamstring tendons, usually the semitendinosus and gracilis tendons. These tendons are located on the inner side of the thigh and are commonly used due to their availability and relative ease of harvest [17].

**Fig. (3)** Hamstring Tendon Autograft [16]

**Advantages:**

Hamstring autografts have shown excellent incorporation and healing potential within the knee joint. They provide sufficient strength and stability to the reconstructed ACL. Compared to BPTB autografts, hamstring autografts generally result in less anterior knee pain and kneeling discomfort. The smaller incisions required for harvesting hamstring tendons result in better cosmetic outcomes [18].

**Disadvantages:**

Hamstring autografts tend to have more initial graft elongation, which may result in increased laxity of the reconstructed ACL. Although less severe compared to BPTB autografts, hamstring autografts can still cause some donor site morbidity, such as hamstring weakness or muscle atrophy. The thickness of hamstring tendons can vary among individuals, which may affect graft strength and fixation options [19].

**B. Bone-Patellar Tendon-Bone (BPTB) Autografts:**

BPTB autografts involve the use of a strip of the patellar tendon, along with small bony plugs from the patella and tibia. The central third of the patellar tendon is commonly used as the graft [20].

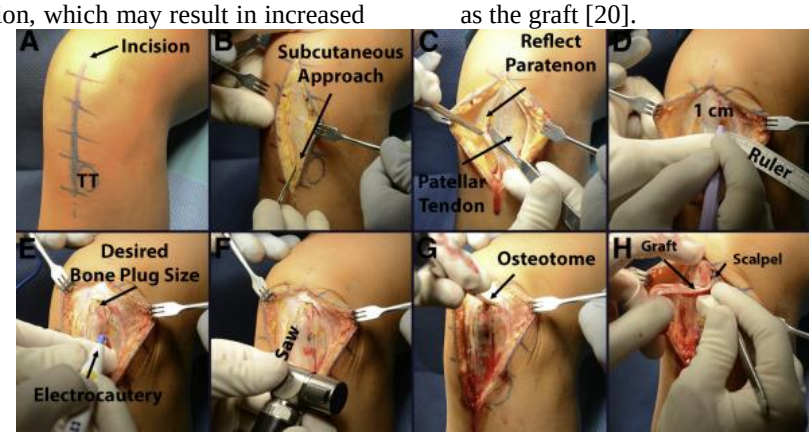


**Fig. (4)**Patellar tendon (bone-tendon-bone) harvest on the knee [21].

**Advantages:**

BPTB autografts offer high initial graft strength and stiffness, which allows for early stability and healing. The bone plugs at both ends of the graft have a good potential for healing and incorporation with the bone tunnels. The bony plugs provide secure fixation within the tunnels, reducing the risk of graft slippage [22].

**Disadvantages:**

One of the main drawbacks of BPTB autografts is a higher incidence of anterior knee pain compared to other graft options.

Some patients may experience patellofemoral problems, such as patellar tendonitis or patellofemoral arthritis, leading to long-term discomfort. BPTB autografts have been associated with a slightly reduced range of motion due to the removal of a portion of the patellar tendon [23].

**C. Quadriceps Tendon Autografts:**

Quadriceps tendon autografts have gained attention as an alternative graft option for ACL reconstruction. This graft is harvested from the central portion of the quadriceps tendon, located above the patella [24].

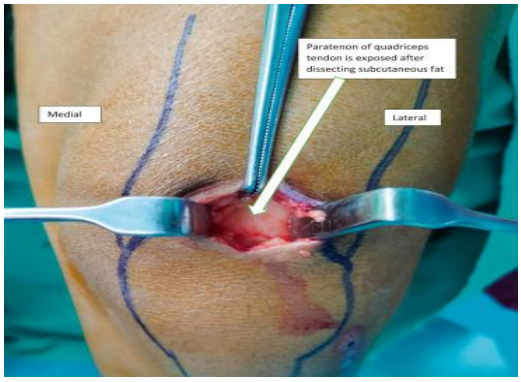


**Fig. (5)** Quadriceps Tendon Autografts [25].

**Advantages:**

Quadriceps tendon autografts have shown biomechanical properties similar to both hamstring and BPTB autografts, offering adequate strength and stability. Harvesting the quadriceps tendon involves a smaller incision and has shown decreased donor site morbidity compared to BPTB autografts. Quadriceps tendon autografts have been associated with lower graft failure rates compared to patellar tendon autografts. Studies have reported a lower incidence of anterior knee pain with quadriceps tendon autografts compared to BPTB autografts [26].

**Disadvantages:**

Quadriceps tendon autografts are generally thicker than hamstring autografts, which may affect graft placement and fixation options. The size and suitability of the quadriceps tendon as a graft may vary among individuals, limiting its availability in some cases [24].

**3. Minimally Invasive Quadriceps Tendon Autograft:**

Quadriceps tendon autografts have gained recognition as a viable graft option for ACL reconstruction. This graft utilizes the central portion of the quadriceps tendon, which is located above the patella and below the quadriceps muscle [26].

❖ **Anatomical Characteristics and Biomechanical Properties:**

The quadriceps tendon is a robust structure that consists of the combined tendons of the four quadriceps muscles: the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. It serves as the terminal insertion point for these muscles, extending from the superior border of the patella to the tibial tubercle [27].

Quadriceps tendon autografts offer several advantages in ACL reconstruction. They provide a graft option that is both anatomically and biomechanically comparable to hamstring autografts and bone-patellar tendon-bone (BPTB) autografts. The quadriceps tendon has similar strength and stiffness characteristics, making it a suitable substitute for the torn ACL [28].

❖ **Clinical Outcomes:**

Several studies have investigated the clinical outcomes of arthroscopic ACL reconstruction using quadriceps tendon autografts. These studies have shown promising results, suggesting that quadriceps tendon autografts can be an effective graft choice [29, 30].

❖ **Advantages and Potential Limitations:**

Quadriceps tendon autografts offer several advantages that make them an appealing option for ACL reconstruction:

Quadriceps tendon autografts exhibit biomechanical properties similar to hamstring autografts and BPTB autografts. They provide adequate strength and stability to restore knee function and prevent anterior tibial translation. Harvesting the quadriceps tendon for autograft eliminates the need for additional incisions and avoids the potential complications associated with other graft sites such as hamstring tendon or patellar tendon harvest. This can result in reduced donor site morbidity, including a lower risk of anterior knee pain and kneeling discomfort. Studies have demonstrated low graft failure rates with quadriceps tendon autografts, indicating the durability and long-term success of this graft option. Some studies suggest that quadriceps tendon autografts may

allow for accelerated rehabilitation protocols due to the strength and stability provided by the graft. This can contribute to earlier return to pre-injury activities and sports participation [31].

However, it is important to consider potential limitations associated with quadriceps tendon autografts: Quadriceps tendon autografts are generally thicker compared to hamstring autografts. This increased thickness may limit graft placement options and fixation techniques, potentially affecting surgical technique and postoperative stability. Harvesting a suitable quadriceps tendon autograft may not be feasible in all patients. The size and quality of the quadriceps tendon can vary among individuals, which may restrict its availability in certain cases [32].

**Table (1)** minimally invasive quadriceps tendon autografts for ACL reconstruction

| Aspect | |
|---|---|
| **Anatomical Characteristics** | - Central portion of the quadriceps tendon harvested<br>- Comprised of tendons from rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius<br>- Extends from superior border of the patella to tibial tubercle |
| **Biomechanical Properties** | - Similar biomechanical properties to hamstring and BPTB autografts<br>- Offers strength and stiffness necessary for knee stability |
| **Clinical Outcomes** | - High success rates in terms of stability and patient satisfaction<br>- Low graft failure rates compared to other graft types<br>- Positive patient-reported outcomes regarding knee stability, functional scores, and satisfaction |
| **Advantages** | - Comparable biomechanical properties to other grafts<br>- Reduced donor site morbidity (e.g., lower risk of anterior knee pain, kneeling discomfort)<br>- Lower failure rates<br>- Potential for faster rehabilitation protocols |
| **Potential Limitations** | - Graft thickness may limit placement and fixation options<br>- Limited availability in some cases due to variability in size and quality of the tendon |

**4. Hamstring Tendon Autograft:**

Hamstring tendon autografts are commonly used in arthroscopic ACL reconstruction. This graft option utilizes the tendons of the semitendinosus and gracilis muscles, which are located on the inner side of the thigh [33].

**Technique and Fixation Methods:**

The hamstring tendon autograft harvesting technique involves making a small incision on the inner side of the knee to expose the tendons of the semitendinosus and gracilis muscles. The tendons are carefully dissected and detached from their muscle origins while preserving their proximal insertion sites on the tibia. Following graft harvesting, the graft is prepared by removing excess soft tissue and sutured to provide adequate length and thickness [34].

The fixation of hamstring tendon autografts can be achieved using various methods. Commonly employed techniques include interference screw fixation, endobutton fixation, and suspensory fixation devices. Interference screws are inserted into the tibial and femoral tunnels to secure the graft in place. Endobutton fixation involves passing the graft through a femoral tunnel and fixing it with a button-shaped device on the lateral aspect of the femur. Suspensory fixation devices use a combination of screws and loops to secure the graft [35].

**Existing Literature and Outcomes:**

A substantial body of literature exists comparing the outcomes of arthroscopic ACL reconstruction using hamstring tendon autografts. Numerous studies have evaluated aspects such as success rates, graft failure rates, patient-reported outcomes, and potential complications associated with this graft option [36].

Overall, studies have reported high success rates for ACL reconstruction using hamstring tendon autografts. Success is typically defined by achieving knee stability, restoring function, and enabling patients to return to pre-injury activity levels. The literature suggests relatively low graft failure rates with hamstring tendon autografts. Long-term follow-up studies have shown graft survival rates ranging from 85% to 95%, indicating the durability of the graft in maintaining knee stability [37, 38].

Patient-reported outcomes following hamstring tendon autograft ACL reconstruction have been generally positive. Patients often report improvements in knee stability, functional scores, and satisfaction levels. Return to pre-

injury activity levels, including sports participation, has been reported in a high percentage of cases. While hamstring tendon autografts are generally well-tolerated, potential complications can arise. Anterior knee pain is one of the most common complications associated with this graft option. Other potential complications include graft site morbidity, such as weakness or muscle atrophy in the hamstring region, and postoperative strength deficits [39].

**Advantages and Potential Limitations:**

**Hamstring tendon autografts offer several advantages in ACL reconstruction:**

Good Graft Incorporation: Hamstring tendon autografts demonstrate excellent incorporation and healing potential within the knee joint, leading to stable and functional knee reconstruction [15].

The graft provides sufficient strength and stiffness to restore knee stability and withstand the forces encountered during physical activities. Compared to other graft options, such as BPTB autografts, hamstring tendon autografts typically result in lower donor site morbidity, including reduced anterior knee pain and kneeling discomfort [40].

However, it is important to consider potential limitations associated with hamstring tendon autografts: Hamstring tendon autografts may exhibit more initial graft elongation compared to other graft types. This elongation can potentially affect graft tension and lead to increased laxity of the reconstructed ACL. Although less severe compared to BPTB autografts, hamstring tendon autografts can still result in donor site morbidity, including hamstring weakness or muscle atrophy. The thickness of hamstring tendons can vary among individuals. Variability in graft thickness can influence graft placement and fixation options [15].

**Table (2)** hamstring tendon autografts for ACL reconstruction

| **Aspect** | |
|---|---|
| **Technique** | - Harvesting of tendons from semitendinosus and gracilis muscles<br>- Small incision on the inner side of the knee<br>- Graft preparation and sutured to provide adequate length and thickness |
| **Fixation Methods** | - Interference screw fixation<br>- Endobutton fixation<br>- Suspensory fixation devices |
| **Existing Literature and Outcomes** | - High success rates in terms of knee stability, function, and return to activity levels<br>- Relatively low graft failure rates<br>- Positive patient-reported outcomes regarding knee stability, functional scores, and satisfaction<br>- Potential complications: anterior knee pain, graft site morbidity, strength deficits |
| **Advantages** | - Good graft incorporation<br>- Adequate strength and stiffness<br>- Reduced donor site morbidity |
| **Potential Limitations** | - Graft elongation<br>- Harvest site morbidity<br>- Graft diameter variability |

**5. Comparing between both techniques:**

When comparing minimally invasive quadriceps tendon autografts and hamstring tendon autografts in arthroscopic ACL reconstruction, several factors should be considered [41].

**Clinical Outcomes:**

Both quadriceps tendon autografts and hamstring tendon autografts have shown excellent results in terms of achieving knee stability. Studies have reported high rates of graft incorporation, successful ligamentization, and restoration of normal joint mechanics for both graft types. Research has demonstrated positive functional outcomes for patients undergoing ACL reconstruction with both graft options. Patients often experience improvements in knee function, range of motion, and subjective functional scores. Return to pre-injury activity levels and sports participation rates have been reported to be high for both graft types [42].

Studies comparing quadriceps tendon autografts and hamstring tendon autografts have shown comparable rates of return to sport. Patients who undergo ACL reconstruction with either graft option can often resume their pre-injury athletic activities,

although the timeline for return may vary based on individual factors. Patient satisfaction rates are generally high for both quadriceps tendon autografts and hamstring tendon autografts. Patients report improved knee stability, reduced symptoms, and enhanced overall quality of life following ACL reconstruction with either graft type [42, 43].

**Potential Complications:**

Both quadriceps tendon autografts and hamstring tendon autografts can be associated with anterior knee pain as a potential complication. However, studies have reported a lower incidence of anterior knee pain with quadriceps tendon autografts compared to hamstring tendon autografts. Quadriceps strength deficits are more commonly observed in patients undergoing hamstring tendon autograft ACL reconstruction due to the harvesting of the tendons. In contrast, quadriceps tendon autografts preserve the quadriceps muscle, potentially leading to better preservation of quadriceps strength [15, 44].

The impact of graft choice on specific athletic activities may vary. Hamstring tendon autografts may result in reduced power of deep knee flexion, which could affect performance in sports requiring extensive knee flexion, such as gymnastics or martial arts. Quadriceps tendon autografts, on the other hand, may have advantages in activities that require quadriceps strength, such as jumping and explosive movements [45].

**Long-Term Outcomes:**

Both quadriceps tendon autografts and hamstring tendon autografts have shown good long-term graft survival rates. The majority of patients experience stable grafts with low rates of graft failure. The development of osteoarthritis following ACL reconstruction is a concern. Studies have suggested that the risk of osteoarthritis is similar between quadriceps tendon autografts and hamstring tendon autografts. The need for secondary surgeries, such as revision ACL reconstruction or meniscal procedures, can occur in both quadriceps tendon autograft and hamstring tendon autograft groups. However, the rates of secondary surgeries are generally low and comparable between the two graft types [46, 47].

## 6. Surgical Techniques and Considerations:

The surgical techniques and considerations for each graft type in ACL reconstruction play a crucial role in achieving successful outcomes [37].

**Minimally Invasive Quadriceps Tendon Autografts:**

Harvesting the quadriceps tendon autograft involves making a small incision above the patella to expose the central portion of the quadriceps tendon. Careful dissection is performed to detach the tendon from its muscle attachments while preserving its proximal insertion on the tibia. The harvested tendon is then prepared by removing excess soft tissue, ensuring appropriate graft length and thickness [48].

Once harvested, the quadriceps tendon autograft may undergo additional preparation steps. This can include trimming the graft to the desired length and thickness, removing any residual muscle or fat, and creating a rectangular shape for easier tunnel passage [49].

Quadriceps tendon autograft fixation can be achieved using various techniques. Commonly used methods include interference screw fixation, endobutton fixation, or suspensory fixation devices. Interference screws are inserted into the tibial and femoral tunnels to secure the graft, while endobutton fixation involves passing the graft through a femoral tunnel and fixing it with a button-shaped device on the lateral aspect of the femur. Suspensory fixation devices utilize a combination of screws and loops to secure the graft [48].

**Hamstring Tendon Autografts:**

Hamstring tendon autografts utilize the tendons of the semitendinosus and gracilis muscles, which are located on the inner side of the thigh. An incision is made to expose the tendons, and they are carefully dissected and detached from their muscle origins while preserving their proximal insertion on the tibia [33].

After harvesting, the hamstring tendon autograft is prepared by removing excess soft tissue and ensuring appropriate graft length. Some surgeons prefer to quadruple the graft by folding it over itself to increase its thickness and enhance graft strength [33].

The fixation techniques commonly used for hamstring tendon autografts include interference screw fixation, endobutton fixation, or suspensory fixation devices. Interference screws are inserted into the tibial and femoral tunnels to secure the graft, while endobutton fixation involves passing the graft through a femoral tunnel and fixing it with a button-shaped device. Suspensory fixation devices utilize screws and loops to achieve graft fixation [50].

**Importance of Proper Surgical Technique:**

Proper surgical technique is crucial for achieving successful outcomes with both graft types in ACL reconstruction. The following

considerations are important for ensuring optimal results: During graft harvesting, it is essential to handle the graft with care to minimize damage to the tendon fibers. This helps maintain the structural integrity and biomechanical properties of the graft [51].

Proper graft preparation involves removing excess soft tissue and ensuring appropriate graft length and thickness. Accurate graft sizing and preparation contribute to proper graft tensioning and secure fixation within the bone tunnels. Precise tunnel placement is critical for achieving proper graft positioning and stability. The tunnels should be accurately placed to replicate the native ACL insertion sites and optimize biomechanical restoration. The choice of fixation method and proper technique for graft fixation are essential for maintaining graft stability and preventing graft slippage or migration. The selected fixation method should provide secure fixation while allowing for adequate graft tensioning. Following surgery, adherence to a well-designed rehabilitation protocol is crucial for optimal recovery and successful outcomes. The rehabilitation program should include progressive strengthening exercises, range of motion exercises, and functional training tailored to each patient's specific needs [52].

Proper surgical technique, including meticulous graft handling, accurate tunnel placement, and secure graft fixation, contributes to graft stability, proper healing, and restoration of knee function. Surgeon expertise and experience in ACL reconstruction play a significant role in ensuring the successful implementation of these techniques [53].

## 7. Conclusions:

In conclusion, the comparative analysis of minimally invasive quadriceps tendon autografts and hamstring tendon autografts in arthroscopic ACL reconstruction reveals that both graft options can yield favorable clinical outcomes. Knee stability, functional outcomes, and return to sport rates are generally comparable between the two graft types. However, there are certain differences and considerations that should be taken into account when choosing the graft type for a specific patient.

Quadriceps tendon autografts offer advantages such as reduced donor site morbidity, lower rates of anterior knee pain, and potential preservation of quadriceps strength. They have shown comparable biomechanical properties to other graft options, high success rates, and low graft failure rates. On the other hand, hamstring tendon autografts have been widely used and have demonstrated good results in terms of knee stability and functional outcomes.

## References

[1] H. Yoo, R. Marappa-Ganeshan. Anatomy, Bony Pelvis and Lower Limb, Knee Anterior Cruciate Ligament. StatPearls [Internet]: StatPearls Publishing; 2021.

[2] A.J.H. Arundale, H.J. Silvers-Granelli, G. Myklebust. ACL injury prevention: Where have we come from and where are we going? J Orthop Res;40:43-54. 2022

[3] S. Ferrero, M. Louvois, T. Barnetche, V. Breuil, C. Roux. Impact of anterior cruciate ligament surgery on the development of knee osteoarthritis: A systematic literature review and meta-analysis comparing non-surgical and surgical treatments. Osteoarthr Cartil Open;5:100366. 2023

[4] S.R. Filbay, H. Grindem. Evidence-based recommendations for the management of anterior cruciate ligament (ACL) rupture. Best Pract Res Clin Rheumatol;33:33-47. 2019

[5] H. Naghibi, D. Janssen, T. Van Tienen, S. Van de Groes, T. Van de Boogaard, N. Verdonschot. A novel approach for optimal graft positioning and tensioning in anterior cruciate ligament reconstructive surgery based on the finite element modeling technique. Knee;27:384-96. 2020

[6] M. Widner, M. Dunleavy, S. Lynch. Outcomes Following ACL Reconstruction Based on Graft Type: Are all Grafts Equivalent? Curr Rev Musculoskelet Med;12:460-5. 2019

[7] P. Ajrawat, T. Dwyer, D. Whelan, J. Theodoropoulos, L. Murnaghan, M. Bhargava, et al. A Comparison of Quadriceps Tendon Autograft With Bone-Patellar Tendon-Bone Autograft and Hamstring Tendon Autograft for Primary Anterior Cruciate Ligament Reconstruction: A Systematic Review and Quantitative Synthesis. Clin J Sport Med;31:392-9. 2021

[8] R.J. Yaras, N. O'Neill, A.M. Yaish. Lateral collateral ligament knee injuries. 2020

[9] R. Hishimura, E. Kondo, Y. Suzuki, M. Matsuoka, K. Iwasaki, T. Onodera, et al. Occurrence Rate of Cyclops Lesion After Anatomic Double-Bundle ACL Reconstruction: Comparison Between Remnant Tissue Preservation and Resection Methods.

Orthop J Sports Med;10:23259671221130688. 2022
[10] R. Ueno, A. Navacchia, N.D. Schilaty, G.D. Myer, T.E. Hewett, N.A. Bates. Anterior Cruciate Ligament Loading Increases With Pivot-Shift Mechanism During Asymmetrical Drop Vertical Jump in Female Athletes. Orthop J Sports Med;9:2325967121989095. 2021
[11] G.G. Arliani, D.C. Astur, E.R. Moraes, C.C. Kaleka, W. Jalikjian, P. Golano, et al. Three dimensional anatomy of the anterior cruciate ligament: a new approach in anatomical orthopedic studies and a literature review. Open Access J Sports Med;3:183-8. 2012
[12] C. Domnick, M.J. Raschke, M. Herbort. Biomechanics of the anterior cruciate ligament: Physiology, rupture and reconstruction techniques. World J Orthop;7:82-93. 2016
[13] R.G. Marx, J. Hsu, C. Fink, K. Eriksson, A. Vincent, W.M. van der Merwe. Graft choices for paediatric anterior cruciate ligament reconstruction: State of the art. J isakos;8:145-52. 2023
[14] M. Marieswaran, I. Jain, B. Garg, V. Sharma, D. Kalyanasundaram. A Review on Biomechanics of Anterior Cruciate Ligament and Materials for Reconstruction. Appl Bionics Biomech;2018:4657824. 2018
[15] A. Runer, L. Keeling, N. Wagala, H. Nugraha, E.A. Özbek, J.D. Hughes, et al. Current trends in graft choice for anterior cruciate ligament reconstruction - part I: anatomy, biomechanics, graft incorporation and fixation. J Exp Orthop;10:37. 2023
[16] M.H. Gerami, F. Haghi, F. Pelarak, S.R. Mousavibaygei. Anterior cruciate ligament (ACL) injuries: A review on the newest reconstruction techniques. Journal of Family Medicine and Primary Care;11:852. 2022
[17] . A. Soni, R.K. Gupta, M. Raghav, G.D. Masih, P. Bansal. Comparison of Bone-Patellar Tendon-Bone Graft, Semitendinosus-Gracilis Graft and Semitendinosus-Gracilis with Preserved Tibial Insertion Graft in Anterior Cruciate Ligament Reconstruction in Sports Persons. Malays Orthop J;15:12-7. 2021
[18] O. Pujji, N. Keswani, N. Collier, M. Black, L. Doos. Evaluating the Functional Results and Complications of Autograft vs Allograft Use for Reconstruction of the Anterior Cruciate Ligament: A Systematic Review. Orthop Rev (Pavia);9:6833. 2017
[19] R. Cristiani, V. Sarakatsianos, B. Engström, K. Samuelsson, M. Forssblad, A. Stålman. Increased knee laxity with hamstring tendon autograft compared to patellar tendon autograft: a cohort study of 5462 patients with primary anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc;27:381-8. 2019
[20] R.M. Frank, J. Higgins, E. Bernardoni, G. Cvetanovich, C.A. Bush-Joseph, N.N. Verma, et al. Anterior Cruciate Ligament Reconstruction Basics: Bone-Patellar Tendon-Bone Autograft Harvest. Arthrosc Tech;6:e1189-e94. 2017
[21] J. Chahla, G. Moatshe, M.E. Cinque, J. Godin, S. Mannava, R.F. LaPrade. Arthroscopic Anatomic Single-Bundle Anterior Cruciate Ligament Reconstruction Using Bone-Patellar Tendon-Bone Autograft: Pearls for an Accurate Reconstruction. Arthrosc Tech;6:e1159-e67. 2017
[22] A.M.N. Zein, M. Ali, A. Zenhom Mahmoud, K. Omran. Autogenous Hamstring-Bone Graft Preparation for Anterior Cruciate Ligament Reconstruction. Arthrosc Tech;6:e1253-e62. 2017
[23] F.D.S. Marques, P.H.B. Barbosa, P.R. Alves, S. Zelada, R. Nunes, M.R. de Souza, et al. Anterior Knee Pain After Anterior Cruciate Ligament Reconstruction. Orthop J Sports Med;8:2325967120961082. 2020
[24] D. Cohen, D. Slawaska-Eng, M. Almasri, A. Sheean, D. de Sa. Quadricep ACL Reconstruction Techniques and Outcomes: an Updated Scoping Review of the Quadricep Tendon. Curr Rev Musculoskelet Med;14:462-74. 2021
[25] R. Raman, B.N. Mishra, A. Sen. A Minimally Invasive and Simple Technique of Superficial Quadriceps Tendon Graft Harvesting. Arthrosc Tech;11:e2347-e55. 2022
[26] H. Horstmann, M. Petri, U. Tegtbur, G. Felmet, C. Krettek, M. Jagodzinski. Quadriceps and hamstring tendon autografts in ACL reconstruction yield comparably good results in a prospective, randomized

controlled trial. Arch Orthop Trauma Surg;142:281-9. 2022

[27] K. Grob, M. Manestar, L. Filgueira, T. Ackland, H. Gilbey, M.S. Kuster. New insight in the architecture of the quadriceps tendon. J Exp Orthop;3:32. 2016

[28] A. Barié, T. Sprinckstub, J. Huber, A. Jaber. Quadriceps tendon vs. patellar tendon autograft for ACL reconstruction using a hardware-free press-fit fixation technique: comparable stability, function and return-to-sport level but less donor site morbidity in athletes after 10 years. Arch Orthop Trauma Surg;140:1465-74. 2020

[29] R.J. Crum, J. Kay, B.P. Lesniak, A. Getgood, V. Musahl, D. de Sa. Bone Versus All Soft Tissue Quadriceps Tendon Autografts for Anterior Cruciate Ligament Reconstruction: A Systematic Review. Arthroscopy;37:1040-52. 2021

[30] A. Meena, S. Di Paolo, A. Grassi, A. Raj, L. Farinelli, C. Hoser, et al. No difference in patient reported outcomes, laxity, and failure rate after revision ACL reconstruction with quadriceps tendon compared to hamstring tendon graft: a systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2023

[31] W. Dai, X. Leng, J. Wang, J. Cheng, X. Hu, Y. Ao. Quadriceps Tendon Autograft Versus Bone-Patellar Tendon-Bone and Hamstring Tendon Autografts for Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis. Am J Sports Med;50:3425-39. 2022

[32] P. Johnson, S.M. Mitchell, S. Görtz. Graft Considerations in Posterior Cruciate Ligament Reconstruction. Curr Rev Musculoskelet Med;11:521-7. 2018

[33] W. Albishi, B. Baltow, N. Albusayes, A.A. Sayed, H.M. Alrabai. Hamstring autograft utilization in reconstructing anterior cruciate ligament: Review of harvesting techniques, graft preparation, and different fixation methods. World J Orthop;13:876-90. 2022

[34] W.L. Yeh, J.M. Chen, C.H. Liu, P.J. Tsai, R. Higashiyama, M. Takaso. Endoscopic Harvest of Autogenous Gracilis and Semitendinosus Tendons. Arthrosc Tech;7:e1019-e24. 2018

[35] 35. B. Solie, J. Monson, C. Larson. Graft-Specific Surgical and Rehabilitation Considerations for Anterior Cruciate Ligament Reconstruction with the Quadriceps Tendon Autograft. Int J Sports Phys Ther;18:493-512. 2023

[36] 36. J.R. Ebert, P.T. Annear. ACL Reconstruction Using Autologous Hamstrings Augmented With the Ligament Augmentation and Reconstruction System Provides Good Clinical Scores, High Levels of Satisfaction and Return to Sport, and a Low Retear Rate at 2 Years. Orthop J Sports Med;7:2325967119879079. 2019

[37] 37. K. Sim, R. Rahardja, M. Zhu, S.W. Young. Optimal Graft Choice in Athletic Patients with Anterior Cruciate Ligament Injuries: Review and Clinical Insights. Open Access J Sports Med;13:55-67. 2022

[38] 38. J.D. Kosy, J.R.P. Phillips, A. Edordu, R. Pankhania, P.J. Schranz, V. Mandalia. Failure to Return to Preinjury Activity Level after Hamstring Anterior Cruciate Ligament Reconstruction: Factors Involved and Considerations in Goal Setting. Indian J Orthop;53:714-20. 2019

[39] 39. P.H. Randsborg, N. Cepeda, D. Adamec, S.A. Rodeo, A. Ranawat, A.D. Pearle. Patient-Reported Outcome, Return to Sport, and Revision Rates 7-9 Years After Anterior Cruciate Ligament Reconstruction: Results From a Cohort of 2042 Patients. Am J Sports Med;50:423-32. 2022

[40] 40. C. Arida, C.G. Tsikrikas, D.S. Mastrokalos, A. Panagopoulos, J. Vlamis, I.K. Triantafyllopoulos. Comparison of Bone-Patella Tendon-Bone and Four-Strand Hamstring Tendon Grafts for Anterior Cruciate Ligament Reconstruction: A Prospective Study. Cureus;13:e19197. 2021

[41] J. Schagemann, T. Koebrich, R. Wendlandt, A.P. Schulz, J. Gille, R. Oheim. Comparison of hamstring and quadriceps tendon autografts in anterior cruciate ligament reconstruction with gait analysis and surface electromyography. J Orthop Traumatol;22:20. 2021

[42] R.P.A. Janssen, N. van Melick, J.B.A. van Mourik, M. Reijman, L.W. van

Rhijn. ACL reconstruction with hamstring tendon autograft and accelerated brace-free rehabilitation: a systematic review of clinical outcomes. BMJ Open Sport Exerc Med;4:e000301. 2018

[43] D. Mouarbes, J. Menetrey, V. Marot, L. Courtot, E. Berard, E. Cavaignac. Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis of Outcomes for Quadriceps Tendon Autograft Versus Bone-Patellar Tendon-Bone and Hamstring-Tendon Autografts. Am J Sports Med;47:3531-40. 2019

[44]. A. Meena, R. D'Ambrosi, A. Runer, A. Raj, M. Attri, E. Abermann, et al. Quadriceps tendon autograft with or without bone block have comparable clinical outcomes, complications and revision rate for ACL reconstruction: a systematic review. Knee Surg Sports Traumatol Arthrosc;31:2274-88. 2023

[45] R. Cristiani, C. Mikkelsen, P. Wange, D. Olsson, A. Stålman, B. Engström. Autograft type affects muscle strength and hop performance after ACL reconstruction. A randomised controlled trial comparing patellar tendon and hamstring tendon autografts with standard or accelerated rehabilitation. Knee Surg Sports Traumatol Arthrosc;29:3025-36. 2021

[46] L. Eggeling, S. Breer, T.C. Drenck, K.H. Frosch, R. Akoto. Double-Layered Quadriceps Tendon Autografts Provide Lower Failure Rates and Improved Clinical Results Compared With Hamstring Tendon Grafts in Revision ACL Reconstruction. Orthop J Sports Med;9:23259671211046929. 2021

[47] R.A. Buerba, S.A. Boden, B. Lesniak. Graft selection in contemporary anterior cruciate ligament reconstruction. JAAOS Global Research & Reviews;5. 2021

[48] K. Malinowski, J. Paszkowski, M. Mostowy, A. Góralczyk, R.F. LaPrade, K. Hermanowicz. Quadriceps Tendon-Bone Full-Thickness Autograft: Reproducible and Easy Harvesting Technique Using Simple Surgical Tools. Arthrosc Tech;10:e1165-e72. 2021

[49] H.S. Slone, W.B. Ashford, J.W. Xerogeanes. Minimally Invasive Quadriceps Tendon Harvest and Graft Preparation for All-Inside Anterior Cruciate Ligament Reconstruction. Arthrosc Tech;5:e1049-e56. 2016

[50] S. Taketomi, H. Inui, K. Nakamura, R. Yamagami, K. Tahara, T. Sanada, et al. Secure fixation of femoral bone plug with a suspensory button in anatomical anterior cruciate ligament reconstruction with bone-patellar tendon-bone graft. Joints;3:102-8. 2015

[51] J. Wilde, A. Bedi, D.W. Altchek. Revision anterior cruciate ligament reconstruction. Sports Health;6:504-18. 2014

[52]. B. Fritsch, F. Figueroa, B. Semay. Graft Preparation Technique to Optimize Hamstring Graft Diameter for Anterior Cruciate Ligament Reconstruction. Arthrosc Tech;6:e2169-e75. 2017

[53] R. Vaishya, A.K. Agarwal, S. Ingole, V. Vijay. Current Trends in Anterior Cruciate Ligament Reconstruction: A Review. Cureus;7:e378. 2015