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Quadriceps Tendon Graft for ACL Reconstruction - How Does it Compare? - A Literature Review with a Case Example

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Quadriceps Tendon Graft for ACL Reconstruction – How Does it Compare? – A Literature Review with a Case Example

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Abstract

Introduction: Anterior Cruciate Ligament (ACL) injuries are one of the most common injuries encountered today. ACL reconstruction surgeries are an extremely popular treatment used to help return patients to their activities post ACL tear. There are several different graft options, with patellar tendon grafts and hamstring tendon grafts being the two most popular. However, quadriceps tendon grafts are becoming more popular. Thus the purpose of this literature review and case report is to provide information for therapists not fully familiar with this approach. In this literature review with a case example, quadriceps tendon grafts will be compared with patellar tendon grafts and hamstring tendon grafts for ACL reconstruction. **Surgical Intervention:** Background on the surgical intervention of patellar tendon, hamstring tendon, and quadriceps tendon graft harvest and placement discussed and compared. **Evidence Based Comparison:** Literature review and comparison of viability and outcomes of each graft type discussed. Main comparisons made considering tissue strength, donor site morbidity, stability and range of motion, functional outcomes, graft re-rupture rates, and patient satisfaction. **Case Description:** The initial post-operative rehabilitation of a 21 year-old male following an ACL reconstruction surgery with a quadriceps tendon autograft and lateral extra articular tenodesis is described. **Discussion:** Quadriceps tendon graft for ACL reconstruction is a safe and viable option that provides stability, quick healing time, and decreased pain based on the literature. Outcome scores of the patient population with this procedure are comparable or favorable to those of patellar tendon and hamstring tendon graft surgeries, supporting the current evidence. This is an up and coming technique that may be used more frequently in the future.

Keywords: Anterior cruciate ligament; knee; reconstruction; sports medicine; orthopedics; physical therapy; rehabilitation

Introduction

Anterior cruciate ligament (ACL) injuries are one of the most common injuries encountered today. From competitive athletes, to leisure athletes, to everyday individuals, there are an estimated 100,000 to 200,000 ACL ruptures per year in the United States (Mall, 2014). Physical therapy clinics are flooded with these patients for non-surgical, and post-operative surgical management. The individual's activity level plays a key part in deciding how to manage an ACL injury. Non-operative management is a possible choice among the non-athletic population who may not be placing high demand on their knee. For the athletic and leisure-athlete population, surgical management is often a very favorable choice.

ACL injuries frequently occur in a non-contact manner. Variables such as quadriceps muscle dominant movement patterns, dynamic knee valgus, muscular imbalances, and gender all play a role in the prevalence of these injuries. This means that not only high impact sports such as football and rugby have players at risk, but rather any individual who runs, jumps, cuts, or walks on an inconsistent surface and puts variable stresses through their knee are also at risk. This could be your elite basketball and soccer players, your city league softball and volleyball players, a runner training for a 5K, or even casual golfers walking down a hill. When this population gets injured, they must ask themselves if they would like to return to their respective activities. If that answer is yes, surgical reconstruction of an ACL tear is the typical choice.

There are up to an estimated 100,000 ACL reconstruction surgeries performed per year (Csintalan, 2008). ACL surgeries first became popular in the early 1970's. Since that time, several techniques have been used, most of which have involved either the patellar tendon or hamstring tendons harvested as the graft. Using the quadriceps tendon graft is becoming more popular in recent years, though it is still used very sparingly compared to patellar and hamstring tendons. While ACL reconstruction surgeries are overall very successful, re-injury rates (especially in the athletic population) are higher than desirable. Surgeons and researchers are still looking to find the best graft and technique to use in order to have the most positive outcome for their patients. The purpose of this literature review with a case example is to compare the up-and-coming technique of using a quadriceps tendon autograft for ACL reconstruction to techniques using patellar and hamstring tendons.

Surgical Intervention

As mentioned above, there are three main types of grafts used for ACL reconstruction: patellar tendon graft, hamstring tendon graft, and quadriceps tendon graft. Those three are all autografts, meaning the tissue is taken from the existing patient for the graft. Allografts are another option that have been used. An allograft is a graft where the tissue is taken from a cadaver rather than the existing patient. Allografts are used less often, as they have been shown to result in higher rates of abnormal stability (Jost, 2011). All grafts discussed in this paper are autografts. In this section I will briefly overview each surgical technique, as well as discuss pros and cons for each of these graft choices.

Patellar Tendon: Patellar tendon autograft are a very popular choice of surgeons, and have been since the ACL reconstruction surgery became popular. The most widely used technique for the patellar tendon autograft is called the bone-patellar tendon-bone harvest. With this technique, the surgeon harvests a bone plug from the distal central patella, takes 1/3rd the width of the patellar tendon down to the tibial tubercle, and then harvests a bone plug from the tibial tubercle. This technique has been very popular as it is an easy procedure to complete for the surgeon, surgeons are able to take a consistent graft from surgery to surgery, and it has been shown to have great strength (Rabuck, 2013). Bone plugs taken on each end of the graft allow for strong fixation strength with screws when the graft is placed, as well as allowing bone to bone healing which presents as a faster and more stable option early in the rehabilitation process compared to tendon to bone fixations (Lui, 2010).

Though patellar tendons are the most widely used graft, there are well documented issues associated with this surgery. Donor site morbidity is one issue that has been consistently documented at higher rates from a patellar tendon harvest compared to other options (Hurley, 2018). There is a higher incidence of anterior knee pain, numbness, and kneeling pain in these patients. It has also been

suggested that harvesting a graft from this area puts patients at an increased risk for developing patellar tendinopathy, as well as possible patellar fracture from where the bone plug is taken (Stein, 2002). Nevertheless, the bone-patellar tendon-bone graft remains the most popular choice. One reason hypothesized may be with surgeon preference, and more tenured surgeons teaching surgical students the techniques they are comfortable with. This in turn leads to more young surgeons performing patellar tendon grafts as it is the surgery they are comfortable with and what they learned during their residencies and fellowships.

Hamstring Tendon: The hamstring tendon autograft harvest is also one of the most popular surgical techniques used for ACL reconstruction. With this technique, portions of the semitendinosis and gracilis tendons proximal to their tibial insertions are taken. These tendons are tied and bundled together to give the graft thickness and support. With this technique there is no bone harvested, and the graft is held in place with screws between tendon and bone. As discussed above, bone to bone healing is preferred with faster healing times and a more stable option, so the tendon to bone healing is one issue this surgical technique presents. It has also been suggested that hamstring tendon autografts may have a higher re-rupture rate compared to other graft options (Biaud, 2009).

Hamstring tendon autografts do present some favorable outcomes, one being far less anterior knee pain compared to other options (Brown, 1993). With the graft being taken out of the hamstrings, the patella and patellar tendon are left untouched. The extensor mechanism of the knee is unharmed, allowing for much easier and less painful knee extension post operatively. It has also been reported that hamstring tendons have the highest stiffness compared to patellar tendon or quadriceps tendon grafts (Rabuck, 2013). This increased stiffness may allow for the tissue to withstand higher loads without stretching out or failing.

Quadriceps Tendon: As mentioned above, the quadriceps tendon autograft is becoming more popular as an autograft option for ACL reconstructions (Kawk, 2018). For the quadriceps tendon harvest, a portion of the proximal patella is taken for a bone plug. The surgeons then harvest the central portion of the quadriceps tendon, including overlying portions of the rectus femoris, vastus medialis, vastus lateralis, and vastus intermedius. This produces a thick, strong graft with a bony plug on one end to fixate when the graft is placed. This allows for bone-to-bone healing and fixation at one end, as well as leaving the patellar tendon untouched to avoid common donor site morbidity issues associated with bone-patellar tendon-bone grafts. The quadriceps tendon graft technique is becoming more popular, and it's outcomes are increasingly being studied. The remainder of this paper will compare and contrast this surgical option with the ones above in terms of outcomes and rehabilitation implications, as well as discuss a case example of a patient who had this procedure completed.

Evidence Based Comparison

There are several factors that surgeons are hoping to achieve with their grafts when they perform an ACL reconstruction. These factors include tissue strength, low levels of donor site morbidity, low likelihood of re-rupture, etc. Within the literature, there are several studies comparing patellar tendon graft variables and outcomes with hamstring tendon grafts. With quadriceps tendon grafts on the rise, more studies have begun to be published comparing all three graft options. In this section, an in depth look at how quadriceps tendon autograft tissue properties and outcomes compare in the literature to patellar tendon grafts and hamstring tendon grafts is taken.

Tissue Strength: When it comes to tissue strength, it is necessary for the graft tissue to be equal to or exceed the strength of a native ACL. Tissue strength can be defined in a few ways, and in the literature it is common to assess the tensile load a tissue can withstand (N), as well as the stiffness of the tissue (N/mm). Rabuck et. al compared these properties in their paper (**Table 1**). The quadriceps tendon graft was found to have higher rates of stiffness and was able to withstand a higher tensile load compared to a native ACL, though hamstring and patellar tendons were found to withstand tensile loads and stiffness even higher still. With these three grafts having higher rates of stiffness, this may provide an advantage of withstanding and dispersing loads that are placed on the tissue. The ACL is a dynamic ligament that has stresses placed through it in several different planes of movement, and with

several different motions performed by athletes. One possible hypothesis would be the higher stiffness indicates the graft is able to withstand these forces throughout the course of the graft, and avoid too much stress being placed on any one area of the graft which could lead to rupture. The quadriceps tendon was found to have the largest cross-sectional area when compared to the two graft types and the native ACL, which may be beneficial. The larger cross-sectional area gives the surgeons more options when they are fixating the graft in to place. They are able to use techniques which allow them a firm hold when fixating tendon to bone on one end of the graft. Overall, the tissue strength of the quadriceps tendon autograft suggests it should be an adequate replacement of the native ACL, despite it being weaker than patellar or hamstring grafts.

Table 1: Tensile load, stiffness, and cross-sectional area across graft types vs native ACL.

Graft	Tensile Load (N)	Stiffness (N/mm)	Cross-Sectional Area (mm ²)
Quadriceps Tendon	2352	463	62
Patellar Tendon	2977	620	35
Hamstring Tendon	4090	776	53
Native ACL	2160	242	44

Note: recreated using data reported by Rabuck et al (2013).

Donor Site Morbidity: Donor site morbidity refers to complications and functional restrictions that a patient goes through following a graft harvest. These are things such as anterior knee pain, weakness of extensor or flexor mechanism, and patellar fracture. Donor site morbidity is the biggest downfall of patellar tendon grafts. It is well known and documented in the literature that patellar tendon grafts are associated with higher rates of anterior knee pain, crepitus, loss of extension, and quadriceps weakness (Mulford, 2013). Kneeling pain is another common issue with patellar tendon reconstructions, and this can present as a large issue depending on the patients' professions or hobbies. Incidence of anterior knee pain, weakness, and patellar fracture are represented in **Table 2**.

Donor site morbidity is impossible to avoid entirely when it comes to a major surgery such as this. Quadriceps tendon and hamstring tendon grafts both have associated morbidities as well. Anterior knee pain, patellar fracture, and extensor weakness have been noted in quadriceps tendon grafts, while the main donor site issue with hamstring grafts is knee flexion weakness, though anterior knee pain has been noted in this population as well. One review (Slone, 2015) discussed five studies that compared donor site morbidity between quadriceps tendon and patellar tendon autografts, with all five reporting a lesser incidence of morbidity in the quadriceps tendon group. One issue to consider with quadriceps tendon grafts is the area of the scar.

Table 2: Incidence of anterior knee pain, weakness, and patellar fracture across graft types.

Graft	Anterior Knee Pain (%)	Weakness† (% Loss)	Patellar Fracture (%)
Quadriceps Tendon	5	11	1.2
Patellar Tendon	17-26	10-18	0.2-1.8
Hamstring Tendon	11	10	Not applicable

Note: recreated using data reported by Rabuck et al (2013).

† extensor weakness for quadriceps and patellar tendon grafts, flexor weakness for hamstring graft.

With a quadriceps tendon graft, the incision and graft are taken proximal to the patella, with hamstring grafts the incision is posterior to the knee, and with a patellar tendon graft, the incision and graft are distal to the patella. With the proximal scar of the quadriceps tendon graft, it is much more visible to the patient when they are in a seated position compared to the scar from a patellar tendon or

hamstring graft. Though cosmetic in nature with no functional deficits, the area of a scar may play a role in the psychological recovery from a knee injury for some patients.

Stability and Range of Motion: Knee stability is one of the most important outcomes for ACL reconstruction surgeries. A stable graft and a stable knee are important for avoiding asymmetrical movement patterns and possible re-injury. Knee stability is evaluated objectively with The Lachman's test, pivot shift test, and KT-1000 (knee ligament quantification device) scores in the literature.

In one review (Hurley, 2018) comparing the Lachman's, pivot shift, and KT-1000 testing across several studies between quadriceps tendon graft reconstructions and patellar or hamstring tendon graft reconstructions, most found equal or better laxity assessments for quadriceps tendon grafts. When compared to patellar tendon reconstructions with Lachman's testing, there was no significant difference across studies. When compared with pivot shift testing, there was no significant difference in all studies but one, and in that study Lund et. al. found positive pivot shift testing significantly less in quadriceps tendon grafts compared to patellar tendon (14% to 38%). KT-1000 testing results were similar, with no significant difference found in all but one study, which was in favor of quadriceps tendon. When compared to hamstring tendon, results were very similar. All but one study found no significant difference in Lachman's and pivot shift testing, with the outlier finding incidence of positive Lachman's to be less with quadriceps grafts. With KT-1000 testing compared to hamstring grafts, the majority of studies found no significant difference, with two outlier studies, one in favor of quadriceps tendon and the other in favor of hamstring. Overall, when looked at objectively in the literature, it appears that quadriceps tendon grafts provide knee stability at similar rates, if not improved rates, when compared to patellar tendon and hamstring tendon grafts.

Functional Outcomes: Functional outcomes are another category of extremely important measures to be considered when comparing graft types. The review completed by Slone et. al. analyzed several studies that compared functional outcomes, focusing on International Knee Documentation Committee (IKDC) scores, Lysholm scores, and isokinetic strength testing. The results they found are summarized in **Table 3** below.

IKDC scores are a subjective measure which are scored by asking patients to rate their function in three different sections: symptoms, sports activity, and knee function. At the end of the test based on results, knees are classified as normal, nearly normal, abnormal, or severely abnormal. The large majority of studies found no significant difference between quadriceps tendon grafts and patellar/hamstring tendon grafts, with most patients falling into normal and nearly normal categories for all the grafts.

The Lysholm score is a functional outcome that takes ratings on pain, instability, locking, swelling, stair climbing, limp, squatting, and need for support. These scores are then added and a final resulting score of 0-100 is given, with 100 being a completely functional knee that has no issues. Slone and colleagues found no significant differences between graft types in Lysholm scores, with the large majority reporting scores in the high 80's and low 90's. This is very similar to what has been seen in patellar and hamstring grafts.

Isokinetic strength testing is a way to test quadriceps strength comparing the operative leg and the contralateral side, using devices such as a Cybex or Biodex machine. Regaining close to symmetrical quadriceps strength is an important objective for physical therapists to work towards, and thus strength testing is an important outcome to be considered. Four studies Slone and colleagues reviewed looked at isokinetic testing with strength scores from 84.7% to 94.7% of the contralateral side. Further, one of the four studies compared these scores from quadriceps tendon grafts to patellar tendon grafts and found no significant difference. In conclusion, it appears upon review that quadriceps tendon grafts present very similarly to patellar tendon and hamstring tendon grafts when considering functional outcomes. It should be noted that these scores varied across studies with being reported at 12 - 48+ month follow up, with 24 - 48+ follow up reporting scores more favorable in terms of positive outcomes.

Table 3: Previously reported outcomes following ACL reconstruction, based on IKDC scores and classifications, Lysholm scores, and Isokinetic knee extension strength testing.

Graft	International Knee Documentation Committee (IKDC)					Lysholm	Knee Extension Strength
	Mean Score	Normal	Nearly Normal	Abnormal	Severely Abnormal	Mean Score	Isokinetic testing
QT	86.1	53.3%	43.3%	3.3%	0%	-	-
QT	-	79%	12%	6%	3%	93.0	91.7% of contralateral side
QT	-	11%	72%	17%	0%	94.0	-
PT	-	66%	31%	3%	0%	95.0	-
QT	-	23%	60%	14%	3%	89.0	-
QT	-	11%	72%	17%	0%	94.0	-
QT	-	-	-	-	-	70.7	No group differences
PT	-	-	-	-	-	71.2	No group differences
QT	87.0	38%	44%	15%	3%	88.1	-
PT	87.9	43%	41%	14%	2%	89.1	-
QT	87.3	45%	37%	15%	3%	88.2	-
Allograft	85.1	36%	41%	17%	6%	86.2	-
QT	-	-	-	-	-	91.1	-
PT	-	-	-	-	-	89.4	-
QT	-	38%	48%	14%	0%	90.1	-
PT	-	37%	47%	15%	0%	92.4	-
QT	-	39.3%	46.4%	14.3%	0%	91.8	-
QT	-	48.4%	41.9%	9.7%	0%	94.5	-
QT	-	0%	87%	13%	0%	94.0	-
QT	-	88%	-	-	-	90	85.1% (60°/s) and 91.2% (180°/s) of contralateral side
QT	-	-	-	-	-	93.0	84.7% of contralateral side
QT	84-	-	-	-	-	-	-
PT	70	-	-	-	-	-	-
QT	-	23.6%	41.8%	30.9%	3.6%	89.0	-

Note: recreated using data from the review by Slone et. al. (2015). QT = quadriceps tendon graft group, PT = patellar tendon graft group. Number of participants in each group varied by study.

Graft Re-Rupture Rate: Graft re-rupture is another outcome of interest when considering ACL reconstruction grafts. Many of the athletic population who elect to undergo an ACL reconstruction do so because they wish to return to their respective sport. Using a strong graft that is able to withstand functional loads placed on the knee following surgery may be the most important outcome of all. How many patients would elect to undergo surgery and therapy if they thought there was a high chance of the surgery failing on them? Of course, there will always be the possibility of re-injury happening, but the goal is to use a graft with the least chance possible of having a rupture. The review completed by Hurley and colleagues examined 8 studies looking at graft re-rupture using quadriceps tendon; four compared to patellar tendon outcomes and four compared to hamstring tendon outcomes. No significant differences were found between groups in any of these studies. The rate of re-rupture for quad tendon grafts ranged from 0 to 2.8%, whereas it ranged from 1.4 to 5.5% for patellar tendon grafts and 0 to 4.9% for hamstring grafts. The results are summarized in **Table 4**.

Table 4: Graft rupture rates (%) previously reported for quadriceps, patellar, and hamstring tendon grafts.

Study	Quadriceps tendon	Patellar tendon	Hamstring tendon
Gieb et. al., 2009	2.0%	3.3%	-
Gorschewsky et. al., 2007	1.6%	2.2%	-
Han et. al., 2008	2.8%	1.4%	-
Lund et. al., 2014	0%	5.5%	-
Cavaignac et. al., 2017	2.2%	-	4.9%
Haner et. al., 2016	0%	-	0%
Hart et. al., 2010	0%	-	0%
Runer et. al., 2017	0%	-	2.5%

Note: table recreated using data from a review by Hurley et. al. (2018).

Patient Satisfaction: The last outcome I will be discussing is patient satisfaction. At the end of the day, patient satisfaction is one of the most meaningful outcomes in any facet of healthcare. Patients come to medical professionals when they have a problem, and they are hoping for that problem to be resolved. In the case of an ACL reconstruction, whether or not a patient is pleased with their knee and with their outcome should be at the forefront of the decisions made regarding their surgery and recovery. Slone et. al. compared four studies within their review that evaluated patient satisfaction, grading satisfaction as very good, good, satisfactory, or poor. One study (Gorschewsky, 2007) found patients with a patellar tendon graft to be significantly more satisfied with their knee than those with a quadriceps tendon. The other three studies found no statistically significant difference between groups. Overall, the large majority of patients rated their knee satisfaction as very good or good, regardless of the graft type they received.

Case Description

The following case is a 21 year-old male patient who had a quadriceps tendon autograft ACL reconstruction with lateral extra articular tenodesis (LEAT) surgery. His surgery was a revision ACL for a re-ruptured ACL reconstruction previously using patellar tendon graft in the ipsilateral knee which took place 4 years prior. The LEAT procedure was done in his revision surgery by taking a strip of the posterior third of the patient’s iliotibial band, moving it deep to the lateral collateral ligament, and fastening it down to the femur. Surgeons may elect to do this in patients who they believe are at a high risk for re-tear, and they want to provide more stability. The LEAT is intended to augment a primary ACL reconstruction and provide greater control of rotational laxity at the knee joint. One review completed (Dewitt, 2017) looked at eight studies that compared pivot shift testing between ACL reconstruction patients with and without the LEAT procedure. Three of the studies had statistically reported significantly less rotational laxity in favor of the LEAT group, while the five others found no significant difference.

The patient was a college student who enjoyed staying active with hobbies such as playing soccer, biking, and hiking. His ACL re-tear happened in the spring while he was playing soccer. He elected to delay surgery until August, as he was going on vacation over the summer. He participated in three physical therapy sessions between March and May before leaving. These sessions consisted of implementing a home exercise program focusing on quadriceps and gluteal stabilizer strengthening. He continued this program throughout the summer and was able to go hiking and cycling as well. He attempted to play soccer, but shortly in to the game he realized his knee did not have the stability necessary to play and he elected to sit out.

Upon returning in August he had his quadriceps tendon ACL reconstruction surgery with LEAT performed. He followed up with physical therapy four days later. At this initial visit, he was on crutches and wearing a knee immobilizer brace. His range of motion was lacking 7 degrees of extension and

achieving 58 degrees of flexion. He was taught a progressive home exercise program consisting of supine knee flexion range of motion to 90 degrees as tolerable, supine knee extension, quadriceps sets, straight leg raises, and ankle pumps. Upon returning for his next visit 2 days later, his motion had improved to full knee extension and 60 degrees of knee flexion. He was able to perform straight leg raises without a knee extensor lag, and also performed weight bearing gait on crutches across a level surface, as well as mini squats and heel raises with upper extremity support at a hand railing.

The patient continued to be seen twice per week in physical therapy. His knee flexion range of motion consistently improved between sessions, and he was able to begin weaning from his crutches and knee brace 2 weeks post-surgery. His pain level throughout the day was minimal, though he complained of a painful feeling in his anterior lateral knee while completing more demanding quadriceps exercises with his knee in a flexed position, such as partial squats and step-ups. This pain subsided after three weeks, and at that time he began to complain of a very sore, "achey" type of pain around all borders of his patella when completing demanding quadriceps exercises.

From weeks 3 to 6, he continued to complete physical therapy twice per week, completed his home exercise program daily, and went to the gym 2-3 times per week to complete quadriceps and gluteal stabilizer exercises. The exercises he was performing in therapy and at the gym consisted of quadriceps and gluteal stabilizer strengthening with squats to 90 degrees as tolerable, lunges, step-ups, step-downs, single leg - leg press, and weighted knee extension from 90-45 degrees. He also completed hamstring strengthening with single leg Russian dead lift, as well as proprioceptive and balance exercises with single leg balance, rocker board exercises, and Bosu ball exercises. He progressed with the intensity of the exercises and improved his strength and endurance consistently over the initial 6 weeks post-operatively.

As he gained back his strength, the pain around his patellar borders steadily decreased in intensity. By his 10th visit, the pain around his patella was minimal, though there was a palpable "click" over his lateral distal femur, near where the IT band was fastened down from his LEAT procedure. This click was not painful, though foam rolling was added to his home exercise program in an attempt to decrease tension of this tissue and avoid irritation. The patient continued physical therapy and at approximately three months post-operative he reported no pain around his knee, with the only lasting irregularity being mild crepitus near his IT band insertion. He was otherwise very pleased with his progress and recovery at that point.

Discussion

When performing an ACL reconstruction surgery, there are several graft choice options that have had excellent outcomes, but without consensus of one single gold standard graft and procedure. The comparisons between patellar tendon, hamstring tendon, and quadriceps tendon grafts have been discussed in this review. It is well recognized that patellar tendon grafts are the most commonly used and provide a strong fixation with good long-term outcomes, though with high rates of anterior knee pain and pain with kneeling. Hamstring grafts are the second most commonly used graft site and demonstrate less donor site morbidity, but they present with a slower healing process with tendon to bone healing, as well as possible decreased fixation strength compared with other grafts. The quadriceps tendon graft is less commonly used, but after evaluating the literature and working with patients first hand, it is clear that this technique is a viable option. Evidence supports that quadriceps tendon grafts can have fast healing rates with strong fixation, decreased long term pain and decreased donor site morbidity.

When considering which graft may be the best, looking at functional outcomes should guide the way. After reviewing the literature on outcomes, it is clear that the quadriceps tendon autograft consistently provides similar, if not improved, outcomes in all areas measured. Tissue properties of this graft are very similar to a native ACL. Donor site morbidity has been reported at lower rates than patellar tendon grafts, though quadriceps tendon grafts give the advantage of strong fixation with bone to bone healing. Stability and range of motion of the knee has been reported at similar rates across studies. Functional outcomes such as IKDC scores, Lysholm scores, and Cybex testing have shown

that this graft is dynamic and able to provide patients with the stability necessary for them to complete the activities they wish. The scores on these functional outcomes consistently range from near 85-95% on a scale of 100. A large goal for physical therapists is to achieve 90% of contralateral leg strength to reintegrate into sport. This graft is allowing these patients to consistently get to these numbers. They are able to build strength, stability, and train safe movement patterns so they are able to return to their sports without apprehension about their knee.

One issue that has been noted rarely in the literature is the retraction of the rectus femoris. This has happened in a small number of patients, and in these patients there have been no functional deficits, only cosmetic. It is still important to note as mentioned earlier, cosmetic issues can play a large role in the psychological recovery of a patient after a knee injury. An example of this cosmetic issue can be seen in the review completed by Slone and colleagues (2015).

With the case example, it was clear this patient's surgery and recovery were progressing well. He had excellent knee range of motion, and the ability to perform a strong quadriceps contraction immediately after surgery. His pain levels were relatively low, and he was able to discontinue use of pain medication after the first few days post-surgery. He did have a few unusual symptoms, such as the lateral knee pain, the peripatellar pain, and clicking near his IT band. It is possible this pain can be attributed to donor site pain. The pain was present with a strong quadriceps contraction, and the tissue of his quadriceps was still in the acute to subacute healing phase. His case is unique in that he had the LEAT procedure done, and it is possible the pain, clicking, and crepitus over his lateral knee may be attributed to this procedure. In the literature, decreased levels of pain were reported consistently in quadriceps tendon grafts compared to others. In the studies, those pain measures were typically reported at least 6 months down the road as long-term outcomes. It is a possibility that harvesting a quadriceps tendon graft may involve more pain around the donor site and knee initially while the acute and subacute healing is still taking place, with less long-term pain down the road.

Overall, the quadriceps tendon graft for ACL reconstruction looks to be a safe and dependable graft based on preliminary evidence to date, and the outcomes in the literature suggest that it should and will be used more in the future. For rehabilitation and clinical indications for these grafts, they should be treated relatively similar to other ACL reconstructions. Physical therapists need to be sensitive to pain over the donor site and keep an eye out for any quadriceps contraction issues. While quadriceps contraction issues haven't been reported at high rates in the literature, the harvest site is directly out of the quadriceps, so this should be on the therapist's mind. It would also be mindful to keep an eye out for retraction of the rectus femoris. This is something that may scare the patient, so it is important to know what you are dealing with and that there have not been functional limitations associated with this cosmetic issue. Rehab should focus on quadriceps strengthening, restoring normal gait mechanics, improving proprioception and dynamic stability of the knee, and returning these patients to the activities they love and wish to return to. In conclusion, the quadriceps tendon graft for ACL reconstruction is a viable and safe option that may become more popular over the next several years.

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