4-1-2022

Outcomes Following Anterior Cruciate Ligament Reconstruction with Patellar Tendon vs Hamstring Autografts: A Systematic Review of Randomized Controlled Trials with a Mean Follow-up of 15 Years

Connor G. Hoge

Robert N. Matar

Lafi S. Khalil

John A. Buchan

Cole M. Johnson

See next page for additional authors

Authors

Connor G. Hoge, Robert N. Matar, Lafi S. Khalil, John A. Buchan, Cole M. Johnson, and Brian M. Grawe

SYSTEMATIC REVIEW

Outcomes Following Anterior Cruciate Ligament Reconstruction with Patellar Tendon vs Hamstring Autografts: A Systematic Review of Randomized Controlled Trials with a Mean Follow-up of 15 Years

Connor G. Hoge, BS[1]; Robert N. Matar, MD[1]; Lafi S. Khalil MD[2]; John A. Buchan BA[1]; Cole M. Johnson BS[1]; Brian M. Grawe MD[1]

Research performed at the University of Cincinnati College of Medicine, Cincinnati, OH, USA

Received: 10 December 2020 *Accepted: 24 July 2021*

Abstract

Background: The two most common surgical treatment modalities for anterior cruciate ligament reconstruction (ACL), patellar tendon (PT) and hamstring tendon (HS) autografts, have been shown to have outcomes that are both similar and favorable; however, many of these are short or intermediate-term. The objective of this systematic review is to evaluate randomized controlled trials (RCTs) with a minimum 10-year follow-up data to compare the long-term outcomes of ACL reconstructions performed using PT and HS autografts.

Methods: This systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. A search of three databases (PubMed, Cochrane and EMBASE) was performed to identify RCTs with a minimum of 10-year follow-up that compared clinical and/or functional outcomes between PT and HS autografts.

Results: Four RCTs with a total of 299 patients were included in the study. The mean follow-up ranged from 10.2 to 17 years (mean, 14.79 years). No significant differences in knee laxity or clinical outcome scores were demonstrated in any of the studies. One study found that PT autografts were significantly more likely to have osteoarthritis identified by radiographic findings. Two studies found that patients with PT autografts reported increase kneeling pain, while none of the four studies reported a difference in anterior knee pain. There were no significant differences in graft failure rates.

Conclusion: This review demonstrates no long-term difference in clinical or functional outcomes between PT and HS autografts. However, radiographic and subjective outcomes indicate that patients with PT autografts may experience greater kneeling pain and osteoarthritis. Therefore, orthopaedic surgeons should consider patient-centric factors when discussing graft options with patients.

Level of evidence: II

Keywords: Anterior cruciate ligament, Autografts, Hamstring tendon autograft, Patellar tendon autograft

Introduction

Anterior cruciate ligament (ACL) rupture necessitating reconstruction is among one of the most common procedures performed by orthopaedic surgeons (1). The most common autograft choices include patellar tendon (PT) and hamstring tendon (HS) grafts (2). Despite several investigations of the strengths and weaknesses of each autograft type, no definitive consensus on superiority is agreed upon in the

Corresponding Author: Connor G. Hoge, Department of Orthopaedic Surgery, University of Cincinnati College of Medicine, Cincinnati, OH, USA
Email: hogecg@mail.uc.edu

THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

literature (2-5). Reported risks of PT autografts include the potential for patellar fractures, patellar tendon ruptures, quadriceps weakness and donor site morbidity including pain with kneeling (2-9). In comparison, harvesting HS autografts in patients undergoing ACL reconstruction is associated with decreased hamstring strength, increased joint laxity, increased graft failure rate, and delayed graft-tunnel healing (2-9). Most studies focus on short-term outcomes between graft types, thus the long-term evaluation of graft types remains inconclusive (2-9).

Over the past decade, systematic reviews comparing outcomes between PT and HS autografts have evaluated short-term data with two-year and five-year minimum follow-up (7, 9). More recently, Poehling-Monaghan and colleagues reported a robust systematic review of outcomes between PT and HS autografts with minimum five-year follow-up (8). Their review included 12 studies of level I and II evidence with a mean follow-up of 8.96 years (range, 5-15.3 years). The authors reported an increase in long-term knee pain and osteoarthritis in the PT cohort, but found no significant differences in laxity or graft failures between the two graft types (8). Four of the studies in their review had a minimum of 10-year follow-up, including three randomized control trials (10-12). Since their review, Sajovic and colleagues (10) have published a new 17-year follow up data of their randomized control trial (13). Additionally, Bjornsson and colleagues have also reported on minimum 10-year follow-up data (14). Therefore, it is prudent to revisit long-term clinical outcomes with a minimum of 10-year follow-up of ACL reconstructions performed using PT vs HS autografts.

In light of the aforementioned additions to the literature, the goal of the present study is to conduct a systematic review of randomized control trials comparing ACL reconstructions performed using PT vs HS autografts with a minimum of 10-years of follow-up data. Primary outcomes evaluated in the present review will include clinical and functional outcomes. Secondary outcomes will include subjective and radiographic outcomes. The authors hypothesize that there will be no significant differences in the long-term outcomes between PT and HS autografts.

Materials and Methods

Study Eligibility

Inclusion criteria for this search query consisted of randomized control trials (RCT) published in English since 2000, comparing ACL reconstructions performed using PT and HS autografts, that reported clinical, functional, radiographic, or patient-reported outcomes in skeletally mature patients with a minimum of 10-year follow-up data. Studies were excluded if they investigated the following: allografts, in-vitro studies, cadaveric and animal studies, and studies which were not RCTs.

Literature Search

A systematic review was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (15, 16). A literature search was conducted in three databases (PubMed, Cochrane and EMBASE) in November 2019. The search strategy was performed using the following search terms: "Anterior Cruciate Ligament Reconstruction" OR "ACL" AND "Treatment Outcome" OR "Outcome Assessment (Health Care)" OR "Clinical effectiveness" OR "Patient Reported Outcome Measures" OR "PROMIS" OR "Patient-Reported Outcomes Measurement Information System" OR "patient-reported outcomes" OR "PROMIS instruments" OR "outcomes." This search captured 272 articles with documented data at a minimum of 10 years follow-up comparing ACL reconstruction performed with PT vs HS autografts.

Study Selection and Data Abstraction

The titles and abstracts of each article were evaluated by two authors independently. Subsequently, both authors independently reviewed the full text of the article if titles and abstracts did not exclude the studies. Additionally, full text was reviewed from any articles reporting outcomes of interest with a minimum of 10-year follow-up data. Included articles were manually reviewed to check for additional relevant articles cited. For RCTs that published series reporting on the same patient population at different follow-up intervals, the study with the longest follow-up was included and its predecessors excluded [Figure 1] (9, 10, 13). Characteristics of the included studies were extracted, including title, journal, first author, publication year, study design, enrollment dates, demographic information (sex, age, etc), mean follow-up, surgical technique, and type of fixation. Clinical and/or functional outcomes extracted included patient reported quantitative outcome measures (International Knee Documentation Committee [IKDC] grade, Lysholm score, Tegner activity scale), clinical outcome assessments (knee laxity measurements with KT-1000 arthrometers, Lachman test, pivot-shift test), radiographic evidence of osteoarthritis (Kellgren-Lawrence [K-L] classification, IKDC grading scale), subjective knee pain (kneeling and anterior knee pain) and graft failure rates. The K-L classification is represented by the following grading scale: 0: normal, 1: doubtful narrowing of joint space and possible osteophytic lipping, 2: definitive osteophytes and possible narrowing of joint space, 3: moderate, multiple osteophytes and definitive narrowing or 4: large osteophytes with marked narrowing of joint space. The IKDC grading scale is as follows: A: normal, B: minimal, C: narrowing up to 50%, D: narrowing greater than 50%.

Risk of Bias Assessment

All studies underwent qualitative assessment using the modified Coleman methodology score (17). Two independent reviewers performed all of the data extraction.

Data Analysis

Primary outcome measurements included antero-posterior knee laxity, clinical outcomes (eg, Lysholm, Tegner, IKDC scores, radiographic outcomes (eg, osteoarthritis), knee pain, and graft failure. Statistical significance was defined as $P < 0.05$

Results

Study Characteristics

Thirteen studies reported 10-year outcomes following ACL reconstruction comparing PT and HS autografts. Seven articles were excluded as they reported identical patient populations at interval follow-up periods. Two additional articles were cohort studies and excluded, resulting in four manuscripts for qualitative analysis [Figure 1] (11-14). The mean follow-up in all four studies had a minimum of 10-year follow-up data. Follow-up means ranged from 10.2 to 17 years (mean 14.79 years) (11-14). A total of 299 patients were included in this review (PT: 135; HS: 164). Age at time of surgery had a mean range from 26 to 28.2 years and age at follow-up had a mean range from 41.3 to 45.5 years. Clinical follow-up rates were reported in all four studies, ranging from 34%-76% (11-14). Modified Coleman methodology scores ranged from 78-87, with a maximum of 90 points possible [Table 1] (11-14).

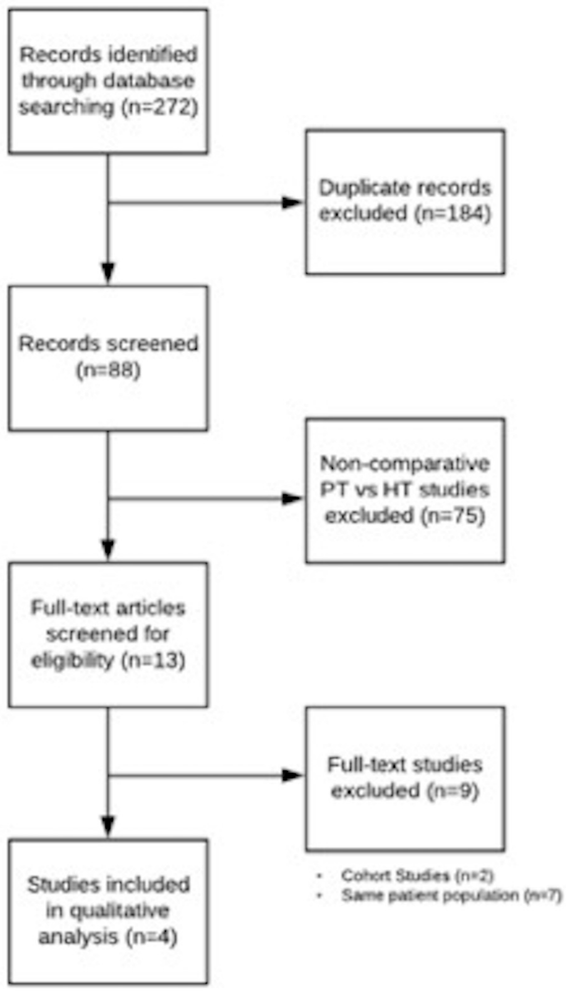

Figure 1. PRIMSA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart demonstrating selection process for inclusion of studies. PT, patellar tendon; HS, hamstring.

Surgical Technique

Three of the four studies were single surgeon series, while the fourth was a multi-surgeon study (11-14). Three studies performed transtibial (TT) drilling, while Sajovic *et al*. performed femoral drilling via an anteromedial (AM) port (11-14). All of the studies used interference screw fixation for the tibial tunnel fixation irrespective of graft type. Two studies used interference screw fixation, while one used endobutton fixation for femoral tunnel fixation irrespective of graft type (12-14). Holm *et al*. used interference screws for tibial and femoral fixation in PT grafts, while they used endobutton fixation for the femur in HS grafts [Table 2] (11).

Anteroposterior Knee Laxity

All four studies included instrumented laxity measurements as mean side-to-side differences (mm) using manual tension with a KT-1000 arthrometer (MEDmetric Corp) (11-14). None of the studies reported any significant differences in anteroposterior (AP) laxity between patients with ACL reconstructions performed with PT vs HS autografts. Two studies reported clinical provocative measures of laxity using either the Lachman or pivot-shifts tests, but neither found a significant difference between the two groups (13, 14). Sajovic *et al*. reported the proportion of patients with <3mm of AP translation upon instrumented testing, with the PT autograft cohort significantly outnumbering the HS cohort (22 vs 16, $P = 0.03$). Despite this finding, the mean side-to-side difference measured remained statistically insignificant between the two cohorts [Table 3] ($P=0.134$) (13).

Clinical Outcomes

Clinical outcomes reported by included studies consist of patient-reported Lysholm scores, Tegner scores, and/or IKDC scores. IKDC scores were recorded by value or by graded scale. Sajovic *et al*. used a scale graded from A through D, representing normal, nearly normal, abnormal, or severely abnormal outcomes, respectively (13). The authors reported 38% of PT and 42% of HS patients had a normal (A) grade ($P > 0.05$). Likewise, in the two remaining studies reporting IKDC scores, no significant differences existed between groups (12, 14). There were no statistically significant differences found in Lysholm or Tegner scores between PT and HS autografts in the three studies that reported on them [Table 4] (11, 13, 14).

Radiographic Outcomes: Osteoarthritis

Radiographic changes were reported by included studies using either the K-L classification for osteoarthritis or IKDC grading system for joint space narrowing. The three studies that reported radiographic changes using the K-L classification did not find any significant differences between PT and HS autografts (11, 12, 14). Sajovic *et al*. reported statistically significant differences in IKDC osteoarthritic changes in the PT group, none of whom had radiologically normal IKDC grading, while seven patients (29%) in the HS group had grade A (normal) IKDC grading ($P = 0.04$) [Table 5] (13).

Table 1. Studies Meeting Inclusion Criteria and Demographic Characteristics. N presented as number of patients; Follow-up presented as means (minimum range – maximum range) years (*months); †Follow-up presented as mean years ± standard deviation. Age represented by mean (standard deviation) years; Gender represented by number of M (male) or F (female) patients. Pub, publication journal and year; LOE, level of evidence; AJSM, American Journal of Sports Medicine, PT: patellar tendon autograft, HS: hamstring autograft; NR, not recorded.

First Author	Pub	LOE	Year of Index Procedure	N At Last Follow-up	Gender (M/F)	Years Follow-up	Age at Surgery	Age at Follow-up	Clinical Follow-up %	Coleman Score
Sajovic (13)	AJSM 2018	2	1999-2000	PT = 24, HS = 24	PT = 15/9, HS = 13/11	17	NR	PT = 45.5 (8.7), HS = 42.5 (7.5)	75%	78
Webster (12)	AJSM 2016	1	1996-1998	PT = 22, HS = 25	PT = 16/6, HS = 20/5	15.3 (14-17)	PT = 26.6 (6.7), HS = 26.1 (5.9)	PT = 41.9 (6.7), HS = 41.3 (6.0)	72%	86
Holm (11)	AJSM 2010	1	NR	PT = 28, HS = 29	PT = 18/10, HS = 15/14	†PT = 10.2 (0.4), †HS = 10.7 (0.4)	26 (15-50)	NR	34%	81
Bjorns-son(14)	AJSM 2016	2	1995-2000	PT = 61, HS = 86	PT = 42/19, HS = 53/33	*PT = 202.6 (164-224), *HS = 191.1 (159-225)	PT: 28.2 (9.1), HT: 26.6 (7.6)	PT = 44.7 (9.1), HT = 42.3 (7.8)	76%	85

Knee Pain

Bjornsson and colleagues reported kneeling discomfort based on a 4-grade knee-walking test in which the patient walked on the floor on their knees without any protective clothing, finding patients in the HS group had significantly better knee-walking ability (*P=0.049*) (14). Two studies found a statistically significant increase in kneeling pain in patients who had a PT compared to those with HS autografts (11, 14). Additionally, Webster *et al*. found increased kneeling pain in their cohort of PT autografts, albeit statistically insignificance (12). Sajovic *et al*. was the only study that reported increased kneeling pain in the HS autograft cohort, but this did not reach statistically significance (13). Two of the studies commented on anterior knee pain, with neither of them finding a difference between the type of autograft [Table 6] (12, 13).

Graft Failure

Failure was defined as a ruptured graft needing reconstruction. All four studies commented on graft failure, although Holm *et al*. did not report whether there was a statistically significant difference between the two graft types (11). None of the other three studies found a

Table 2. Surgical Techniques of Drilling the Femoral Tunnel. PT: patellar tendon autograft, HS: hamstring autograft, AM: anteromedial, TT: transtibial, IFS: interference screw fixation, END: endobutton fixation

Author	# of Surgeons	Surgical Technique	PT: Type of Fixation (femoral/tibial)	HS: Type of Fixation (femoral/tibial)
Sajovic (13)	1	AM	IFS/IFS	IFS/IFS
Webster (12)	1	TT	END/IFS	END/IFS
Holm (11)	1	TT	IFS/IFS	END/IFS
Bjornsson (14)	6	TT	IFS/IFS	IFS/IFS

THE ARCHIVES OF BONE AND JOINT SURGERY. ABJS.MUMS.AC.IR
VOLUME 10. NUMBER 4. APRIL 2022

Table 3. Manual and Instrumented Laxity Measurements. Reported by Included Studies. †Side-to-side differences represented by millimeters ± standard deviation. Lachman and Pivot test grading represented by N (%); PT, patellar tendon autograft; HS, hamstring autograft, NR, not recorded. Statistically significant differences between PT and HS groups are represented in Bold, *P<0.05*

Author	Graft Type	†Side-to-Side	Lachman 0-1	Lachman 2-3	Pivot 0-1	Pivot 2-3
Sajovic (13)	PT	1.33 ± 1.93	24 (100)		24 (100)	
	HS	2.17 ± 1.86	24 (100)		24 (100)	
Webster (12)	PT	0.6 ± 1.5	NR	NR	NR	NR
	HS	1.2 ± 1.3	NR	NR	NR	NR
Holm (11)	PT	3.0 ± 3.2	NR	NR	NR	NR
	HS	2.0 ± 3.5	NR	NR	NR	NR
Bjornsson (14)	PT	1.0 ± 2.7	54 (88.5)	7 (11.5)	48 (78.7)	12 (19.7)
	HS	1.5 ± 3.0	66 (76.7)	20 (23.3)	73 (84.9)	13 (15.1)

Table 4. Clinical Outcomes Reported by Included Studies. Continuous scores represented by mean ± standard deviation. Categorical scores represented by N (%); PT, patellar tendon autograft; HS, hamstring autograft; IKDC, International knee documentation committee score; NR, not recorded. Statistically significant differences between PT and HS groups are represented in Bold, *P<0.05*.

Author	Graft Type	IKDC	Lysholm	Tegner
Sajovic (13)	PT	A=9(38%), B=13(54%), C=2(8%)	93 ± 8.2	4 (17%) ≥ 7.0
	HS	A=10(42%), B=13(54%), C=1(4%)	94 ± 9.4	7 (29%) ≥ 7.0
Webster (12)	PT	88.1 ± 12.3	NR	NR
	HS	84.4 ± 13.5	NR	NR
Holm (11)	PT	NR	84.2 ± 15.4	4.3 ± 2.2
	HS	NR	86.1 ± 15.1	4.8 ± 2.3
Bjornsson (14)	PT	67.3 ± 20.8	79.4 ± 16.9	4.1 ± 1.7
	HS	74.0 ± 18.8	80.7 ± 15.3	4.0 ± 1.7

Table 5. Radiographic Outcomes Reported by Included Studies. Continuous scores represented by mean ± standard deviation. Categorical scores represented by N (%); PT, patellar tendon autograft; HS, hamstring autograft; IKDC, International knee documentation committee score; K-L, Kellgren-Lawrence score; NR, not recorded. Statistically significant differences between PT and HS groups are represented in Bold, *P = 0.04*.

Author	Graft	K-L (0-1)	K-L (2-4)	IKDC (A-B)	IKDC (C-D)
Sajovic (13)	PT	NR	NR	**A = 0%, B = 67%**	**C = 21% D= 12%**
	HS	NR	NR	**A = 29%, B = 50%**	**C = 13%, D = 8%**
Webster (12)	PT	74%	26%	NR	NR
	HS	68%	32%	NR	NR
Holm (11)	PT	0 = 7.1%, 1 = 28.6%	2=39.3% 3 = 25.0%	NR	NR
	HS	0 = 13.8%, 1 = 31.0%	2=48.3% 3=6.9%	NR	NR
Bjornsson (14)	PT	0 = 27.9%, 1 = 23%	2 = 36.1% 3 = 9.8% 4 = 3.3%	NR	NR
	HS	0 = 30.2%, 1 = 29.1%	2=26.7% 3 = 9.3% 4 = 4.7%	NR	NR

Table 6. Knee Pain as Reported by Included Studies. Categorical scores represented by N (%); PT, patellar tendon autograft; HS, hamstring autograft; NP, not pleasant; D, difficult; I, impossible; NR, not recorded. *Specific values were not presented in the study, *P = .35*. Statistically significant differences between PT and HS groups are represented in Bold, *P < 0.05*.

Authors	Graft	Kneeling Pain	Anterior Knee Pain
Sajovic (13)	PT	33	*
	HS	46	*
Webster (12)	PT	52 (11)	38 (8)
	HS	41 (10)	27 (7)
Holm (11)	PT	39 (11)	NR
	HS	29 (8)	NR
Bjornsson (14)	PT	OK=49.2 (30), NP=24.6 (15), D=13.1 (8), I=13.1 (8)	NR
	HS	OK= 62.8 (54), NP=24.4 (21), D=7.0 (5), I=5.8 (6)	NR

Table 7. Graft Failure Rates and Causes Identified in Included Studies. NR, not recorded; NS, not statistically significant. Categorical scores represented by N (%); Statistically significant differences between PT and HS groups are represented in Bold, *P < 0.05*.

	Patellar Tendon		Hamstring		
Author	**Failure, % (n)**	**Cause**	**Failure, % (n)**	**Cause**	**Significance**
Sajovic (13)	9.4 (3)	NR	6.3 (2)	NR	NS
Webster (12)	5 (1)	Traumatic	12 (3)	NR	NS
Holm (11)	10 (3)	Traumatic	11 (3)	Traumatic	NR
Bjornsson (14)	6.6 (4)	NR	8.1 (7)	NR	NS

statistically significant difference in failure between PT and HS autografts [Table 7] (12-14).

Discussion

A number of studies have compared ACL reconstruction performed with either PT or HS autografts (2-9, 11-14). Most of these studies report short-term or intermediate-term outcomes with follow-up averaging less than 10 years (2-9). In addition, many studies are prospective or retrospective cohort studies, which are subject to biases inherent to their methodology. The current study presents a systematic review of updated RCTs and those with minimum follow-up of at least 10 years and a mean of 15 years comparing PT and HS autografts. The main findings of this review agree with our primary hypothesis, demonstrating similar clinical and functional outcomes between PT and HS autografts. Interestingly, the results of this review suggest that at long-term follow up greater than 10 years, patients in whom a patellar tendon autograft was used may develop increased radiographic evidence of osteoarthritis and incidence of anterior and kneeling knee pain.

The historical advantage of PT autografts flanked by bone-plugs is the rapid osteo-integration inside the graft tunnels providing rigid fixation, which is less robust than tendon-to-bone healing in HS autografts (18). The concern for accomplishing rigid fixation derives from the increased risk of meniscal injuries and osteoarthritis in patients with ACL deficient knees, knee laxity, or instability (19). Functional outcomes in the reviewed studies were investigated with a combination of instrumented knee laxity assessments and provocative manual tests, none of which differed significantly between PT and HS autograft cohorts. Although Sajovic *et al*. reported that the PT cohort had a greater proportion of patients with <3mm of AP translation during instrumented testing than the HS cohort (22 vs 16, *P =0.03*), side-to-side differences remained similar between the groups (13). These findings indicate that with regards to knee laxity and stability at long-term follow-up, neither PT nor HS autograft demonstrates superiority. This is in contrast to studies that have shown HS autografts to result in greater knee laxity compared to PT autografts at short-term follow-up (20, 21). To the author's knowledge, Thompson and colleagues cohort study with 20-year data represents the longest follow-up comparison of knee laxity between PT and HS autografts, in which no significant differences were found (22). They reported 76% of HS and 84% of PT patients had a Lachman grade of 0 and neither groups had patients with a Lachman grade of 2 or 3 (*P=0.33*). They also found no significant differences in instrumented laxity or pivot-shift tests between the two autografts at the 20-year follow-up, consistent with the findings of the present review that fail to demonstrate superiority of a particular autograft (22).

The present investigation found no significant differences between PT and HS autograft cohorts with regards to long-term clinical outcomes measured by IKDC, Tegner or Lysholm scores. This is consistent with long-term studies utilizing the Tegner activity scale (11, 23) and IKDC and Lysholm scores (22). When deciding between autograft choices, it is important for the orthopedic surgeon to discuss these findings in addition to the functional, radiographic, and subjective outcomes. The clinical outcome measures included in this review have been validated to represent the clinical response to intervention (24, 25). It is prudent to treat the patient with a patient-centered approach, recognizing that clinical outcomes may be positively correlated with what the patient perceives as a successful intervention irrespective of what radiographic or subjective endpoints may be measured (26).

Radiographic outcomes reviewed among PT and HS cohorts demonstrated no significant differences at long-term follow-up in Kellgren-Lawrence classification system (11, 12, 14). Sajovic and colleagues reported a significantly increased number of patients in the PT cohort with OA determined by radiograph, finding 100% of PT patients had some signs of OA compared to 71% of HS patients (*P=0.04*). Furthermore, they found an increased amount of high grade degenerative changes in PT patients compared to the HS patients (33% of PT patients with C or D grade vs 21% of HS group) (13). Prior studies have also found increased risk of osteoarthritis among patients with PT autografts (10, 22, 27). Thompson *et al*. reported radiographically detectable osteoarthritic changes more predominantly in PT than HS autograft cohorts (61% vs 41%, *P=0.008*) (22). Despite prior reports in the literature, three out of the four RCTs in the present review did not find significant long-term osteoarthritic differences between the two grafts (11, 12, 14).

Autografts harvested from the anterior knee have historically been reported to carry a higher risk of anterior knee pain and kneeling pain (8, 28, 29). This was found to be true in two of the studies included for review (11, 14). Using a 4-grade knee-walking test, Bjornsson and colleagues demonstrated patients with PT autografts were significantly more likely to rate walking on their knees as “Difficult” or “Impossible” compared to patients with HS grafts (14). Nevertheless, knee pain is not present in all patients nor reported as a statistically different difference in all studies (12, 13). Therefore, a one-graft-fits-all approach is likely to lead to poor outcomes in certain patient populations, and rather the orthopedic surgeon should be cognizant of kneeling requirements patients may have for employment or religious reasons and discuss these concerns while weighing graft options.

Prior investigations have identified HS autografts as significant predictors of graft failure and increased risk of revision surgery (30, 31). Conversely, a meta-analyses by Xie *et al*. reported a risk ratio of graft failure of 0.86 in favor of PT autografts that was not statistically significant (95% CI, 0.57–1.28; *P=0.45*) (32). Likewise, at 20-year follow-up Thompson and colleagues reported no significant differences in failure rates between PT and HS autografts (10% vs 18%, *P=0.13*) (22). The present review found no significant differences in graft failure between the two autografts in all four studies reviewed. While the studies included in the present review may not contain sample sizes large enough to detect significant differences, the strength of evaluating RCTs is the mitigation of confounding variables. Likewise, the minimum follow-up of 10 years enables a greater likelihood of identifying re-rupture and revision surgery than studies with short term follow-up.

Limitations

There are several limitations to our study. First, the percentage of patients lost to follow-up can skew results. However, this is likely due to our minimum 10-year follow-up criteria, which we believe is a strength of our study in terms of long-term outcomes. Surgical techniques were not consistent throughout the studies as there was a variety of different approaches and fixations methods utilized. Ultimately, as the data was not pooled into a meta-analysis but rather presented as a systematic review, this should not limit the readers’ ability to derive conclusions from each study individually. Additionally, the subjective nature of some outcomes included in the studies makes them less generalizable to other heterogenous patient populations. Without thorough analysis of patient employment, recreational sports, return to sport rates and at the same level of sport, these outcomes cannot be directly interpreted as successful or not for each patient. Lastly, radiographic outcomes which showed significant differences at long-term follow-up cannot be correlated to patient complaints or arthritic knee pain and therefore the clinical significance of imaging findings is unable to be evaluated in this review.

This review of randomized control trials comparing PT and HS autografts used for ACL reconstruction with a minimum of 10-year follow-up demonstrates no difference in clinical or functional outcomes between groups. However, radiographic and subjective outcomes indicate that patients with PT autografts may experience greater anterior knee and kneeling pain and degenerative osteoarthritis. As PT and HS autografts demonstrate similar long-term outcomes, orthopedic surgeons should consider patient-centric factors when discussing graft options with patients. As surgical techniques and rehabilitation protocols continue to improve, future studies may delineate patient factors most suitable per graft type.

Disclosure: The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Connor G. Hoge BS[1]
Robert N. Matar MD[1]
Lafi S. Khalil MD[2]
John A. Buchan BA[1]
Cole M. Johnson BS[1]
Brian M. Grawe MD[1]
1 Department of Orthopaedic Surgery, University of Cincinnati College of Medicine, Cincinnati, OH, USA
2 Department of Orthopaedic Surgery, Henry Ford Hospital, Detroit, MI, USA

References

1. Mall NA, Chalmers PN, Moric M, Tanaka MJ, Cole BJ, Bach Jr BR, et al. Incidence and trends of anterior cruciate ligament reconstruction in the United States. The American journal of sports medicine. 2014;42(10):2363-70.
2. Gifstad T, Sole A, Strand T, Uppheim G, Grontvedt T, Drogset JO. Long-term follow-up of patellar tendon grafts or hamstring tendon grafts in endoscopic ACL reconstructions. Knee Surg Sports Traumatol Arthrosc. 2013;21(3):576-83.
3. Maletis GB, Cameron SL, Tengan JJ, Burchette RJ. A prospective randomized study of anterior cruciate ligament reconstruction: a comparison of patellar tendon and quadruple-strand semitendinosus/gracilis tendons fixed with bioabsorbable interference screws. Am J Sports Med. 2007;35(3):384-94.
4. Mohtadi N, Chan D, Barber R, Oddone Paolucci E. A Randomized Clinical Trial Comparing Patellar Tendon, Hamstring Tendon, and Double-Bundle ACL Reconstructions: Patient-Reported and Clinical Outcomes at a Minimal 2-Year Follow-up. Clin J Sport Med. 2015;25(4):321-31.
5. Rahr-Wagner L, Thillemann TM, Pedersen AB, Lind M. Comparison of hamstring tendon and patellar tendon grafts in anterior cruciate ligament reconstruction in a nationwide population-based cohort study: results from the danish registry of knee ligament reconstruction. Am J Sports Med. 2014;42(2):278-84.
6. Dhammi IK, Rehan Ul H, Kumar S. Graft choices for anterior cruciate ligament reconstruction. Indian J Orthop. 2015;49(2):127-8.
7. Magnussen RA, Carey JL, Spindler KP. Does autograft choice determine intermediate-term outcome of ACL reconstruction? Knee Surg Sports Traumatol Arthrosc. 2011;19(3):462-72.
8. Poehling-Monaghan KL, Salem H, Ross KE, Secrist E, Ciccotti MC, Tjoumakaris F, et al. Long-Term Outcomes in Anterior Cruciate Ligament Reconstruction: A Systematic Review of Patellar Tendon Versus Hamstring Autografts. Orthop J Sports Med. 2017;5(6):2325967117709735.
9. Sajovic M, Vengust V, Komadina R, Tavcar R, Skaza K. A prospective, randomized comparison of semitendinosus and gracilis tendon versus patellar tendon autografts for anterior cruciate ligament reconstruction: five-year follow-up. Am J Sports Med. 2006;34(12):1933-40.
10. Sajovic M, Strahovnik A, Dernovsek MZ, Skaza K. Quality of life and clinical outcome comparison of semitendinosus and gracilis tendon versus patellar tendon autografts for anterior cruciate ligament reconstruction: an 11-year follow-up of a randomized controlled trial. Am J Sports Med. 2011;39(10):2161-9.
11. Holm I, Oiestad BE, Risberg MA, Aune AK. No difference in knee function or prevalence of osteoarthritis after reconstruction of the anterior cruciate ligament with 4-strand hamstring autograft versus patellar tendon-bone autograft: a randomized study with 10-year follow-up. Am J Sports Med. 2010;38(3):448-54.
12. Webster KE, Feller JA, Hartnett N, Leigh WB, Richmond AK. Comparison of Patellar Tendon and Hamstring Tendon Anterior Cruciate Ligament Reconstruction: A 15-Year Follow-up of a Randomized Controlled Trial. Am J Sports Med. 2016;44(1):83-90.
13. Sajovic M, Stropnik D, Skaza K. Long-term Comparison of Semitendinosus and Gracilis Tendon Versus Patellar Tendon Autografts for Anterior Cruciate Ligament Reconstruction: A 17-Year Follow-up of a Randomized Controlled Trial. Am J Sports Med. 2018;46(8):1800-8.
14. Bjornsson H, Samuelsson K, Sundemo D, Desai N, Sernert N, Rostgard-Christensen L, et al. A Randomized Controlled Trial With Mean 16-Year Follow-up Comparing Hamstring and Patellar Tendon Autografts in Anterior Cruciate Ligament Reconstruction. Am J Sports Med. 2016;44(9):2304-13.
15. Harris JD, Quatman CE, Manring MM, Siston RA, Flanigan DC. How to write a systematic review. Am J Sports Med. 2014;42(11):2761-8.
16. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg. 2010;8(5):336-41.
17. Coleman BD, Khan KM, Maffulli N, Cook JL, Wark JD. Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. Victorian Institute of Sport Tendon Study Group. Scand J Med Sci Sports. 2000;10(1):2-11.
18. Fu FH, Bennett CH, Lattermann C, Ma CB. Current trends in anterior cruciate ligament reconstruction. Part 1: Biology and biomechanics of reconstruction. Am J Sports Med. 1999;27(6):821-30.
19. Sanders TL, Kremers HM, Bryan AJ, Fruth KM, Larson DR, Pareek A, et al. Is Anterior Cruciate Ligament Reconstruction Effective in Preventing Secondary Meniscal Tears and Osteoarthritis? Am J Sports Med. 2016;44(7):1699-707.
20. Beynnon BD, Johnson RJ, Fleming BC, Kannus P, Kaplan M, Samani J, et al. Anterior cruciate ligament replacement: comparison of bone-patellar tendon-bone grafts with two-strand hamstring grafts. A prospective, randomized study. J Bone Joint Surg Am. 2002;84(9):1503-13.
21. Cristiani R, Sarakatsianos V, Engstrom B, Samuelsson K, Forssblad M, Stalman A. 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. 2019;27(2):381-8.

22. Thompson SM, Salmon LJ, Waller A, Linklater J, Roe JP, Pinczewski LA. Twenty-Year Outcome of a Longitudinal Prospective Evaluation of Isolated Endoscopic Anterior Cruciate Ligament Reconstruction With Patellar Tendon or Hamstring Autograft. Am J Sports Med. 2016;44(12):3083-94.
23. Barenius B, Nordlander M, Ponzer S, Tidermark J, Eriksson K. Quality of life and clinical outcome after anterior cruciate ligament reconstruction using patellar tendon graft or quadrupled semitendinosus graft: an 8-year follow-up of a randomized controlled trial. Am J Sports Med. 2010;38(8):1533-41.
24. Briggs KK, Lysholm J, Tegner Y, Rodkey WG, Kocher MS, Steadman JR. The reliability, validity, and responsiveness of the Lysholm score and Tegner activity scale for anterior cruciate ligament injuries of the knee: 25 years later. Am J Sports Med. 2009;37(5):890-7.
25. Higgins LD, Taylor MK, Park D, Ghodadra N, Marchant M, Pietrobon R, et al. Reliability and validity of the International Knee Documentation Committee (IKDC) Subjective Knee Form. Joint Bone Spine. 2007;74(6):594-9.
26. Kahlenberg CA, Nwachukwu BU, Ferraro RA, Schairer WW, Steinhaus ME, Allen AA. How Are We Measuring Patient Satisfaction After Anterior Cruciate Ligament Reconstruction? Orthop J Sports Med. 2016;4(12):2325967116673971.
27. Keays SL, Bullock-Saxton JE, Keays AC, Newcombe PA, Bullock MI. A 6-year follow-up of the effect of graft site on strength, stability, range of motion, function, and joint degeneration after anterior cruciate ligament reconstruction: patellar tendon versus semitendinosus and Gracilis tendon graft. Am J Sports Med. 2007;35(5):729-39.
28. Ibrahim SA, Al-Kussary IM, Al-Misfer AR, Al-Mutairi HQ, Ghafar SA, El Noor TA. Clinical evaluation of arthroscopically assisted anterior cruciate ligament reconstruction: patellar tendon versus gracilis and semitendinosus autograft. Arthroscopy. 2005;21(4):412-7.
29. Wipfler B, Donner S, Zechmann CM, Springer J, Siebold R, Paessler HH. Anterior cruciate ligament reconstruction using patellar tendon versus hamstring tendon: a prospective comparative study with 9-year follow-up. Arthroscopy. 2011;27(5):653-65.
30. Laboute E, James-Belin E, Puig PL, Trouve P, Verhaeghe E. Graft failure is more frequent after hamstring than patellar tendon autograft. Knee Surg Sports Traumatol Arthrosc. 2018;26(12):3537-46.
31. Persson A, Fjeldsgaard K, Gjertsen JE, Kjellsen AB, Engebretsen L, Hole RM, et al. Increased risk of revision with hamstring tendon grafts compared with patellar tendon grafts after anterior cruciate ligament reconstruction: a study of 12,643 patients from the Norwegian Cruciate Ligament Registry, 2004-2012. Am J Sports Med. 2014;42(2):285-91.
32. Xie X, Liu X, Chen Z, Yu Y, Peng S, Li Q. A meta-analysis of bone-patellar tendon-bone autograft versus four-strand hamstring tendon autograft for anterior cruciate ligament reconstruction. Knee. 2015;22(2):100-10.