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ORIGINAL ARTICLE

Prospective Comparison of Auto and Allograft Hamstring Tendon Constructs for ACL Reconstruction

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Abstract Although allograft use for primary anterior cruciate ligament reconstruction has continued to increase during the last 10 years, concerns remain regarding the long-term function of allografts (primarily that they may stretch with time) and clinical efficacy compared with autograft tendons. We attempted to address these issues by prospectively comparing identical quadrupled hamstring autografts with allograft constructs for primary anterior cruciate ligament reconstruction in patients with a minimum followup of 3 years. Eighty-four patients (37 with autografts and 47 with allografts) were enrolled; the mean followup was 52 ± 11 months for the autograft group and 48 ± 8 months for the allograft group. Outcome measurements included objective and subjective International Knee Documentation Committee scores, Lysholm scores, Tegner activity scales, and KT-1000 arthrometer measurements. The two cohorts were similar in average age, acute or chronic nature of the anterior cruciate ligament rupture, and incidence of concomitant meniscal surgeries. At final followup, we found no difference in terms of Tegner, Lysholm, KT-1000, or International Knee Documentation Committee scores. Five anterior cruciate ligament reconstructions failed: three in the autograft group and two in the allograft group. Our data suggest laxity is not increased in allograft tendons compared with autografts and clinical outcome scores 3 to 6 years after surgery are similar.

Level of Evidence: Level II, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Primary ACL reconstruction is estimated to be the sixth most commonly performed orthopaedic procedure in the United States with approximately 50,000 to 175,000 performed annually [30, 51]. The incidence of acute rupture in the general population has been estimated at one in 3000 [34]. Furthermore, during the last decade, there have been increases in female athletic participation and cultural emphasis to maintain physical activity later in life. Many have assumed these two cultural trends will increase the demand for primary repair [5, 21].

Currently, primary ACL reconstruction most commonly is performed using autograft tissue harvested from the middle third of the patellar tendon. Purely ligamentous grafts, a combined semitendinosus and gracilis tendon construct, have become increasingly popular during the last 10 years with several reports supporting their efficacy [20, 24, 29, 41]. Any autograft has the distinct disadvantage of harvest-site morbidity, increased operative time, and dependence on donor tissue integrity. Additional disadvantages include patellar injuries with bone-tendon-bone (BTB) autografts, postoperative neuroma, additional scars, and the possibility of harvested tissue being insufficient for repair [6, 15, 20, 42]. Sacrifice of the hamstring tendon is

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Each author certifies that his institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research, and that informed consent was obtained.

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not without risk during harvesting, specifically nerve damage to the saphenous nerve has been reported [43]. Postoperatively, there is a reported decrease ranging from 10% to 20% in knee flexor strength, a decrease presumed to affect internal rotation strength enough to warrant restricted use in certain populations of athletes; sprinters and activities requiring prolonged or deep squatting [25, 36, 44, 50].

Allograft tissue has certain advantages, which include lack of donor-site morbidity and reduced operative time. Some data suggest ACL reconstruction using an allograft source allows for a more aggressive rehabilitation protocol with less postoperative pain and stiffness as compared with autografts [2, 35, 42]. Various allograft tissue types exist, including patellar, achilles, tibialis, and peroneus longus tendons [51]. Semitendinosus and gracilis grafts are common sources and can be used in combination to form a quadruple hamstring construct for ACL reconstruction. This construct shows strength and stiffness comparable to BTB and is sufficient for reconstruction [21, 42]. Despite these advantages, concerns regarding allograft use include possible disease transmission, delayed graft incorporation and remodeling, increased laxity, and failure with prolonged use [3, 15, 33, 35]. Several studies have compared allografts with autografts in primary ACL reconstruction with results consistently showing equivalent clinical efficacy, however, these studies use bony attachments and use bone to bone tunnel ingrowth (BTB tendons), a possible consideration with exclusively soft tissue grafts [11, 22, 38, 46].

We asked whether (1) hamstring tendon allograft tissue stretches with time leading to increased laxity or an increased rate of failures, and (2) hamstring allograft constructs have a similar clinical performance in primary ACL reconstruction based on accepted clinical outcome scores as compared with traditional hamstring autograft constructs.

Materials and Methods

We prospectively enrolled 104 patients scheduled for primary ACL reconstruction by the senior author (AAS) from 1997 to 2000. We included patients with complete ACL rupture verified by MRI, who were skeletally mature and between the ages of 15 and 55 years. Patients were excluded if they had a previous ACL or ligamentous injury to the primary or contralateral knee which might effect rehabilitation or subjective scoring. Patients with concomitant MCL, LCL, or PCL injury, or an injury pattern needing cartilage restoration, realignment with osteotomy, or replacement of damaged meniscus with an allograft also were excluded from the study pool (Table 1). Eighty-four of the 104 patients (81%), 37 with autografts and 47 with allografts, were available for a minimum 36-month followup; 20 of the 104 patients could not be contacted for followup greater than 1 year after surgery and were excluded. The autograft group had a minimum followup of 38 months (mean, 52 months; range, 38–70 months), and the allograft group had a minimum followup of 36 months (mean, 48 months; range, 36–64 months) (Table 2). Institutional Review Board approval from the host institution was obtained before enrolling patients.

In addition to the standard surgical consent process for ACL reconstruction, patients were informed about allograft constructs, hamstring tendon autograft graft constructs, and the harvest procedure. The pertinent positives and negatives of both constructs were explained, and then the patient was asked to consent to randomization for graft selection for this study. Approximately 75% of the patients available at final followup had consented to randomization. Patients refusing allograft use or who specifically requested allograft use were placed in the appropriate unrandomized group. To increase study power, randomized and nonrandomized groups were pooled. Pooling also was necessary to ensure validity of this study because it was not clear if a small number of patients were randomized before surgery. Consequently, we thought pooling the patient population and accepting the data as a Level II therapeutic study was a more ethically conservative stance.

Study power was derived from a post hoc power analysis. The power of the final sample size for an accept-support study design, using a significance level of 5% and a test power greater than 80%, was calculated on the basis of two separate primary outcome measures. Failure in functional status as measured by the Lysholm score was designated to be a score difference greater than 15 points. This difference correlates with subjective sensation of instability and a lower patient satisfaction grade [31].

Table 1. Inclusion criteria

Complete ACL tear confirmed by MRI requiring primary ACL reconstruction
No additional ligament injury or laxity requiring surgical intervention; MCL, LCL, and PCL integrity intact
Radiographic evidence of skeletal maturity; patient between 15 and 55 years of age
No previous ACL or other ligament injuries to the primary or contralateral knee requiring reconstructive surgery
Patients not requiring a concurrent meniscal allograft, osteotomy, or major cartilage restoration or resurfacing procedure

ACL = anterior cruciate ligament; MCL = medial collateral ligament; LCL = lateral collateral ligament; PCL = posterior cruciate ligament.

Table 2. Patient demographics and operative characteristics

Cohort demographics	Semitendinosus and gracilis tendons		p Value*
	Autograft hamstrings	Allograft hamstrings	
Total number	37	46	
Males (number, %)	20 (54%)	26 (58%)	
Females (number, %)	17 (46%)	20 (42%)	
Age (years)	27 ± 7	31 ± 10	0.14
Followup (months; range)	52 ± 11 (38–70)	48 ± 8 (36–64)	0.07
Acute reconstructions (< 12 weeks)	18 (49%)	24 (52%)	
Chronic reconstructions (> 12 weeks)	19 (51%)	22 (48%)	
Subjects with meniscal repairs	14 (38%)	14 (30%)	0.48
Subjects with menisectomies	24 (65%)	32 (70%)	0.65
Total subjects with meniscal surgeries	34 (92%)	40 (87%)	0.48

* Mean age and followup compared with two-tailed independent sample t-test, all others with chi square test.

Table 3. Accept-support study power analysis

Measure	Observed difference between groups	Current sample sizes powered to detect absolute differences
Change in Lysholm score	5.2	8.7
Change in KT-1000 measurement	0.05	1.2

A second parameter is direct measurement of knee laxity by KT-1000 arthrometer side-to-side laxity with greater than 3 mm being a conservative determinant of increased laxity suggesting failure or graft stretch (Table 3). With the ethical constraint of patient education and choice, our prospective study was impossible to completely randomize.

Demographic comparison of cohorts did not identify any differences by two-tailed independent sample t-test or chi square test, in age, gender, concomitant meniscus injury, and percentage of chronic ACL ruptures defined as ACL-deficient knees for greater than 12 weeks before undergoing reconstruction despite incomplete randomization (Table 2). Similarly, intercohort preoperative Tegner, Lysholm, and subjective IKDC were similar as determined by independent t-test or chi square test (Tables 4, 5). In the absence of true randomization, we believed the two groups representing well-matched, clinically comparable cohorts were sufficient to use in this study of direct outcome measurement of allograft to autograft hamstrings for primary ACL reconstructions.

Surgery was performed in an identical standardized fashion for both cohorts of patients by the senior author (AAS). Autogenous hamstrings were harvested through a longitudinal incision centered over the pes anserinus insertion on the tibia. The semitendinosus and gracilis tendons were harvested using a closed tendon stripper and prepared in a quadruple construct with running baseball

Table 4. Knee laxity at final followup as a determinate for clinical outcome

KT-1000 arthrometer maximum manual side-to-side difference	Allograft ST&G hamstrings (Mean ± SD)	Autograft ST&G hamstrings (Mean ± SD)
Preoperative	6.0 ± 1.3	5.8 ± 1.5
Final followup	1.6 ± 1.5†	1.4 ± 1.3†
−1 to 2 (successful)	32 (87%)	40 (87%)
3 (borderline)	2 (5%)	5 (11%)
4 or greater (failure)	3 (8%)	1 (2%)
p value* = 0.33		

* Comparison of autograft hamstrings versus allograft hamstrings successful procedures, chi square test; †final score differs from preoperative score, $p < 0.001$ as determined by paired t-test; SD = standard deviation; ST&G = semitendinosus and gracilis tendons.

sutures at all four ends. The first 20 allograft constructs were processed by cryopreservation, after reported infections using cryopreserved graft tissue, fresh-frozen allograft constructs were used for the final 27 grafts. Perioperativly, both constructs were prepared in an identical fashion to the autograft construct after harvest. Graft constructs were sized to within 0.5 mm and pretensioned to 20 pounds for a minimum 20 minutes to reduce post-implantation graft creep [18, 26]. The minimum length of the quadruple construct was 120 mm to allow additional direct soft tissue to bone tibial-metaphyseal fixation in addition to interference screw fixation. After graft procurement, endoscopic reconstruction was performed in all cases. In a standard fashion the knee was surveyed for any chondral or meniscal disease, which was addressed with standard techniques including chondroplasty, meniscectomy, or meniscal repair. The tibial tunnel first was prepared by underdrilling 2 mm from the measured size of

Table 5. Subjective functional outcome measurement by Lysholm and IKDC

Clinical outcome questionnaire	Autograft ST&G hamstrings (Mean ± SD)	Allograft ST&G hamstrings (Mean ± SD)	p Value*
Lysholm score			
Preoperative	71.3 ± 8.6	67.7 ± 17	0.16
Final followup	91.0 ± 7.7†	92.7 ± 10†	0.75
Subjective IKDC scores			
Preoperative	57.5 ± 8.4	54.9 ± 13.1	0.29
Final followup	87.6 ± 10.2†	87.0 ± 11.7†	0.82

* Comparison of autograft hamstrings versus allograft hamstrings, subjective scores analyzed by chi square test; †final score differs from preoperative score, p = 0.07 (Lysholm), p = 0.05 (IKDC) paired t-test; IKDC = International Knee Documentation Committee; SD = standard deviation; ST&G = semitendinosus and gracilis tendons.

the graft construct and dilated in 0.5-mm increments to the desired size. Using an over-the-top guide with a 6-mm offset, a femoral socket was prepared in a similar fashion to 35 mm in depth by underdrilling and dilating to the appropriate size. The Acufex Endodrill bit (Smith & Nephew, Mansfield, MA) was used to drill through the center of the socket out the anterolateral femur. The total femoral length was measured, and the appropriate continuous loop EndoButton® (Smith & Nephew) was chosen so there would be 25 mm of graft in the femoral tunnel. Additional femoral fixation was performed with a 23-mm length bioabsorbable interference screw placed anterior to the graft (Arthrex, Naples, FL). The screw used on the femoral side was the same diameter as the femoral socket. Thereafter, the knee was cycled 30 to 40 times and brought to 5° short of full extension. Tibial fixation was achieved with a 28-mm length bioabsorbable interference screw that was 1.5 to 2.0 mm larger than the tibial tunnel diameter. Secondary tibial fixation was performed on the metaphysis of the tibia below the tunnel with a spiked washer and screw construct. Double fixation of the grafts was performed for two reasons. First, we wanted to eliminate fixation as a potential variable as much as possible. With a construct rigidly fixed on both sides, the only important variable would be the graft source. Second, from a biomechanical point of view, the interference screws provided proximal fixation of the grafts close to the joint line. This was to prevent the windshield wiper effect of the graft in the tunnel that sometimes has been implicated in tunnel widening. The metaphyseal fixation helped protect against theoretical cyclic slippage that has been reported with biointerference screw fixation of soft tissue grafts [7, 8, 18].

An identical postoperative rehabilitation protocol was used in both sets of patients and included immediate range of motion, home exercise, physical therapy, and continuous passive motion with importance placed on extension and flexion exercises. Weightbearing was permitted as tolerated unless the patient had a meniscal repair, in which case the patients were allowed touchdown weightbearing for approximately 4 weeks wearing a Bledsoe brace (Bledsoe Brace Systems; Grand Prairie, TX) locked in extension while walking. In patients without meniscal repairs, weightbearing was allowed as tolerated, and once the patient had good quadriceps control and at least 90° flexion, they were weaned off assistive devices and the Bledsoe brace and they wore an off-the-shelf Don-Joy (DJO; Vista, CA) ACL brace. Progressive range of motion and strengthening exercises were performed in a routine fashion with straight-ahead jogging permitted at 14 to 16 weeks, sports-specific training starting between 16 and 20 weeks, and return to full sports activities at 24 weeks if all parameters were met.

Clinical assessment was obtained by either the sports medicine fellow of the senior author or an orthopaedic resident (HJ, SK, AJH, JH); observers were blinded regarding whether patients had an autograft or allograft. We obtained the Lysholm functional score [31] and the International Knee Documentation Committee (IKDC) objective and subjective evaluation system [27, 28]. Preinjury activity was assessed with the Tegner subjective questionnaire [49], and knee laxity was quantitatively measured using a KT-1000 arthrometer (MEDmetric® Corporation, San Diego, CA) to quantitatively compare side-to-side anteroposterior knee laxity. Preoperative subjective questionnaires were completed before surgery, after consent and approval to study enrollment by the patient. Therefore, Lysholm and IKDC values were recorded before surgery and reflect the preoperative but not the preinjury state. We defined success as nearly normal and normal IKDC ratings. Objective data were collected during the initial visit and during a preoperative examination performed after general anesthesia was administered. At that time, complete ligamentous examination and KT-1000 arthrometer measurements were performed on both knees as an internal control at the maximum manual setting. Side-to-side differences in knee laxity were measured quantitatively with a KT-1000 arthrometer at maximal manual pressure only.

KT-1000 data also were categorized by the following subjective criteria: successful repair was judged a maximum manual side-to-side difference of −1 mm to +2 mm; borderline repair was considered a +3-mm difference; and failure was considered a side-to-side difference of 4 mm or greater. Graft stretch in the two groups was compared using the KT-1000 maximum manual measurements between groups. The two groups had similar mean preoperative knee laxities (Table 4) [12].

Patients subsequently were followed with office visits scheduled at 2 weeks, 6 weeks, 3 months, 6-months, 1 year, and then annually. An attempt was made to collect data during each office visit, but complete data sets were available only for initial visits, preoperative assessments, and final followups. Although data were collected during regularly scheduled followups, the frequency of rescheduled or missed appointments resulted in large variability in the temporal followup interval. Consequently, we limited the data to preoperative and final followups for clarity of the data and to reduce the clutter of numerous data points.

In this comparison study we attempted to validate the hypothesis that there is no clinically detectable difference in Lysholm scores, IKDC ratings, Tegner activity scales, and KT-1000 arthrometer measurements between patients treated with allograft and autograft tissue for primary ACL reconstruction at 3 years. Differences between the allograft and autograft groups were determined with the chi square test for categorical variables (objective functional outcomes for IKDC, subjective functional outcomes for Lysholm and IKDC, cohort demographics) or independent t-test for continuous variables (all other variables). Means were adjusted with analysis of covariance. We also compared clinical outcomes on the basis of mean change from preoperative score to final followup score as a determination of clinical improvement. The mean score at final followup was subtracted from the preoperative score to yield a Δ-score for that clinical measure. These Δ-scores then were compared between cohorts by an independent t-test. The level of significance was set at 5%; the results are presented as means and 95% confidence intervals unless otherwise stated.

Results

At final followup there was no difference ($p = 0.33$) in side-to-side laxity between the two cohorts but both improved ($p < 0.001$) over preoperative laxity (Table 4). KT-1000 measurements showed successful outcomes were maintained at 3 years in 87% (32 of 37) of the autograft group and 87% (40 of 46) of the allograft group, as predefined by the stability criterion; 5% (two of 37) in the autograft group and 11% (five of 47) in the allograft group were considered to have borderline failures, whereas 8% (three of 37) in the autograft group and 2% (one of 47) in the allograft group had laxity greater than 4 mm and thus were defined as having failed reconstructions (Table 4).

There were no differences between cohorts in Lysholm, subjective or objective IKDC, or Tegner activity scores at final followup (Tables 5–7). As expected, both cohorts had equivalent preoperative to final followup improvements in all clinical outcome scores. However, there was no change in the amount of improvement as determined by the delta

Table 7. Objective functional outcome ratings according to IKDC guidelines*

IKDC scoring	Autograft ST&G hamstrings (Mean ± SD)	Allograft ST&G hamstrings (Mean ± SD)
Objective IKDC scores		
Preoperatively		
Nearly normal	0	1
Abnormal	28	37
Severely abnormal	9	8
Final followup		
Normal	12	19
Nearly normal	19	19
Abnormal	4	6
Severely abnormal	2	2
Satisfactory results	84%	83%

* Mean score comparison of autograft versus allograft hamstrings analyzed by chi square test, $p = 0.51$ for preoperative and $p = 0.80$ for final followup; IKDC = International Knee Documentation Committee; SD = standard deviation; ST&G = semitendinosus and gracilis tendons.

Table 6. Tegner scores of preinjury and final followup activity levels

Tegner questionnaire score	Autograft ST&G hamstrings (Mean ± SD)	Allograft ST&G hamstrings (Mean ± SD)	
Total number	37	46	
Preinjury score	7.2 ± 1.1	6.8 ± 1.3	0.14
Final followup score	6.8 ± 1.2†	6.9 ± 1.3	0.08

Comparison of autograft hamstrings versus allograft hamstrings, independent t-test; †final score differs from preoperative score, $p = 0.08$, paired t-test; SD = standard deviation; ST&G = semitendinosus and gracilis tendons.

Table 8. Comparison of measurement outcome changes

Clinical outcome measure	Mean ± standard error		p Value, independent sample t-test (Group 1 versus Group 2)
	Autograft (n = 7)	Allograft (n = 7)	
Preoperative Tegner score	7.2 ± 0.2	6.8 ± 0.2	
Final Tegner score	6.8 ± 0.2	6.9 ± 0.2	
Difference in Tegner scores	−0.4 ± 0.25*	0.05 ± 0.2*	0.14
Preoperative Lysholm score	71.3 ± 1.5	67.3 ± 2.4	
Final Lysholm score	91.0 ± 1.2	92.8 ± 1.3	
Difference in Lysholm scores	19.7 ± 1.6†	25.5 ± 3.1†	0.052
Adjusted difference in Lysholm scores‡	20.3 ± 2.3	25.0 ± 2.0	0.12
Preoperative IKDC score	57.5 ± 1.4	54.9 ± 1.9	
Final IKDC score	87.5 ± 1.7	86.8 ± 1.7	
Difference in IKDC scores	30.0 ± 1.9†	31.8 ± 2.5†	0.48
Preoperative KT-1000 measurement	6.0 ± 0.2	5.9 ± 0.2	
Final KT-1000 measurement	1.4 ± 0.2	1.5 ± 0.2	
Difference in KT-1000 measurements	4.6 ± 0.3†	4.5 ± 0.3†	0.70

* Two-year versus preoperative change not significantly different from zero in each group; †2-year versus preoperative change significantly different from zero in each group, $p < 0.001$; ‡adjustment for age did not affect mean differences or p values in Tegner, IKDC, or KT-1000; IKDC = International Knee Documentation Committee.

(Δ) change from preoperative to final followup scores between allograft constructs as compared with autograft constructs at 3 years followup (Table 8).

Three patients with failed results in the autograft group and two with failed results in the allograft group underwent revision surgery. The three patients in the autograft group with failed results included two females who had acute rerupture of their ACL 1 year after reconstruction after sustaining injuries in sporting events (one while playing soccer, one while playing field hockey). The third patient with a failed result in the autograft group was a male who had progressive laxity of the knee develop during the first 14 months after surgery. Of the two patients in the allograft group with failed reconstructions (one cryopreserved and one fresh frozen), one was a recreational basketball player who sustained an acute injury 1 year after the initial surgery, and the other was a recreational tennis player who had instability symptoms develop from repetitive microtrauma 18 months after reconstruction surgery. There were no cases of arthrofibrosis, infection, nerve injury, deep venous thrombosis, or failure of fixation in either treatment group during the study.

Discussion

Hamstring tendons are clinically effective as a graft choice with strength and stiffness comparable to the previous gold standard graft choice, central-third patella tendon graft [19, 22, 24, 40, 47]. We asked whether (1) hamstring tendon allograft tissue stretches with time leading to increased laxity or an increased rate of failures, and (2) hamstring allograft constructs have a similar clinical performance in primary ACL reconstruction based on accepted clinical outcome scores as compared with traditional hamstring autograft constructs. We presumed allograft constructs would provide equally stable constructs with similar laxities at greater than 3 years followup when compared with identical autograft constructs.

Limitations of our study include pooling of randomized and nonrandomized patients into respective cohorts. We recognize this as a limitation but the pooling increases the power of the comparison and the cohorts were comparable in every potential confounder examined. We believe the increased power offsets the concern about lack of full randomization and patients have a right to determine whether they will be randomized. Second, we were not able to accurately monitor rehabilitation progress in either group; however, this trend was not evident in patients in the allograft group whose average self-reported activity scores increased after surgery (Table 4). Twenty of 104 (19%) patients were lost to followup which is a limitation, but we consider this acceptable given the duration of the study and number of patients available at final followup. Additional limitations of this study include data being limited to ACL reconstructions using hamstring tendons as the graft choice, and the results from this study are from surgeries performed by one experienced surgeon. The conclusions may not be generalizable to other sorts of reconstructions. Finally, 20 of the hamstring allograft constructs were cryopreserved and 27 were fresh frozen.

Owing to limited numbers, we did not attempt to segregate and compare the two processing methods in the allograft cohort. One cryopreserved allograft and one fresh-frozen allograft had failed results.

Graft tissue source, bone containing or all soft tissue, is still debated among surgeons reconstructing the ACL. Numerous studies have been published comparing traditional gold standard BTB graft with an all soft tissue graft such as hamstring tendon. One theory is that bone-to-bone healing in the tunnel provides a more stable construct with better graft integration and stability. However, the majority of the results show hamstring tendons have comparable clinical results to BTB with less donor-site morbidity, potentially less postoperative motion problems, less anterior knee pain, and less kneeling pain [1, 5, 6, 14, 24, 39, 45]. Several systematic reviews have been published to consolidate and address the issue of graft choice but some variability in results leads to some lack of clarity [16, 19, 24, 47]. One report regarding discordant systematic reviews clearly shows there are lower rates of anterior knee pain in hamstring tendon autografts and suggests there is not enough evidence to support patellar grafts provide better stability [40].

There have been studies comparing allograft constructs with similar autograft constructs for primary ACL reconstruction with results suggesting equivalent clinical efficacy. However all of these studies use bone containing grafts (BTB tendons) [22, 38, 46, 48]. It is possible that the bone-to-bone healing is a factor in allograft processed tissue, although no data specifically address this issue, and it is possible that there is slower healing theoretically exhibited by exclusively soft tissue grafts [23, 37, 42]. This may lead to an increased rate of failures secondary to graft stretch with repetitive tensioning, but this concept is yet unproven clinically. Furthermore, harbored infection is more difficult to treat in dense calcified tissue like bone compared with tendinous tissue, and to date all documented disease transmissions from allograft tissue have been from a bone-containing graft [4, 10, 42]. Based on these principles we thought it was important to validate the efficacy of an all soft tissue graft such as a hamstring tendon.

Our objective was to compare similar graft constructs in similar patient populations. Specifically, we attempted to address the question of long-term viability of grafts as determined by increased laxity or graft failure at followup greater than 3 years. Based on KT-1000 measurements we found no evidence of increased laxity in allograft constructs or an increase in failure rate as compared with identical autograft constructs. Second, we used known clinical outcome measures to determine clinical efficacy of graft choice for ACL reconstruction. All measures were similar in both groups which suggests the four-bundle hamstring tendon allograft is clinically comparable to identical autograft tendon.

It is not unique to consider the multiple advantages of using the allograft hamstring construct. If graft integrity clinically is equal, then other discrepancies between graft choices become more of a consideration and support the use of allograft constructs [3]. One of these considerations is the substantial learning curve for harvesting tendons properly and completely. There often is variability in the quality and length of the tissue potentially compromising the strength of the graft and the fixation. In addition, hamstring weakness may be more important than we previously thought and may play a role in certain types of athletic endeavors or daily activities (eg, sprinting or activities that require a long period of deep squatting) [9]. Isokinetic testing 2 years after autograft hamstring ACL reconstruction showed more loss in knee flexion strength than previously recognized according to Nakamura et al. [36]. Segawa et al. also studied graft donor-site morbidity by quantifying persistent weakness of internal rotational torque after autogenous hamstring harvesting [44].

As allograft use increases, transmission of disease continues to be a controversial reason for not using allograft tissue. In addition, there may be issues regarding graft incorporation and healing [3, 4, 13, 15, 17, 23, 32]. The data are unclear but suggest allograft tissue leads to longer remodeling times and incorporation in the bone tunnels as observed with autograft tissue. This is an underlying premise in the concept that allografts are prone to stretch or clinically have a higher failure rate. Addressing this clinical question was the central objective of our study, and at greater than 3 years followup we found no evidence of increased laxity.

We used allograft hamstrings in this study comparing identical constructs. We believe the data probably can be extrapolated to apply to other soft tissue, nonirradiated, cryopreserved, or fresh-frozen allograft constructs such as the increasingly popular tibialis tendon, which likewise is an all soft tissue allograft construct except that it is a double-strand rather than a quadruple-strand construct. Furthermore, there have been no reported cases of disease transmission with an all soft tissue fresh-frozen allograft source such as hamstring or tibialis tendons.

Our data, specifically the KT-1000 data (Table 5), provide evidence suggesting allograft constructs do not stretch with time and do not have increased laxity leading to clinical failure during the time of the study. Five patients had failed reconstructions in this study—three in the autograft group and two in the allograft group. All failures occurred within 18 months after the index procedure. Although slower incorporation remains a basic science concern in reference to allograft tissue, we used a standard rehabilitation protocol and allowed the same time to return

to sports in both groups. The theoretical slower biologic incorporation of soft tissue to bone did not manifest itself clinically, similar to the experience with autograft reconstructions, allowing accelerated rehabilitation programs and quicker return to sports.

At short- to intermediate-term followup, an allograft hamstring construct performs just as well as an autograft hamstring construct in all clinically monitored parameters. Given some of the potential advantages of allograft constructs (no donor-site morbidity, shorter operative time, a potential graft tissue source for backup when harvested tissue is inadequate, and the ability to preoperatively select the appropriate length and diameter graft, thus adjusting to the size and weight of the patient), allograft constructs are becoming more widely used. The performance of the allograft counterpart of the typical autograft hamstring construct performs as well by all criteria at short- to intermediate-term followup.

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