Anterior Cruciate Ligament Reconstruction Using a Combination of Autograft and Allograft Tendon

A MOON Cohort Study

James E. Darnley,* BS, Benjamin Léger-St-Jean,*† MD, Angela D. Pedroza,* MPH, David C. Flanigan,*† MD, Christopher C. Kaeding,*† MD, and Robert A. Magnussen,*†‡ MD, MPH

Investigation performed at The Ohio State University Wexner Medical Center, Columbus, Ohio, USA

Background: Anterior cruciate ligament (ACL) reconstruction with hamstring autografts less than 8.5 mm in diameter is associated with worse patient-reported outcome scores and increased risk of revision surgery compared with reconstructions performed with larger grafts. One proposed solution to small autograft harvest is to create a hybrid graft by augmenting autografts with allograft tissue to increase graft diameter.

Purpose: To compare hybrid autograft/allograft ACL reconstruction to autograft ACL reconstruction, specifically analyzing the patient-reported outcome scores and the risk of revision surgery at 2 years postoperative.

Study Design: Cohort study; Level of evidence, 3.

Methods: From the years 2002 to 2009, a total of 34 patients were identified from a prospectively collected database as having undergone hybrid ACL reconstruction. Twenty-seven of 34 (79.4%) patients had a 2-year follow-up. These 27 patients were matched by age (within 1 year) and sex to 27 patients who underwent hamstring autograft ACL reconstruction during the same period. At the 2-year mark, revision surgery risk and patient-reported outcome scores were compared between the 2 groups.

Results: The mean age for the hybrid and matched groups (±SD) was 20.9 ± 7.0 years. Both the hybrid and control groups had 17 males and 10 females. There was no significant difference in preoperative patient-reported outcome scores, meniscus tears, or cartilage lesions between the 2 groups. Graft size was larger in the hybrid group (9.5 ± 0.6 mm) than in the autograft group (8.4 ± 0.9 mm) ($P < .001$). At 2 years postoperative, patient-reported outcome scores were similar between the hybrid and autograft groups. Revision surgery was required in 5 (18.5%) patients who underwent hybrid reconstruction compared with 2 (7.4%) of those who underwent autograft reconstruction ($P = .26$).

Conclusion: Patients who undergo ACL reconstruction with hybrid hamstring grafts and hamstring autografts report similar patient-reported outcome scores at 2 years postoperative but may be at increased risk for revision ACL reconstruction.

Keywords: ACL reconstruction; hybrid graft; allograft; outcomes

The anterior cruciate ligament (ACL) is the most commonly reconstructed ligament in the knee, with approximately 100,000 reconstructions performed each year in the United States.[3] A common method of ACL reconstruction utilizes hamstring autograft.[1] This technique has been shown to provide a stable knee after surgery for most patients; however, revision surgery is necessary in some cases. Several studies have demonstrated that grafts less than 8.5 mm in diameter are associated with a greater risk of revision[15,16,20] and worse patient-reported outcome scores.[16]

Several solutions have been proposed for the problem of small hamstring autograft harvest. One option is to use the tendon as is, accepting a potential increased risk of revision due to the small graft. A second possibility is to fold the tendons to yield a thicker 5- or 6-strand graft rather than the traditional 4-strand graft.[11,12] As this method makes the graft shorter, in addition to making it thicker, it may not be possible with short tendons.[23] A third option is to opt for a different autograft or allograft source. Additional autograft harvest increases morbidity, while allograft reconstruction has been associated with increased graft failure risk in young, active patients.[9,10] An additional proposed solution to inadequate graft diameter is to augment the patient's own tendon with an allograft, creating a

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hybrid autograft/allograft. This construct seeks to address the problem of small graft diameter, but it is unclear whether the introduction of allograft tissue may lead to poorer outcomes.[14] One recent retrospective study by Burrus et al[4] showed that such hybrid ACL grafts may fail at a greater rate (13.8% vs 3.4%; $P = .16$) and have less favorable outcome scores than a matched hamstring autograft group.

The purpose of this study was to compare the 2-year postoperative outcomes of patients treated with hybrid ACL reconstruction with those who underwent hamstring autograft ACL reconstruction. We hypothesized that similar patient-reported outcomes and failure risk would be noted in the 2 groups.

METHODS

Patient Population

Following approval by the institutional review board at our institution, patients who underwent hybrid ACL reconstruction were identified from a prospectively collected database. A total of 393 patients undergoing ACL reconstruction were enrolled in the database at our institution between 2008 and 2011, including 79 revision reconstructions. Of the 314 primary ACL reconstructions enrolled, 252 patients received hamstring autografts, 28 received allografts, and 34 patients underwent hybrid autograft/allograft ACL reconstruction. Twenty-seven of 34 patients (79.4%) were available for 2-year follow-up. Each patient underwent harvest of his or her native hamstrings that yielded a graft of less than 8 mm in diameter. These 27 patients were matched by age (within 1 year) and sex with 27 patients who underwent hamstring autograft ACL reconstruction during the same time period. An investigator who was blinded to patient outcomes performed the matching. No patients had additional knee ligament injuries other than grade 1 medial cruciate ligament (MCL) injuries.

Collected data included graft size, patient demographics (sex, age at surgery), intraoperative findings (meniscus and cartilage status), femoral tunnel drilling technique (transtibial vs independent), and patient-reported outcome scores (International Knee Documentation Committee [IKDC],[7] Knee injury and Osteoarthritis Outcome Score [KOOS],[22] and Marx activity score[17]) prior to surgery. At 2 years postoperative, patients were contacted and provided information regarding any subsequent ipsilateral knee surgery (including revision ACL reconstruction) and completed the same patient-reported outcomes that they had provided preoperatively.

Surgical Technique

The semitendinosus and gracilis tendons were harvested via a standard anterior approach, stripped of any remaining muscle, whipstitched on both ends, and doubled over to form a 4-strand graft. Grafts were then measured on the back table to determine the diameter. Grafts with a diameter of less than 8 mm were augmented with a semitendinosus tendon allograft at the discretion of the operating surgeon. All allografts were processed and sterilized using a proprietary technique involving aseptic harvest, antibiotic washes, and freezing that was free of high-dose irradiation (>2.5 Mrad) or ethylene oxide exposure (Musculoskeletal Transplant Foundation). Some grafts received low-dose irradiation per the proprietary process depending on the findings of their analysis during preparation. In the majority of cases, only 1 autograft hamstring tendon, usually the semitendinosus, was combined with an allograft semitendinosus tendon to form the graft (n = 18). When the native semitendinosus was too short, the native gracilis was combined with allograft tendon to form the hybrid graft (n = 2). At times, both the native semitendinosus and gracilis tendons were combined with the allograft semitendinosus to make a 6-strand graft (n = 7).

An arthroscopic-assisted technique was then used to complete the ACL reconstruction. Femoral tunnels were drilled through a transtibial method or outside-in method per the preference of the attending surgeon. The femoral tunnel was consistently drilled to be the same diameter as the prepared graft. In all cases, femoral fixation was performed using a cortical button. Tibial fixation was achieved with the use of an interference screw backed up with either a staple or a screw and washer. An accelerated ACL postoperative rehabilitation was used in all patients.[25] Return to sport typically occurred at 8 months if all of the rehabilitation goals had been met. There was no change in the rehabilitation protocol compared with standard practice at our institution for ACL reconstruction with an autograft tendon.

Statistics

Patient demographics and outcome data were gathered and tabulated, and summary statistics were generated. Comparison of normally distributed continuous variables between the hybrid and autograft groups was performed using paired *t* tests, while continuous variables that were not normally distributed were compared utilizing Wilcoxon signed-ranks tests. Dichotomous variables were compared using the McNemar test, and categorical variables with multiple levels were compared between the 2 groups using conditional logistic regression. A power analysis determined

‡Address correspondence to Robert A. Magnussen, MD, MPH, OSU Sports Medicine, 2050 Kenny Road, Suite 3100, Columbus, OH 43221, USA (email: robert.magnussen@gmail.com).

*OSU Sports Medicine, Sports Health and Performance Institute, The Ohio State University, Columbus, Ohio, USA.

†Department of Orthopaedics, The Ohio State University, Columbus, Ohio, USA.

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TABLE 1
Preoperative Data[a]

Outcome	Autografts (n = 27)	Hybrids (n = 27)	*P* Value
Age, y	20.9 ± 7.0	20.9 ± 7.0	Matched
Sex, male:female, n	17:18	17:18	Matched
IKDC	48.5 ± 16.1	45.4 ± 14.2	.31
KOOS-ADL	81.0 ± 15.0	76.0 ± 21.5	.28
KOOS-QOL	28.9 ± 14.1	33.8 ± 22.3	.32
KOOS-Sport	35.2 ± 21.7	78.3 ± 29.9	.64
KOOS-Pain	70.1 ± 15.3	66.9 ± 17.9	.46
KOOS-Symptoms	67.4 ± 17.4	63.3 ± 18.6	.33
Marx activity score, median (IQR)	14 (6-16)	16 (12-16)	.06

[a]Data are reported as mean ± SD unless otherwise indicated. ADL, activities of daily living; IKDC, International Knee Documentation Committee; IQR, interquartile range; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, quality of life.

that at least 24 patients per group were required to detect a 10-point difference in IKDC scores between the hybrid and autograft groups with 80% power and $\alpha = 0.05$. All statistical tests were performed using Stata (version 12.1; StataCorp).

RESULTS

Of the 34 patients who underwent ACL reconstruction using a hybrid autograft/allograft tendon between 2008 and 2012, a total of 27 (79.4%) were available for follow-up at 2 years postoperative. These 27 patients were matched with 27 patients reconstructed with hamstring autograft to form the study group. There were 17 males and 10 females in each group. The mean age of the patients (±SD) was 20.9 ± 7.0 years (range, 13-46 years). No significant differences in preoperative IKDC, KOOS, or Marx activity score were noted between the 2 groups (Table 1). No significant differences in associated collateral ligament, meniscus, or cartilage injuries or femoral tunnel drilling technique was noted between the 2 groups (Table 2). The final graft size was noted to be larger in the hybrid group (9.5 ± 0.6 mm) than the autograft group (8.4 ± 0.9 mm) ($P < .001$).

Two years postoperatively, no significant differences in KOOS, IKDC, or Marx activity score were noted between the hybrid and autograft groups (Table 3). Both groups demonstrated significant improvements in KOOS and IKDC compared with preoperative values ($P < .001$). Revision ACL surgery was performed in 5 patients in the hybrid group (18.5%) and 2 patients in the autograft group (7.4%) ($P = .26$). The mean time to revision was 11.3 months in the hybrid group and 8.8 months in the autograft group. During the follow-up period, contralateral ACL reconstruction was performed in 1 patient in the hybrid group (3.7%) and 3 patients in the autograft group (11.1%) ($P = .32$). The overall risk of subsequent ACL reconstruction in either knee in the 2-year follow-up period was 22.2% in the hybrid group and 18.5% in the autograft group ($P = .71$).

TABLE 2
Intraoperative Data

Outcome	Autografts (n = 27)	Hybrids (n = 27)	*P* Value
Collateral ligament injuries			≥.999
None	25	25	
Grade 1 MCL	2	2	
Medial meniscus tears			.39
None	14	15	
Resection	8	6	
Repair	4	2	
Untreated	1	4	
Lateral meniscus tears			.07
None	10	14	
Resection	11	11	
Repair	3	1	
Untreated	3	1	
Cartilage lesions			
Medial compartment			.94
Grade 0/1	20	21	
Grade 2-3	6	5	
Grade 4	1	1	
Lateral compartment			≥.999
Grade 0/1	19	19	
Grade 2-3	8	8	
Grade 4	0	0	
Patellofemoral compartment			.14
Grade 0/1	22	26	
Grade 2-3	5	1	
Grade 4	0	0	
Femoral tunnel drilling technique			.07
Transtibial	14	8	
Outside-in	13	19	
Graft size, mm, mean ± SD (range)	8.4 ± 0.9 (7-10)	9.5 ± 0.6 (8-10)	<.001

DISCUSSION

The most important finding of this study is that although hybrid hamstring autograft/allograft reconstruction results in similar patient-reported outcomes scores to those achieved with hamstring autograft ACL reconstruction, these grafts may be associated with an increased risk of revision surgery. Only 1 previously published study addresses the outcomes of hybrid grafts for ACL reconstruction.[4] While both studies are underpowered to detect a difference in failure risk between hybrid and autograft hamstring grafts, both studies noted a relatively high failure risk in the hybrid group (17.8% in the current study and 13.8% in the study by Burrus et al[4]). For comparison, prior work evaluating the effect of hamstring autograft size on outcomes of ACL reconstruction demonstrated revision risks of 7.0% and 8.6% for patients reconstructed with autografts of 8 mm or less in diameter.[15,16] While these populations are not directly comparable due to the flexible criteria for the use of hybrid grafts in both studies, the reported failure risks are not encouraging.

TABLE 3
Two-Year Outcome Data[a]

Outcome	Autografts (n = 27)	Hybrids (n = 27)	*P* Value
IKDC	81.5 ± 15.6	80.3 ± 13.2	.77
KOOS-ADL	96.1 ± 7.5	95.0 ± 7.9	.61
KOOS-QOL	65.7 ± 21.5	69.9 ± 18.9	.45
KOOS-Sport	80.1 ± 20.4	79.3 ± 20.5	.88
KOOS-Pain	90.2 ± 9.8	90.4 ± 9.7	.94
KOOS-Symptoms	83.9 ± 12.7	84.1 ± 12.4	.93
Marx activity score, median (IQR)	9 (4-13)	8 (3-14)	.81
Revision ACL surgery performed, n (%)	2 (7.1)	5 (17.8)	.26

[a]Data are reported as mean ± SD unless otherwise indicated. ACL, anterior cruciate ligament; ADL, activities of daily living; IKDC, International Knee Documentation Committee; IQR, interquartile range; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, quality of life.

Hybrid grafts were suggested as a potential solution to the problem of small hamstring graft harvest because they do offer several advantages, the most important of which is the avoidance of a small graft without additional harvest morbidity.[14] The mean hybrid graft diameter in the current study was 9.5 ± 0.6 mm in a group of patients in whom a standard doubled gracilis/semitendinosus graft diameter was less than 8 mm. Because previous publications have associated small graft diameter with increased revision risk,[15,16,20] it was hypothesized that increasing the graft size through allograft augmentation may decrease failure risk. The findings of the current study and that by Burrus et al[4] bring this hypothesis into question.

The reason for the relatively high failure risk of hybrid grafts is not completely clear, although the presence of allograft material in the graft is clearly a concern, given the increased risk of allograft failure in young, active patients.[9] While the etiology of increased allograft failure rates is likely multifactorial, different patterns of revascularization and ligamentization may contribute. Numerous animal studies[5,8,19] and as well magnetic resonance imaging (MRI) studies[18] in humans have demonstrated slower revascularization and ligamentization in allografts. The presence of allograft tissue in a hybrid graft may thus potentially compromise graft mechanical properties. The mean time to hybrid graft revision in the current study was 11.3 months; in the study of Burrus et al,[4] all hybrid graft failures occurred within 9.7 months of surgery. It has been suggested that patients with allograft reconstructions should return to sport at a slower pace than the traditional 6-month mark to allow the graft to incorporate.[9]

Allograft processing has also been shown to influence allograft mechanical properties.[6,21] Thus, one must carefully consider the allograft processing technique that was utilized when evaluating any graft that contains some allograft tissue. Both the current study and that by Burrus et al[4] utilized grafts without high-dose terminal irradiation. Low-dose irradiation such as that utilized in these studies has been shown to have minimal effect on graft mechanical properties.[2,6] Grafts processed with other techniques or fresh-frozen grafts may yield different results.

Another explanation of the high failure risk of hybrid grafts is that the patient population that has smaller hamstring tendons is simply a higher risk group than those with larger grafts for reasons other than graft size. Younger age (a known risk factor for graft failure) has been shown by several authors to be associated with smaller graft size,[16,20] although graft size has been shown to be an independent predictor of revision risk when controlling for age.[15] Ma et al[13] looked at 536 patients who underwent autograft ACL reconstruction and found that height and female sex were indicators of a small graft size, while Treme et al[24] showed that weight or a body mass index less than 18 kg/m^2 and height were risk factors for small graft diameter.

The current study demonstrated similar patient-reported outcome scores when reconstruction was performed with hamstring autograft or hybrid grafts. This finding contrasts the study of Burrus et al,[4] in which the hybrid group had a significantly worse IKDC score (71.3 ± 19.5) than the autograft group (85.7 ± 13.0). A potential reason for this difference is a greater number of meniscal repair failures (n = 5) in the hybrid group relative to the autograft group (n = 1) in the study by Burrus et al.[4]

There are several limitations to this study that should be addressed. First, graft failure was defined as the performance of a revision ACL reconstruction, which likely underestimates the true failure risk as some patients who suffered graft failure may not seek revision surgery. Furthermore, as is the case with the previous study in the literature on this topic,[4] this study is underpowered to determine whether the difference in failure risk between the 2 groups is statistically significant. A post hoc power analysis determined that our sample of 27 patients per group was only powered to detect a failure risk in the hybrid group that was greater than 37.5% with 80% power and $\alpha = 0.05$. Additionally, the study falls just short of 80% clinical follow-up (79.4%), potentially increasing the risk of bias. Finally, differences in the 2 groups that were not large enough to reach statistical significance (activity level, femoral tunnel drilling technique) and possibly other unidentified risk factors may have led to selection bias, as this study was not randomized. Despite these limitations, the current study supports previously published work on hybrid autografts that suggest an increased risk of failure. Larger studies are necessary to confirm these findings and explore the etiology of any increased failure risk.

CONCLUSION

Patients who undergo ACL reconstruction with hybrid hamstring grafts and hamstring autografts report similar patient-reported outcome scores at 2 years postoperative. Further work is required to investigate potential increased risk of revision ACL reconstruction.

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