Allograft Anterior Cruciate Ligament Reconstruction in Patients Younger Than 30 Years: A Matched-Pair Comparison of Bone–Patellar Tendon–Bone and Tibialis Anterior

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Abstract

We conducted a study to compare patient-reported outcomes and graft-rupture rates of bone–patellar tendon–bone (BPTB) and tibialis anterior (TA) allograft primary anterior cruciate ligament (ACL) reconstruction in patients younger than 30 years.

Patients were retrospectively identified as having undergone ACL reconstruction with either a BPTB (n = 20) or a TA (n = 20) allograft. Each patient in the BPTB group was matched to a patient in the TA group based on sex, age at time of surgery, height, weight, and preoperative activity level. The Lysholm Knee Scoring Scale and the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form were administered at a minimum of 1 year after surgery.

Mean Lysholm scores were 92.9 (BPTB) and 93.0 (TA), and mean IKDC scores were 92.6 (BPTB) and 90.3 (TA). The differences were not statistically significant. Overall graft-rupture rates for the study period were 4.7% (BPTB) and 1.9% (TA) ($P = .18$). There was no statistically significant difference in patient-rated outcomes and graft-rupture rates between BPTB and TA allografts for ACL reconstruction at a minimum of 1 year after surgery.

Future research efforts should focus on mid- and long-term follow-up and objective outcomes.

Since 1984,[1] use of allografts in anterior cruciate ligament (ACL) reconstruction has increased. Operations with allografts are shorter, and there is no donor-site morbidity. The allograft tissues most commonly used for reconstructive knee ligaments are bone–patellar tendon–bone (BPTB) and Achilles tendon.[2] Although less common, use of tibialis anterior (TA) tendon as an ACL allograft option dates back to 1986.[3]

Although BPTB autografts have been described as the gold standard,[4-8] several studies[9-14] have found no significant differences between BPTB autografts and allografts based on a variety of outcomes. Given the more recent introduction of the TA tendon as a typical ACL allograft option, less data has been published on these grafts, with very few comparisons to other graft types. No studies have directly compared patient-reported outcomes between BPTB allografts and TA allografts for ACL reconstruction.

We conducted a study to obtain a matched comparison of patient-reported outcomes and graft-rupture rates of BPTB and TA allograft primary ACL reconstruction in patients younger than 30 years. We hypothesized there would be no significant differences between the groups.

Materials and Methods

This study received institutional review board approval. Patients who had primary ACL reconstruction with BPTB allograft or TA allograft between January 2006 and February 2011 were retrospectively included in the study. All BPTB allografts were performed by Dr. Ciccotti, and all TA allografts by Dr. Cohen. Patients who later had revision ACL reconstruction were identified in order to determine the graft-rupture rate for each graft type during the study period.

For the matched-pair comparison, patients with previous surgery on the repaired knee and patients over 30 years of age at time of surgery were excluded. Each of the 20 patients in the BPTB group was matched to a patient in the TA group based on sex, age within 1 year at time of surgery, height within 12 cm, weight within 8 kg, and preoperative activity level. Patients included in the study were not consecutive. Rather, patients' cases were retrospectively reviewed to determine appropriate

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matched pairs based on the criteria mentioned. Patients were contacted by telephone at a minimum of 1 year after surgery. They were evaluated based on their scores on the Lysholm Knee Scoring Scale and the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form. Both sets of scores were compared using a paired *t* test.

Surgical Technique

BPTB Allograft. ACL reconstruction was performed with the patient in the supine position using a tourniquet and a lateral leg post. Standard arthroscopic portals were placed, including superomedial outflow, anterolateral visualization, and anteromedial instrumentation portals. A diagnostic arthroscopy was performed, and any concomitant meniscal or chondral surgery was performed. The remnant of the ACL was then debrided. A limited notchplasty was performed, if any anatomical narrowing was identified. The anatomical origin and insertion sites were then marked using a thermal device. On the femoral side, this was done at either the 9:30 position (right knee) or the 2:30 position (left knee). On the tibial side, this was done at the central aspect of the tibial insertion (medial to but in line with the anterior horn of the lateral meniscus). The fresh-frozen BPTB allograft was then sized with the femoral plug 9 mm × 20 mm and with the tibial plug 10 mm × 20 mm. Heavy sutures were placed in both ends of the graft to facilitate graft passage. The graft was then set aside in a saline-moistened sponge. The tibial guide pin was then placed using a standard ACL guide set to 50°/55°. This guide was placed through the anteromedial portal and engaged on the tibia through a 2-cm incision, approximately 4 cm distal to the joint and 2 cm to 3 cm medial to the tibial tubercle. The guide pin was then overdrilled with a compaction reamer the same size as the graft's tibial bone plug. A standard over-the-top femoral guide was then placed through the tibial tunnel and engaged on the posterior aspect of the femoral notch at the previously determined site. A beath pin was then inserted through the femoral guide while the knee was held in 100° to 110° of flexion. The appropriately sized reamer was then placed over the beath pin and drilled to 5 mm to 10 mm farther than the length of the femoral bone plug. The BPTB allograft was then pulled into place in a retrograde fashion under direct visualization via the sutures through the eyelet of the beath pin. The femoral bone plug was then fixed with a bioabsorbable interference screw (Stryker Howmedica, Mahwah, New Jersey) placed through an accessory portal. The graft was cycled to remove any crimp, and the tibial bone plug was externally rotated 90° in the tibial tunnel. The tibial bone plug was then fixed with another bioabsorbable interference screw with the knee maintained in full extension.

TA Allograft. ACL reconstruction was performed with the patient in the supine position using a tourniquet, a lateral leg holder, and a paint roller to position the knee in 90° of flexion. Three arthroscopic portals were used: standard anterolateral and anteromedial, and an accessory medial portal for drilling the femoral tunnel. After the diagnostic arthroscopy and any concomitant meniscal or chondral treatment, the ACL was debrided. The anatomical insertion site was then marked using a thermal device at the central aspect of the tibial insertion (medial to but in line with the anterior horn of the lateral meniscus). On the femur, the ACL stump was removed from the lateral intercondylar notch, and a microfracture awl was used to mark the femoral insertion site just posterior to the bifurcate ridge at the 9:30 position (right knee) or 2:30 position (left knee). No notchplasty was performed. The tibial guide pin was placed using an ACL guide set to 50°/55° and then overdrilled with a compaction reamer the same size as the graft. A pin was then inserted freehand through the tibial tunnel and was overdrilled using an acorn half-reamer transtibially only if it was able to reach the previously marked location on the femur. If the pin was too vertical, then the femoral tunnel was drilled through the medial portal with the knee flexed to 110°. The fresh-frozen TA allograft was doubled after whip stitches were placed on each end and then sized. An Endobutton (Smith & Nephew, Andover, Massachusetts) suspensory fixation device with a 15-mm loop was used for the femoral side. An interference screw and sheath (Biosure Sync; Smith & Nephew) was used for tibial fixation and was placed with the graft under longitudinal traction and the knee in full extension.

> [Our] results suggest that BPTB allograft and TA allograft are both appropriate options for primary ACL reconstruction.

Postoperative Rehabilitation

The knee was placed in full extension in a hinged knee orthosis. The brace was unlocked once quadriceps function was adequate, typically 2 to 3 weeks after surgery. Physical therapy was initiated at this point. Brace use was discontinued 4 to 6 weeks after surgery. Low-impact, in-line aerobic activity began within 2 to 3 months; straight-ahead running at 4 months; cutting and pivoting activities at 5 to 6 months, and full return to sports at 6 to 9 months.

Statistical Analysis

Paired *t* tests were used to compare all continuous outcomes between the BPTB and TA groups. Chi-squared tests were used to compare dichotomous outcomes. $P < .05$ was considered statistically significant.

Results

During the study period, 275 ACL reconstructions were performed with BPTB allografts, and 104 with TA allografts. At a minimum follow-up of 18 months after ACL reconstruction, 13 (4.7%) of the BPTB patients and 2 (1.9%) of the TA patients underwent revision ACL reconstruction. The difference was not statistically significant (P = .18).

According to the matched-pair comparison, the femoral tunnel was drilled using a transtibial approach in all 20 BPTB patients and in 11 TA patients; an anteromedial portal approach was used in the other 9 TA patients. Mean (SD) femoral tunnel length was 35.0 (0.0) mm in the BPTB group and 41.9 (6.1) mm (range, 28 to 56 mm) in the TA group (P < .001). Mean (SD) graft diameter at the central portion of the graft was 10.0 (0.0) mm in the BPTB group and 9.1 (0.9) mm in the TA group (P = .003). Both differences were statistically significant. Concomitant procedures were performed in 13 (65%) of the 20 BPTB patients and in 12 (60%) of the 20 TA patients (P = .64) (**Table I**).

Twenty matched pairs were selected. Patient comparisons are listed in **Table II**. No significant differences were found between the 2 groups in terms of age at time of surgery, height, weight, time to follow-up, subjective IKDC score at follow-up, and Lysholm score at follow-up. Mean (SD) subjective IKDC scores were 92.6 (7.8) for BPTB patients and 90.3 (8.7) for TA patients (P = .44). Mean (SD) Lysholm scores were 92.9 (6.0) for BPTB patients and 93.0 (8.0) for TA patients (P = .95). Each group consisted of 17 males and 3 females. All matched patients had similar preinjury activity levels (played the same sport or a similar sport at similar intensity levels). None of the matched patients had a complication that required revision surgery, and none had surgery on the same knee between ACL reconstruction and follow-up.

Table I. **Concomitant Procedures**

Concomitant Procedure	No. of Patients[a] BPTB	TA
Partial medial meniscectomy	2	2
Partial lateral meniscectomy	9	5
Medial meniscus repair	3	4
Lateral meniscus repair	0	2
PCL and posterolateral corner reconstruction	0	1
Removal of loose body	1	0

Abbreviations: BPTB, bone–patellar tendon–bone; TA, tibialis anterior; PCL, posterior cruciate ligament.
[a]Some patients had multiple concomitant procedures.

Table II. **Patient Comparisons**

		BPTB	TA	*P*
Age at surgery, y	Mean	23.9	24.2	.10
	SD	4.5	4.3	
	Range	16-30	16-30	
Height, cm	Mean	177	177	.99
	SD	9.6	8.7	
	Range	152-191	163-191	
Weight, kg	Mean	80.9	83.5	.30
	SD	16.7	18.9	
	Range	61.2-123	54.4-121	
Time to follow-up, mo	Mean	29.9	25.6	.43
	SD	16.6	13.1	
	Range	12.9-68.8	12.0-55.6	
Subjective IKDC score	Mean	92.6	90.3	.44
	SD	7.8	8.7	
	Range	69.0-100	72.4-100	
Lysholm score	Mean	92.9	93.0	.95
	SD	6.0	8.0	
	Range	76-100	76-100	

Abbreviations: BPTB, bone–patellar tendon–bone; TA, tibialis anterior; subjective IKDC, Subjective Knee Evaluation Form, International Knee Documentation Committee; Lysholm, Lysholm Knee Scoring Scale.

Discussion

Both BPTB and TA allografts are used for ACL reconstruction, but there have been no direct comparisons of patient-reported outcomes or graft-rupture rates. The graft tissues most commonly used for reconstructive knee ligament surgery are BPTB.[2] As use of TA has increased only recently, there is less follow-up data for these grafts. When more clinical information on patient outcomes after ACL reconstruction with TA allografts becomes available, use of these grafts may become standard, allowing for more effective use of cadaver donors.

Lee and colleagues[15] directly compared BPTB and TA allografts for ACL reconstruction at 39- and 34-month follow-ups, respectively. Outcomes were assessed using the Lachman test, the pivot shift test, the KT1000 arthrometer (Medmetric, San Diego, California), and the IKDC Objective Examination Form. No significant differences were found between the groups. Lee and colleagues[15] concluded that there were no differences in knee stability between the groups, and that each group had more postoperative range of motion than a third group consisting of hamstring autograft patients. Several studies have reported postoperative subjective IKDC scores for patients with BPTB allograft[11,13,16-18] (range, 78 to 88) and TA allograft[19-21] (range, 77.6 to 92). Studies have also reported Lysholm scores for patients with BPTB allograft[4,13,16,22-25] (range, 78.3 to 93.8) and TA allograft[21,26] (range, 83.5 to 88). Given the small number of published subjective IKDC and Lysholm scores in TA allograft patients, as well as the high variability in IKDC scores among patients in these studies, we thought it unnecessary to perform a power analysis before initiating this study.

In case series and case-control studies, BPTB graft-rupture rates have ranged from 0% to 45%, number of patients from 26 to 183, and follow-up from 24 to 80 months.[4,12,16,17,22-25,27] Fresh-frozen or irradiated (1.2-2.5 Mrad) allografts were used in these studies. The large range in graft-rupture rates shows that outcome is affected by several factors, including patient activity level, surgical technique, and graft sterilization technique. Only 2 studies have reported a graft-rupture rate for TA allografts in ACL reconstruction.[20,26] Nyland and colleagues[20] retrospectively studied 18 patients with cryopreserved TA allografts and found a graft-rupture rate of 7.8% at 2-year follow-up. Singhal and colleagues[26] also used cryopreserved TA allografts and found a graft-rupture rate of 23% in 69 patients at a mean follow-up of 55 months.

Based on the ranges of subjective IKDC and Lysholm scores reported in various studies, these patient-reported outcome scores are similar for BPTB and TA allograft patients. In our study, the first to directly compare these scores between the 2 groups, we found no statistically significant differences based on 20 matched pairs. Further, the graft-rupture rate was comparably low for both graft types (the relatively short minimum follow-up, 18 months, may have had an impact on this rupture rate). No statistically significant difference was found between the groups for graft rupture. The graft-rupture rates in our study are also similar to the reported graft-rupture rates of autograft ACL reconstruction with either patellar tendon[7,28-31] or hamstring.[28,31]

Our study had some limitations. First, it was retrospective and had a short follow-up (1 year minimum). Many patients' return to full activity was 6 to 12 months after ACL repair, and thus our study presents very early postoperative results. Second, we did not assess objective outcomes, such as the objective IKDC, the KT1000, the pivot shift test, or the single-leg hop test. Future research should use objective outcome measurements and focus on longer term follow-up. Third, graft-rupture data were analyzed using known ruptures in patients who underwent revision surgery at our institution, and thus rupture rates in this study may represent an underestimate of the true data. Fourth, a transtibial approach was used in all BPTB patients, but an anteromedial approach was used in some TA patients. As studies have shown, a transtibial approach does not yield anatomical graft placement[32] and may not restore rotational knee stability,[33] thereby possibly affecting outcomes between the 2 groups in our study.

The strengths of this study include its matched design for sex, age, height, weight, and preoperative activity level. Further, all BPTB graft ACL reconstructions were performed by a single surgeon, while all TA reconstructions were performed by another single surgeon.

Conclusion

We have shown no statistically significant differences between BPTB allografts and TA allografts for ACL reconstruction in terms of graft-rupture rate, subjective IKDC score, and Lysholm score. These results suggest that BPTB allograft and TA allograft are both appropriate options for primary ACL reconstruction.

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