Allograft Anterior Cruciate Ligament Reconstruction in Patients Younger than 25 Years

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Abstract

Purpose The purpose of this study was to evaluate the outcomes for patients younger than 25 years who had anterior cruciate ligament (ACL) reconstructions with allograft tissue.

Methods A total of 52 ACL reconstructions performed with fresh-frozen, nonirradiated tibialis or Achilles allografts in active patients younger than 25 years. Outcome evaluations included the International Knee Documentation Committee (IKDC) objective and subjective forms, KT-1000 arthrometry and Lysholm.

Results Forty-two patients were available for follow-up at an average follow-up of 65 months (range, 33–99 months). The average age at surgery was 17 years and 7 months (range, 11 years 10 months–24 years 8 months). Objective and subjective data were obtained from 37 patients with 1 requiring revision, and 5 patients had only subjective data. IKDC objective results were 29-A and 5-B. KT-1000 differences were 0 mm for 4 patients, 1 mm for 23, 2 mm for 8, 3 mm for 1, and > 5 mm for 1 patient. The average IKDC subjective score was 90.2 ± 15.0 and average Lysholm score was 90.0 ± 11.

Conclusion The result of our study found that using nonirradiated Achilles or tibialis tendon allografts for ACL reconstructions in active patients younger than 25 years can achieve good outcomes, with a low rate of failure.

Keywords

- anterior cruciate ligament
- anterior cruciate ligament reconstruction
- allograft

For young active patients who undergo anterior cruciate ligament (ACL) reconstruction, there has been a hesitancy to use allografts for reconstruction because of concerns regarding the increased failure rates compared with autografts. Questions remain because limited clinical data are available for allografts in patients younger than 25 years. Furthermore, only data from recent clinical studies can be evaluated to avoid the use of irradiated allograft tissue, which has demonstrated a greater failure rate than nonirradiated allograft tissue.[1–3] Even low-dose irradiation (< 2.5 mRad) to the allograft tissue may increase the failure rate compared with nonirradiated tissue.[4] Moreover, criteria for appropriate patient selection (i.e., activity level) for an allograft ACL reconstruction are unclear in the younger age group.

A recent study involving 79 patients 18 years or younger who underwent ACL reconstruction resulted in 35% (7 of 20) of the patients in the allograft group and 3% (2 of 59) of the patients in the autograft group requiring revision ACL surgery.[5] This is an apparent 15-fold increase in failure rate for the allograft; however, five of the seven patients in the allograft group had a failure because of a probable premature return to sports participation. In addition, allografts used in this study were from two sources: one source performed low-dose irradiation and the other did not.

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In contrast, a recent presentation involving 108 athletes younger than 25 years requiring ACL reconstruction showed a similar failure rate between allografts and autografts: 13% (6/46) in the allograft group and 11% (7/62) in the autograft group.[6] Furthermore, in a separate study, no statistically significant difference in failure rates of Achilles allografts was demonstrated across patient age groups (< 18, 18–25, 26–40, and ≥ 41 years) where a single surgeon performed the surgeries using one tissue source for the allograft.[7] Overall, several other studies reported mixed outcomes for allograft ACL reconstruction in younger patients, but limited conclusions can be drawn from these studies because of limitations such as small patient numbers, conclusions based on subset analyses, missing allograft treatment details, or differing surgical techniques and allograft sources, as well as various age cutoffs to define young patients.[8–13] Therefore, although the general perception is that allografts do not have a role in this patient population, many studies in younger patients have limitations that make it difficult to derive any conclusion.

The purpose of this study was to evaluate the outcomes for patients younger than 25 years who had ACL reconstructions with tibialis or Achilles tendon allograft tissue under conditions with reduced variability (i.e., the data were generated by one surgeon using the same surgical technique and a single source for nonirradiated allograft tissue). Our hypothesis is that when variables affecting a successful ACL reconstruction are reduced, an allograft ACL reconstruction may serve as a durable, functional graft in active, young patients.

Methods

Patient Selection

All patients younger than 25 years who underwent ACL reconstruction by the lead author with an allograft for an isolated ACL tear or ACL tear plus meniscectomy or repair of meniscal tear during a 3-year period were eligible for this study. All patients provided written Institutional Review Board-approved consent and Health Insurance Portability and Accountability Act authorization.

Tissue Source

All tibialis anterior and Achilles tendons were provided by the Musculoskeletal Transplant Foundation (Edison, NJ) and preserved as fresh-frozen allografts. No allografts were processed using irradiation.

Surgical Technique

All the ACL reconstructions were performed with the same surgical technique, except graft fixation, which was based on the patient's growth plate status. The initial step in treatment after injury was to regain motion, particularly extension, and minimize swelling to reduce arthrofibrosis. Once these objectives were achieved, patients underwent the surgical procedure.

After examination of the knee under general anesthesia to confirm that the ACL was clinically deficient, arthroscopy was performed. With the ACL further confirmed to be incompetent, the surgical assistant proceeded with graft preparation. The graft type (Achilles or anterior tibialis) was selected in part by availability, but if the patient's growth plates were without signs of nearly full closure, a tibialis graft was used. The Achilles tendon allografts were fashioned to be 9 mm in diameter with a 20 cm bone plug for the tibial side. The tibialis allografts were all double looped with diameter of 8.5 to 9 mm with both grafts typically 8.5 cm in length. The grafts were placed under 15 to 20 pounds of tension during and after graft preparation.

While the graft was being prepared, the arthroscopy continued; all but the tibial stump of the torn ACL was removed to enable visualization of the posterior aspect of the femoral notch to aid in proper graft placement. Before proceeding with the ACL reconstruction, the knee was evaluated for any additional pathology. If the menisci were torn, every effort at repair was attempted and an inside-out technique was used.

Having addressed all other knee pathology, attention was returned to the femoral notch. A 5 mm off-set guide was placed through the anteromedial portal to mark a target hole in the femur just above the 2 and 10 o'clock positions for the left and right knees, respectively. Next, the tibial tunnel was prepared, the tibial guide was set at a 52.5 degrees angle, and a pin was passed up through the tibia so that it entered the center of the old ACL foot plate. If there was any question of the location, the posterior aspect of the anterior horn attachment of the lateral meniscus and the point directly between the tibial spines were used as references. Once the pin entered the knee, it was driven further up into the notch, with the goal of hitting the pilot hole. If this was not achievable, the angle in the medial/lateral plane was modified. Although the tibial tunnel was occasionally more oblique to achieve hitting the femoral pilot hole than in the now-preferred anteromedial approach, a tibial tunnel length of at least 25 mm was achieved in all cases.

With the tibial guide pin in proper position, it was overreamed with a 6 mm drill; subsequently, the drill diameter matched the graft size. This method of a smaller drill first was used to enable any slight position modifications of the tunnel to maximize the desired position. In addition, our previous experience suggests that the likelihood of damage to the tibial spines/articular cartilage was minimized using this two-drill technique. The guide pin was then passed up into the femur and the appropriately sized drill was used to complete tunnel preparation, with the depth typically 30 mm.

The fixation of the grafts was chosen on the basis of the patient's maturation state and the concern of growth plate injury. If the growth plates were closed or the development state showed nearly full maturation, the grafts were secured with BioScrews (Arthrex Inc., Naples, FL). If the patient showed no signs of entering puberty, the grafts were secured with an ENDOBUTTON (Smith-Nephew, Hanover, MA) on the femur and a post on the tibia. If the patient was in early puberty, the grafts were secured on the femur with an ENDOBUTTON and a BioScrew on the tibia. The completed graft is shown in ▸Fig. 1.

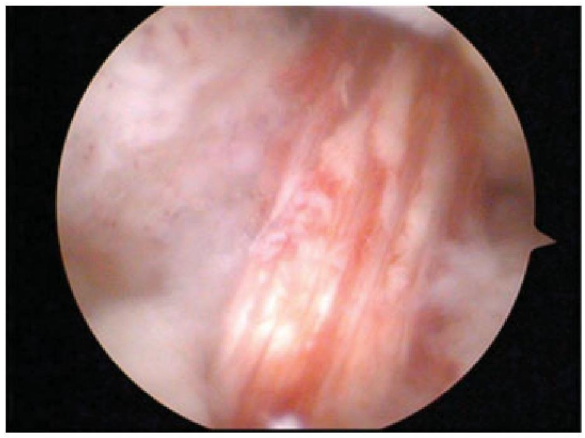

Fig. 1 Arthroscopic view of graft upon completion of the procedure.

Rehabilitation

A uniform postoperative rehabilitation program was followed by all patients with close monitoring throughout the course of care. Typically, a patient was seen within a few days before the surgery and given extensive instructions and handouts regarding the initial postoperative care and exercises to follow. Postoperatively, patients were placed in a brace and permitted full extension and limited flexion to 90 degrees for the first 4 weeks. Weight bearing was allowed as tolerated unless a meniscus repair was performed, for which only partial weight bearing was allowed during this time.

At 4 weeks, formal physical therapy was initiated and full weight bearing was permitted. Stationary bicycling and straight-leg-kick swimming were permitted. Jogging was initiated at 12 weeks and functional/sports-specific exercises at 20 weeks. Patients were released to full activities at 6 months following surgery if the strength, endurance, and functional testing were normal. However in many cases, full activity status was achieved after 7 to 8 months. It was stressed that regardless of how well the patient was doing, graft healing required one to error on the conservative side of time before progressing in rehab.

Study Design

This was a retrospective study evaluating outcomes for patients who were 25 years old or younger and had undergone ACL reconstruction using tibialis or Achilles tendon allograft tissue by the lead author during a 3-year period. Consenting patients were encouraged to return to the office for an objective examination and to complete subjective health and outcomes assessments. Phone interviews were conducted to complete the subjective assessments when patients were unavailable for office visits.

Assessments

Demographic information and medical history were collected. Patients provided information on their general health using the Short Form-36 Health Survey. Patients also completed subjective evaluations specific to the reconstructed knee (i.e., IKDC subjective knee form and Lysholm scale). The IKDC subjective knee form evaluated pain, activity level, and knee function for both sports and daily activities, with a scale from 0 to 100. The Lysholm scale evaluated pain, knee function, and specific activities, with a scale of 0 to 100; scores are generalized as excellent (95–100), good (84–94), fair (65–83), or poor (< 65). An objective test of knee function was performed using the IKDC knee examination form, which included the KT-1000 arthrometer maximum side-to-side differences, as well as 45 degrees posterior-anterior, lateral, and 30 degrees patella X-rays of the reconstructed knee. Patient satisfaction and the objective parameters of a clinically stable and functional knee were considered a successful outcome.

Statistical Analyses

Comparisons were made between the patient's reconstructed knee and both the nonoperative knee after surgery and the operative knee before injury. Statistical analyses were performed with paired and Student *t*-tests; $p < 0.05$ was considered statistically significant.

Results

Patients

Demographics

A total of 52 patients had ACL reconstructions who were eligible for inclusion in this study with data from 42 obtained. Both objective and subjective information were obtained from 37 patients and 5 patients provided subjective data only. The patient population was predominately female ($n = 31$). All but five injuries occurred during sports participation (four accidents in females and one in males, not sports related). Female patients participated in basketball ($n = 12$), soccer ($n = 5$), volleyball ($n = 2$), gymnastics ($n = 2$), cheerleading ($n = 2$), and dance, martial arts, skiing, and softball (1 in each activity). Male patients participated in football ($n = 4$), soccer ($n = 3$), basketball ($n = 2$), and volleyball ($n = 1$). Excluding the one failure, the average patient follow-up was 65 months (range, 34–99 months).

Surgical Pathology

Among the 42 evaluable patients, 23 had isolated ACL reconstructions. The remaining patients had ACL reconstructions with meniscus surgeries: six patients with a lateral meniscus repair, seven patients with a medial meniscus repair, four patients with a partial lateral meniscectomy, and two patients with a partial medial meniscectomy. Most patients had ACL reconstruction using the tibialis anterior tendon. Among the 31 female patients, 17 had ACL reconstruction using a tibialis anterior tendon (14 with Achilles tendon). Among the 11 male patients, 9 had ACL reconstruction using a tibialis anterior tendon (2 with Achilles tendon). The majority of patients had femoral and tibial fixation with a BioScrew ($n = 36$), 3 patients had an ENDOBUTTON on the femur and a post on the tibia, and 3 patients had an ENDOBUTTON on the femur and a BioScrew on the tibia.

Patient-Reported Outcomes

A total of 41 patients provided data for the IKDC subjective knee and Lysholm scale scores (►Table 1). The IKDC subjective knee evaluation consisted of 31 patients (76%) with a score from 90 to 100 points, 6 patients (15%) with a score from 70 to 89 points, 3 patients (7%) with a score from 40 to 69 points, and 1 patient (2%) with a score of 33.3. The Lysholm evaluation consisted of 32 patients (78%) with a good or excellent score (84–100 points), 7 patients (17%) with a fair score (65–83 points), and 2 patients (5%) with an unsatisfactory score.

The majority of patients (88%) indicated that they returned to the same activity level as before without discomfort (►Table 2). Among the two patients who indicated a moderate return to activity levels, one patient had an IKDC subjective score of 72.4 and a Lysholm score of 84, and the other patient had an IKDC subjective score of 97.7 and a Lysholm score of 88. The only patient who indicated a low return to activity levels was limited because of patellofemoral arthritis.

Objective Measures

Physical Examination

Among 36 patients with IKDC knee examination data, the majority were objective grade A (normal; $n = 30$) and 6 patients received a B (nearly normal). Among the patients receiving an IKDC grade B, three were because of patella discomfort, two were because of radiographic degenerative changes, and one was because of a KT-1000 score of 3 mm.

The KT-1000 testing was performed by the lead author except in one patient who resided out of state. The KT-1000 maximal side-to-side difference was 2 mm or less in approximately 95% of the patients (►Table 3). Among the eight patients with a 2 mm difference, three patients had ACL reconstruction with an Achilles allograft. The patient with a 3 mm difference had ACL reconstruction using an Achilles allograft, and the patient with a 5 mm difference that required revision had initial reconstruction using a tibialis anterior allograft.

Subsequent Surgeries

Five patients with intact grafts required a subsequent surgery: two for a medial meniscectomy, two for a contralateral ACL, and one for debridement/anterior synovectomy. The patients with a subsequent medial meniscectomy had this surgery 2 years after the original ACL reconstructions (one Achilles and one tibialis; both patients older than 16 years), which included a meniscus repair (one medial meniscus repair and one partial lateral meniscectomy). Both patients had a full return to their preinjury sport activity levels following their original ACL surgery, with an IKDC grade A and KT-1000 differences of 1 and 2 mm. The two patients with a contralateral ACL had their surgeries 1 and 3 years after their original ACL reconstructions (one Achilles and one tibialis; both patients younger than 15 years): one case was an isolated ACL reconstruction and the other case included a partial lateral meniscectomy. Both patients had achieved a full return to their preinjury sport activity levels following their original ACL surgery. One patient had anterior fibrosis with decreased extension and underwent scar excision. Her extension improved to within 5 degrees of the contralateral knee, but she continued to have mild anterior knee discomfort. The appearance of her graft is shown in ►Fig. 2.

There was one reconstruction failure at 13 months after ACL surgery (tibialis anterior tendon and a medial meniscus repair) in a male patient who was 22 years old and tore his native ACL and allograft while playing soccer in both instances (►Fig. 3). This patient had a KT-1000 measurement of 2 mm before the reconstruction failure.

Discussion

ACL reconstruction is typically performed with autograft tissue, and the most common autograft tissue sources are bone-patellar tendon-bone or hamstring. The use of allograft tissue for ACL reconstruction has gained popularity because of decreased patient pain, no donor morbidity, and decreased surgical time compared with reconstruction using autograft tissue. Further, numerous studies have shown that, in general, allografts can provide functional outcomes similar to autografts.[1,14–23] Critical analyses revealed that many studies

Table 1 Patient-reported surgical outcomes

	Score, mean (SD) ($n = 41$)
IKDC subjective knee	90.2 ± 14.8
Lysholm scale	91.0 ± 11.0

Abbreviations: IKDC, International Knee Documentation Committee; SD, standard deviation.

Table 2 Patient-reported activity level

	Patients, *n* (%) ($n = 41$)
Return to preinjury activity level	
Full	36 (88)
Full, with some discomfort	2 (5)
Moderate	2 (5)
Low	1 (2)

Table 3 KT-1000 maximal side-to-side difference

	Patients, *n* (%) ($n = 37$)
0 mm	4 (10)
1 mm	23 (62)
2 mm	8 (22)
3 mm	1 (3)
5 mm	1 (3)

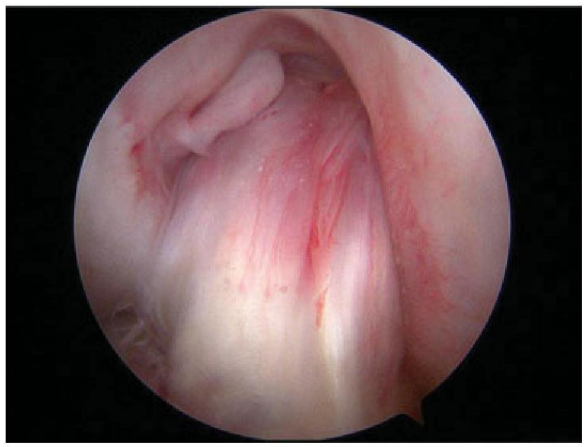

Fig. 2 Arthroscopic appearance of graft shown in ►**Fig. 1** at 6 months postoperatively. The patient whose graft is shown in ►**Fig. 1** required a second surgery for anterior fibrosis. The photo is the anterior cruciate ligament at the time of the second surgery and demonstrates good graft healing.

reporting frank differences in failure rate between allografts and autografts included mechanically inferior irradiated grafts.[1,24,25]

Although the overall results for allografts and autografts are without statistically significant differences, many studies have demonstrated notable differences in outcomes for the young athletic population.[5,11,26] For example, Barrett et al reported among 111 patients who were younger than 40 years and had ACL reconstructions with allograft bone-patellar tendon-bone, those classified as high activity per Tegner activity level were 2.6 to 4.2 times more likely to experience a reconstruction failure compared with low-activity patients.[11] The conclusion was that fresh-frozen bone-patellar tendon-bone allografts should not be used in young patients who have a high activity level. In their efforts to explain why the results for the young active group were poor,

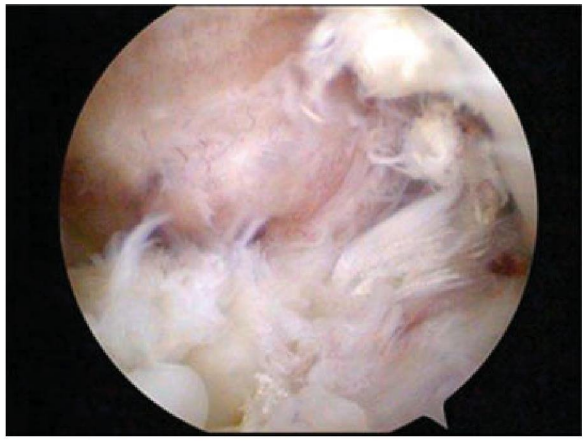

Fig. 3 Anterior cruciate ligament reconstruction that failed 13 months after surgery. The 22-year-old male patient played soccer, which was the cause of both injuries; the figure shows the allograft at the time of revision surgery.

the investigators hypothesized that younger patients returned to a high level of activity before the graft was fully incorporated. Analysis of this study revealed additional factors that may also account for the significant failure rate difference. The study spanned more than 12 years, during which allograft preparation and technology may have changed. The time from injury to reconstruction also varied between the autografts and allografts. Among the autografts, 87% were in acute injuries but only 61% of the allografts were in acutely injured knees. Thus, a possible bias may have existed by selecting autografts more often in the "healthier" knee and patient. In fact, among the allograft failures, 47% where placed in chronically ACL-deficient knees.

In another study, Ellis et al compared bone-patellar tendon-bone autografts and allografts in 90 patients aged 18 years or younger with closed physes: 70 autografts, but only 20 allografts.[5] Among the 79 patients available for follow-up, 9 (11%) patients receiving an autograft had a revision and 7 (35%) patients receiving an allograft had a revision. The time to allograft revision was a mean of 9.1 months (range, 5.3–12.0 months). Analysis of this study found that the allograft sources were from two tissue banks, with one using a low-dose radiation processing method. In addition, compliance in the rehabilitation program was poor. Indeed, among the seven allograft failures, five occurred in patients who were performing sports activities before clearance.

Finally, Pallis et al compared allograft and autograft for ACL reconstructions in 120 U.S. Military Academy cadets and showed profound differences in outcome.[26] Over a 5-year period, 122 ACL reconstructions were performed before the cadets' matriculation: 61 were bone-patellar tendon-bone, 45 were hamstrings, and 16 were allografts. Among the failures requiring revision, seven (11%) were bone-patellar tendon-bone, six (13%) were hamstring, and seven (44%) were allograft. Overall, it was 6.7 times more likely that a cadet who received an allograft ACL would fail compared with a cadet who received an autograft. A thorough review of these data showed several important variables. The surgeries were performed by a multitude of surgeons and the surgical technique could not be controlled. In addition, the source of the allograft was not standardized and the use of radiation in processing the allograft was unknown. Moreover, most of the cadets who had ACL allografts presented to the Academy already had unstable knees. Of the knees examined at matriculation, 36% of the allograft ACLs had a positive pivot shift, while 14% of the hamstrings and 16% of the bone-patellar tendon-bone grafts demonstrated the same.

We became interested in this study when our experience did not concur with the poor outcomes noted in other studies of allograft ACL reconstructions in young active patients. During the 3-year period studied, we performed 518 ACL reconstructions, but only 52 were allografts in patients younger than 25 years. Thus, the use of allografts for ACL reconstructions in this patient category was not routine, and the author was not biased toward their use.

The patients who received an allograft in this group commonly presented with the request of allograft tissue for

their ACL reconstruction. Therefore, a bias was present in which the patients were, in general, more knowledgeable than the general patient population regarding ACL injuries and surgery. In addition, the importance of following the postoperative protocol and rehabilitation requirements was better understood and followed. There was also a bias in the fact that, while the patients were all active and most were involved in sports, it was not our recommendation to use allografts in high-impact sports, such as football. The football players who had allograft ACL reconstruction were adamant regarding their graft selection, and fortunately, all have done well.

The results of this study may also be better than the previous studies because many variables were standardized. The grafts were not irradiated and were provided by only one tissue bank certified by the American Association of Tissue Banks. Only one surgeon in a high-volume practice performed the surgeries, with one assistant preparing the grafts. A standardized rehabilitation protocol was used and the patients were continually counseled that it was important to not be more aggressive than the protocol outlined. The patients were not cleared for resuming full activities until a minimum of 6 months and only after functional testing was normal.

In addition, the type of graft may hypothetically play a role. The vast majority of studies comparing autografts to allografts were with bone-patellar tendon-bone. In our study, only Achilles and anterior tibialis tendons were used. Baer and Harner reported that the ultimate tensile strength of a bone-patellar tendon-bone graft is 2,977 N, whereas a tibialis anterior and Achilles graft is 4,122 and 4,617 N, respectively.[27] It should be stressed that the association between graft type and ACL failure rate is only conjecture, and to our knowledge has not been proven to be of clinical significance.

Limitations

This study does have several limitations: it provides level 4 evidence, the number of patients was not large, and several patients could not be located. We found that it was not uncommon for this younger age group to have numerous changes in address because of completion of school and change in employment compared with an older age category, which typically has a more stable residence.

In fact, 5 of the 10 patients not available for follow-up had their last known residence to be out of state. Finally, the use of allografts for ACL reconstructions in contact sports or professional athletes was not encouraged, which shows some bias.

Conclusion

Use of nonirradiated Achilles or tibialis tendon allografts for ACL reconstructions in active patients younger than 25 years achieved good outcomes and had a low failure rate, although patients participating in contact sports (i.e., football) were few and none were training professionally.

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