Effect of Donor Age on Patellar Tendon Allograft ACL Reconstruction

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Abstract

Anterior cruciate ligament reconstruction with patellar tendon allograft tissue is a common orthopedic procedure. It is unknown what effect, if any, the donor age has on clinical outcomes. Biomechanical studies have shown the strength of cadaveric patellar tendon to be independent of age, but no clinical studies have evaluated patient outcomes related to this variable. The purpose of this study was to evaluate the effect of allograft donor age on clinical outcomes of patients undergoing allograft anterior cruciate ligament reconstruction with patellar tendon allograft.

Case logs were reviewed to identify primary anterior cruciate ligament reconstruction with allograft patellar tendon by a single surgeon using a standard endoscopic transtibial technique with interference screw fixation. Revision and multiligamentous surgeries were excluded. Seventy-seven patients who met these criteria were identified. Allografts were fresh-frozen, aseptically harvested patellar tendons from a single tissue bank. The donor age was obtained. Clinical outcomes were obtained by contacting patients by telephone and retrospective chart review. Pre- and postoperative Lysholm and Tegner knee scores were used for comparison.

Data from 75 patients with an average follow-up of 24 months were obtained. Average donor age was 44 years (range, 14-65 years), and average patient age was 37 years (range, 18-60 years). Statistical analysis of pre- and postoperative Lysholm scores demonstrated statistically significant improvement ($P<.001$). Using donor age as a continuous variable, no effect was found on postoperative improvement in Lysholm score or Tegner score ($P=.6$).
Over the past 2 decades, anterior cruciate ligament (ACL) reconstruction has evolved into a reliable and successful procedure, with overall clinical success rates surpassing 90%. Graft choice for reconstruction has varied, but most would consider an autogenous source, using either patellar tendon or hamstring tendons, as the gold standard. However, use of allograft tissue as a substitute for a torn ACL has produced results in the literature clinically comparable with that of autograft replacement.1–4

Because a limited supply of allografts exist and cost can be a factor, it is important to know what factors influence patient outcome when selecting a graft. In selecting allograft, some advocate choosing tissue from younger donors on the premise that younger donors will have stronger tissue and, therefore, result in improved clinical outcomes. This theory is based on a few studies that have reported an inverse relationship between age and the strength of the intact human femur–ACL–tibia complex.5,6 Nevertheless, several biomechanical studies have demonstrated that the structural properties of allograft are independent of age.7,8 To the current authors’ knowledge, no studies have evaluated the effect of allograft donor age on clinical outcomes.

The purpose of this study was to determine whether the donor age is a factor in clinical outcome for ACL reconstruction. In this series, the authors examined the clinical outcomes in patients who underwent ACL reconstruction with patellar tendon allograft obtained from donors ranging from 14 to 65 years of age. They hypothesized that donor age would have no effect on clinical results of patellar tendon allograft ACL reconstruction.

**Materials and Methods**

This study was a retrospective review of all patients who underwent primary ACL reconstruction using patellar tendon allograft performed by the senior author (J.J.K.) between 2002 and 2006. The inclusion criteria were patients with closed growth plates who underwent primary ACL reconstruction with fresh-frozen patellar tendon allograft and a minimum 10-month follow-up. Patients who underwent concomitant microfracture, meniscal repair, and meniscal debridement were included. Exclusion criteria included patients who underwent revision ACL reconstruction, multiligamentous knee reconstruction, or meniscal transplant surgery. Institutional review board authorization was obtained.

Seventy-seven patients met the inclusion criteria for the study. Of those 77 patients, 2 were clinical failures and were excluded from the study. The patients included were 35 women and 40 men, average age was 37.2±9.9 years, and mean follow-up was 24±13.9 months. Average donor age was 44.6±15.2 years, and 24 (32%) donors were women and 51 (68%) were men.

For each patient, pre- and postoperative Lysholm and Tegner knee scores were obtained by retrospective chart review and by contacting patients via telephone. Lysholm and Tegner knee scores are validated, patient-administered measures of knee function and activity level in early time periods after ACL reconstruction.9 Statistical analysis was performed to determine the effect of donor age and sex on the postoperative improvement in Lysholm and Tegner scores. In addition, the 2 clinical failures were compared with the 75 successes to determine whether any significant variables could be identified.

All reconstructions were performed by a single surgeon (J.J.K.). All patients underwent an examination under anesthesia, and all had a positive Lachman and pivot shift tests. In each case, central third bone–patellar tendon–bone allografts (9 to 12 mm in width) were used. Grafts were secured using titanium interference screw fixation. Partial meniscectomy, meniscal repair, chondroplasty, and microfracture were performed, as necessary, at the time of ACL reconstruction. All allografts were obtained from a single tissue bank (LifeNet, Virginia Beach, Virginia) certified by the American Association of Tissue Banks. Grafts obtained after 2004 (n=33) received low-dose irradiation (10.8-16.4 kGy), grafts obtained prior to 2004 (n=44) were not irradiated. All patients were enrolled in the same accelerated rehabilitation protocol postoperatively.

All analyses were conducted with SAS version 9.1 software (SAS Institute Inc., Cary, North Carolina). Continuous variables were summarized as mean±SD, and categorical variables were summarized as counts and percentages. Donor age was used as a continuous variable to determine the effect of donor age on postoperative improvement of Lysholm and Tegner scores. Donor sex was used as a categorical value.

Improvement in postoperative Lysholm score was used as a continuous variable defined as the difference between scores pre- and postoperatively. Linear regression models were used to explore the effect of donor age, patient age, side of surgery, patient sex, donor sex, and follow-up time on improvement in postoperative Lysholm score. Regression results are summarized with regression coefficients and their respective standard errors.

Improvement in Tegner score was used as a categorical variable, with improvement defined as a 3-unit or more increase compared with the preoperative value (lack of improvement was defined as an increase less than 3 units). Logistic regression models were used to explore the effect of the various predictors on postoperative improvement in Tegner score. For Lysholm and Tegner scores, individual models were performed for each predictor, as well as multivariate models including all predictors simultaneously. A P value of .05 or less was considered significant.

**Results**

All patients except 1 had improvement in postoperative Lysholm score. Mean im-
provement was 30.2 ± 10.4 points. Sixty patients had improvement in their Tegner score, whereas the remaining 15 patients had scores that remained the same. In addition, 27 patients experienced a postoperative increase in Tegner score of 3 units or more, whereas 48 patients experienced a postoperative increase of less than 3 units. Mean improvement was 1.99 ± 1.50 points.

After performing bivariate linear regression to determine the effect of donor age on improvement in postoperative Lysholm score, it was determined that each year of advancing donor age conferred a mean increase of 0.05 ± 0.08 point to postoperative improvement. This result was not statistically significant (P = .51). After performing bivariate logistic regression to determine the effect of donor age on the improvement of postoperative Tegner score, it was determined that each year of advancing donor age decreased the odds of a 3-point improvement in Tegner score by 0.009 times (95% confidence interval [CI], 1–.991). This result was not statistically significant (P = .58).

After performing bivariate linear regression to determine the effect of donor sex on postoperative Lysholm score, it was determined that female donors conferred an average increase of 3.12 ± 2.57 points greater than male tissue donors. This result was not statistically significant (P = .23). After performing bivariate logistic regression to determine the effect of donor sex on postoperative Tegner score, it was determined that the odds of a female donor conferring a 3-point improvement was 0.84 times (95% CI, 0.30–2.34) that of male donors. This was not statistically significant (P = .74).

Ultimately, all models found that donor age, donor sex, patient age, and patient sex had no statistically significant effect on outcome as measured by the increase in Lysholm or Tegner scores. However, when preoperative Tegner score was included in the multivariate model, a 1-point increase in preoperative Tegner decreased the odds of a 3-point postoperative improvement by .425 times (95% CI, 1–0.575). Therefore, a higher preoperative score was associated with less improvement (P = .01).

The 2 clinical failures occurred at 18 and 36 months postoperatively, respectively. Donor age of these failures was 14 and 52 years, respectively. When compared with the other patients, donor age was not a statistically significant factor in predicting failure (P = .32).

**DISCUSSION**

Anterior cruciate ligament reconstruction is becoming more common in older age groups, and, in turn, allografts are being selected with increasing frequency. Until now, proponents of allografts have encouraged the use of allografts harvested from younger donors; however, with the increasing popularity and costs associated with allografts, surgeons may not have the luxury of controlling the parameters of the allografts that they use. The goal of the current study was to determine the effects of donor age and sex on clinical outcomes in patients undergoing allograft ACL reconstruction.

Previous investigators have documented an age-related decline in the biomechanical properties of the human ACL as a function of age. Noyes and Grood compared the failure load and stiffness of the femur–ACL–tibia complex in young (16–26 years) and old (48–86 years) human specimens and found that the failure loads were 1730 and 734 N, respectively, with stiffness values reported at 182 and 129 N/mm, respectively. Similarly, Woo et al reported the failure load of the femur–ACL–tibia complex in young-adult (22–35 years), middle-aged (40–50 years), and older-age (60–97 years) groups to be 2160, 1503, and 658 N, respectively. The older specimens also had a higher rate of midsubstance failure (12/18) than the young-adult (5/18) or middle-aged (8/18) groups.

More recent studies looking specifically at biomechanical properties of donor tissue used for ACL reconstruction have reported that the structural properties of allograft are generally independent of age. Blevins et al evaluated tensile strength, modulus, and failure mode at 2 strain rates in 82 fresh-frozen, bone–patellar tendon–bone allografts from donors aged 17 to 54 years. They found no statistically significant correlation between age and tensile strength at either strain rate; however, they found a weak but statistically significant negative correlation between age and modulus at both strain rates. Flahiff et al evaluated force at failure, tensile stress, and modulus of elasticity of patellar tendon allografts from donors aged 18 to 55 years and found no significant correlation between age and any of the mechanical properties (P > .05). Kang et al evaluated the bone mineral density of bone–tendon–bone allografts from donors aged 21 to 58 years and evaluated how the bone mineral density reacted to age among low-dose (10–13 kGy) irradiated grafts. The bone mineral density was not found to change significantly with age, although grafts from male donors consistently had a higher bone mineral density. Greaves et al evaluated force at failure, stiffness, and deformation for 3 age groups (15–45, 46–55, and 56–65 years). They observed no statistically significant difference for ultimate load to failure, stiffness, stress, or deformation for irradiated single- and double-strand tibialis tendon allografts by comparing load to failure, stiffness, and deformation for 3 age groups (15–45, 46–55, and 56–65 years). They observed no statistically significant difference for ultimate load to failure, stiffness, stress, or deformation for irradiated single- or double-strand tibialis tendons among the 3 age groups. However, an age-related decrease in failure stress was observed among nonirradiated tendons. Ultimately, they concluded that the strength of tibialis tendons across all age ranges exceeds the clinically recommended strength required for ACL reconstruction.

Although these biomechanical results are convincing, in vitro results do not necessarily translate into patient-oriented outcomes. Nevertheless, based on the
biomechanics results and clinical experience, the current authors hypothesized that clinical outcomes from allograft ACL reconstruction would be independent of donor age.

To test this hypothesis, donor age was treated as a continuous variable, and regression analysis was performed to determine whether statistically significant negative correlations existed between donor age and improvement in postoperative Lysholm and Tegner knee scores. Ultimately, no statistically significant correlation was found between donor age or sex and improvement in Lysholm or Tegner scores.

One weakness of this study was that it was a retrospective review of the senior surgeon’s surgical logs. In addition, the choice of allograft is a complicated decision by the patient and surgeon; therefore, the potential for selection bias exists.

REFERENCES