Clinical Outcomes Following Primary Anterior Cruciate Ligament Reconstruction with Hamstring Autograft versus Planned Hybrid Graft

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Abstract

Few studies have compared outcomes between autografts versus hybrid grafts (combination of autograft and allograft) for anterior cruciate ligament reconstruction (ACLR). The purpose of this study was to compare revision rate and patient-reported outcomes following primary ACLR with a hamstring autograft versus a preoperatively planned hybrid autograft-allograft. At a minimum 2-year follow-up, patients who had undergone primary ACLR with a double-stranded semitendinosus and gracilis hamstring autograft (A) or a planned hybrid (H) graft (single-strand semitendinosus with nonirradiated peroneus longus or tibialis posterior allograft) were contacted to fill out a survey containing the Knee Injury and Osteoarthritis Outcome Score (KOOS), Subjective International Knee Documentation Committee (IKDC) score, Single Assessment Numeric Evaluation (SANE), 12-Item Short-Form Health Survey (SF-12), and visual analog scale (VAS) for activity level prior to injury and at follow-up. From this collection of patients, a matched-pair comparison was made between groups, with patients matched by gender, age at the time of surgery, and follow-up time. Revision rate at follow-up was 8.4 and 2.4% in the A and H groups, respectively ($p = 0.073$). A total of 148 surveys were completed (83 A, 65 H), from which 36 matched pairs were formed. Within the matched pairs, average age at surgery did not differ significantly between groups (A: 35.7 years, H: 36.0 years, $p = 0.23$). Time to follow-up was 4.3 and 3.7 years in the A and H groups, respectively. Patients with a hybrid graft had significantly higher KOOS Quality of Life subscores (A 69.6, H 79.2, $p = 0.028$), subjective IKDC scores (A 72.6, H 79.7, $p = 0.031$), and SANE scores (A 83.2, H 91.4, $p = 0.015$) at follow-up. Otherwise, no significant differences were found in patient-reported outcome scores between groups. A preoperatively planned hybrid graft, with use of a fresh-frozen, nonirradiated allograft, should be considered as a viable alternative for primary ACLR in older patients.

Keywords

- anterior cruciate ligament reconstruction
- hamstring autograft
- hybrid graft
- graft failure

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The use of hybrid grafts composed of a combination of autograft and allograft tissue was only recently described in 2015.[1] These grafts, typically formed by combining autologous hamstring tendon with a soft tissue allograft, have gained interest among orthopaedic surgeons for their use in anterior cruciate ligament reconstruction (ACLR). Hybrid grafts are most commonly used for ACLR in cases of hamstring autograft sizing issues. According to Alvarez-Pinzon et al,[1] the only indication for hybrid graft use is when autologous tissue is inadequate or damaged during harvest. In these cases, an allograft is used to augment a patient's small hamstring tendons in an attempt to reduce the risk of graft rupture. However, there have been no published studies to date which describe the use of a preoperatively planned hybrid graft for ACLR. By planning for the use of a hybrid graft before surgery, it is only necessary to harvest the semitendinosus tendon rather than the semitendinosus and gracilis tendons. Thus, hybrid grafts may potentially offer the advantages of reduced donor-site morbidity postoperatively compared with the use of a hamstring (semitendinosus-gracilis) autograft. The purpose of this study was to compare graft failure rates and patient-reported outcomes between patients undergoing primary ACLR with a hamstring autograft versus a planned hybrid autograft-allograft. The authors hypothesized that no significant differences would be found between groups.

Materials and Methods

Institutional Review Board approval was obtained prior to beginning the study. Patients having undergone primary ACLR by the senior author (E.C.M.) from 2007 to 2013 were retrospectively reviewed. Patients were included if they underwent primary ACLR with either a hamstring autograft (A) or a planned hybrid autograft-allograft (H) with a minimum 2-year follow-up. Patients were excluded if their procedure was a revision ACLR, if concomitant collateral ligament reconstruction was performed, or if they underwent ACLR with a graft type other than hamstring autograft or hybrid graft. In addition, patients who underwent primary ACLR with an unplanned hybrid graft (for purposes of graft size augmentation) were excluded.

Patients who had not required a known revision procedure were contacted at least 2 years postoperatively and asked to take a survey that included a visual analog scale (VAS) from 0 to 10 of activity level at preinjury and time of follow-up, the Knee Injury and Osteoarthritis Outcome Score (KOOS),[2] Subjective International Knee Documentation Committee (IKDC) score,[3] Single Assessment Numeric Evaluation (SANE), and 12-Item Short-Form Health Survey (SF-12).[4] A change in activity level was calculated by subtracting the preinjury activity level from the activity level at follow-up for each patient. Study data were collected and managed using REDCap (Research Electronic Data Capture)[5] tools hosted at our institution.

Following a comparison of outcome scores between all patients who completed the survey, a matched-pair analysis was performed by matching patients from both groups based on sex, age at surgery within 3 years, and follow-up time. An attempt was also made to match patients based on graft diameter within 0.5 mm, though this was found to be impossible given that hybrid graft patients had considerably larger graft diameters.

Patient charts were reviewed to determine which patients later required a revision ACLR. In addition, all patients who completed the survey were asked if a revision ACLR was later required. From these two sources, a hamstring autograft revision risk was calculated by dividing the number of hamstring autograft patients who later underwent revision ACLR by the total number of patients undergoing primary ACLR with a hamstring autograft during the study period. The same was done to calculate a hybrid graft revision risk.

Graft Selection

All patients had a discussion of graft types for ACLR with the senior author prior to surgery. For those who desired a hamstring autograft, this was performed. For patients who desired an allograft, the option of a hybrid graft was suggested as an alternative to solely utilizing the allograft. The rationale explained to the patients was that some studies[6–8] have demonstrated a higher failure rate with allograft for ACLR. It was discussed that, by combining the autograft with one hamstring tendon of their own, that this possibly, albeit unproven, may increase the rate of the graft healing compared with an allograft alone. Additionally, by taking one hamstring tendon rather than two, there may be less morbidity involved. Patients who were counseled on the planned hybrid graft option understood this concept was theoretical and that no published clinical outcomes existed.

Surgical Technique

Hamstring Autograft

The hamstring tendons were harvested using an open-ended tendon harvest stripper through a small 3-cm vertical incision anteromedial to the tibia. Muscle was stripped using Mayo scissors. The gracilis and semitendinosus tendons were then folded over and fit tightly in a sizer to form a quadrupled hamstring tendon autograft. After these were combined with number 2 high-density sutures, the graft was placed in 10-pound tension on a moist sponge on the back table. All femoral tunnels were drilled into an anatomic location through the anteromedial portal. Graft fixation was performed with an adjustable loop button (ToggleLoc, Biomet, Warsaw, IN) on the femur. The graft was then fixed after cycling with either a 16-mm spiked washer and screw or a TunneLoc (Biomet) interference screw in extension.

Hybrid Graft

The procedure for hybrid autograft-allograft was identical to above except that the semitendinosus tendon was used for the autograft portion of the hybrid graft. A nonirradiated, aseptically procured posterior tibialis or peroneus longus allograft was used in combination with the autograft. The edges of the autograft and allograft were sutured together using number 2 high-density sutures (►**Fig. 1**). The combination

Fig. 1 Hybrid graft. Following harvest of the semitendinosus tendon (left), this was combined with a soft tissue, nonirradiated allograft (right) and sutured together prior to implantation.

autograft-allograft was then implanted in an identical fashion as above.

Statistical Analysis

Student's *t*-tests were used to compare outcome scores between the complete A and H groups. Matched-pair *t*-tests were used to compare outcome scores between the matched-pair cohorts. A chi-square test was performed to compare revision rates between the two groups.

Results

Overall, 212 potential candidates were identified during the study period based on the initial inclusion and exclusion criteria. This included 119 patients with a hamstring autograft (A) and 93 patients with a hybrid graft (H). Nine patients were excluded for undergoing ACLR with a hybrid graft for purposes of graft size augmentation, leaving 84 eligible hybrid graft patients. Based on retrospective review of patient charts and survey responses, a revision ACLR was performed for two hybrid graft patients (2/84, 2.4%) and 10 hamstring autograft patients (10/119, 8.4%) ($p = 0.073$). This left 191 eligible patients without a revision procedure at the time of study initiation (►**Fig. 2**).

One hundred forty-eight patients (148/191, 77%) were successfully contacted for follow-up, including 83 hamstring autograft and 65 hybrid graft patients. Among these patients, average age at the time of surgery was 28.6 ± 9.9 and 40.4 ± 10.3 years in the A and H groups, respectively ($p < 0.0001$). Average follow-up time was 4.7 ± 1.9 and 3.5 ± 0.9 years in the A and H groups, respectively ($p < 0.0001$). Average hamstring graft diameter was 7.5 ± 0.5 mm (range, 6.5–9.0 mm), compared with 9.1 ± 0.5 mm (range, 7.5–10.0 mm) for the hybrid autograft-allograft combination ($p < 0.0001$). Patient-reported outcomes are shown in ►**Table 1**. No significant differences were found between the groups, though there was a trend toward a significantly higher SF-12 Mental Component Summary (MCS) in the hybrid graft group ($p = 0.054$).

From all the completed surveys, 36 matched-pairs were formed based on sex, age at surgery within 3 years, and follow-up time. This included 17 males and 19 females in each group. Average age at the time of surgery was 35.8 ± 9.3 years (range, 14–57 years) and 36.0 ± 9.3 years (range, 13–54 years) in the A and H groups, respectively. Time to follow-up was 4.4 ± 1.7 years (range, 2.3–8.9 years) and 3.7 ± 1.0 years (range, 2.2–6.7 years) in the A and H groups, respectively. Patient-reported outcomes for the matched-pair comparison are shown in ►**Table 2**. The majority of outcome scores were higher in the hybrid graft group, with statistical significance reached for the KOOS Quality of Life (QOL) subscale score ($p = 0.028$), the SANE score ($p = 0.015$), and the subjective IKDC score ($p = 0.031$). In addition, there was a trend toward a significantly higher KOOS Symptoms subscale score in the hybrid graft group ($p = 0.067$).

Discussion

Few published studies have analyzed outcomes following ACLR with hybrid autograft-allografts.[9–13] Li et al[11] performed a level II, prospective randomized study to compare hamstring autograft, γ-irradiated tibialis anterior allograft, and hybrid graft composed of semitendinosus autograft and γ-irradiated tibialis anterior allograft. A total of 95 patients completed a minimum 5-year follow-up. At final follow-up, KT-1000 showed significantly more anterior laxity in the allograft group compared with the other two groups. Otherwise, no significant differences were found between groups in terms of Lachman, pivot-shift, objective or subjective IKDC scores, Lysholm, or Tegner activity scores.

Burrus et al[9] performed a retrospective matched-pair cohort study to compare outcomes after ACLR with hamstring autograft ($n = 29$) versus hybrid graft ($n = 29$) with semitendinosus or gracilis autograft and semitendinosus or tibialis anterior allograft. Indications for hybrid graft were a

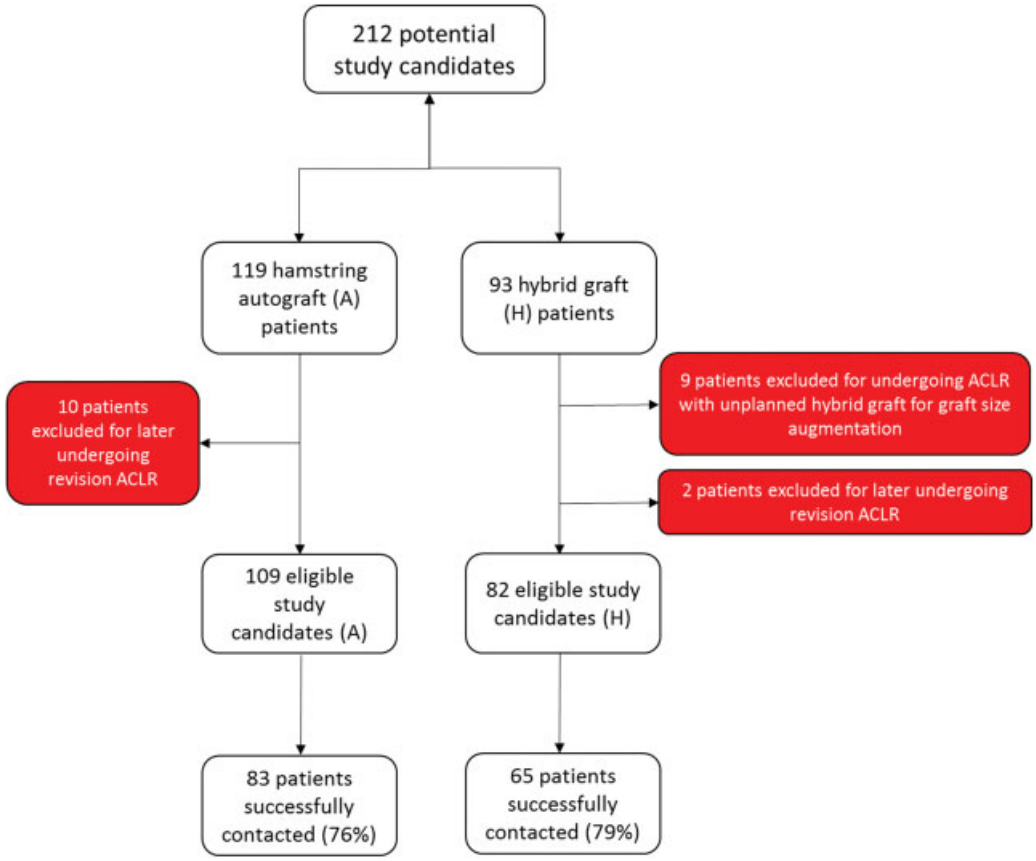

Fig. 2 Patient eligibility and follow-up rates. ACLR, anterior cruciate ligament reconstruction.

hamstring autograft diameter of less than 7.5 mm. Rate of graft failure/compromise (i.e., partial graft rupture) was significantly higher in the hybrid group at an average follow-up of 44 and 48 months in the hybrid and autograft groups, respectively. Furthermore, Lysholm and IKDC scores were significantly lower in the hybrid group. However, similar to the study above, the allografts used for hybrid grafts in this study were treated with low-dose irradiation (1.2–1.9 Mrad).

According to Alvarez-Pinzon et al,[1] the only indication for hybrid graft use is when autologous tissue is inadequate or damaged during harvest. This same group performed a retrospective cohort study based on this indication to compare graft failure rate and clinical outcomes between patients undergoing primary ACLR with hamstring autograft ($n = 71$) versus hybrid graft ($n = 24$) with hamstring autograft and tibialis allograft.[14] Average follow-up was 26.9 months. No significant differences were found between groups in terms of graft tear rate or outcome scores, including the IKDC, University of California Los Angeles (UCLA) ACL QOL assessment, or VAS pain score.

A recent study by the Multicenter Orthopaedic Outcomes Network (MOON) Group demonstrated similar patient-reported outcome scores in a matched-pair analysis of hybrid graft ($n = 27$) versus hamstring autograft ($n = 27$) for ACLR.[10] However, as in previous studies, a hybrid graft was only utilized in cases of hamstring autograft with a diameter of less than 8 mm, and was augmented with a semitendinosus tendon allograft. Furthermore, although allografts used in this study were free of high-dose irradiation (> 2.5 Mrad), some were treated with low-dose irradiation. At 2-year follow-up, 5 hybrid graft patients (18.5%) and 2 hamstring autograft patients (7.4%) required revision surgery, though this difference was not statistically significant.

Irradiated allografts have been shown to result in lower biomechanical strength[15] and higher laxity and graft failure rates[16,17] compared with nonirradiated allografts, and so their use in hybrid grafts may diminish the outcomes in these patients. Many of the studies mentioned above[9–11,13] have utilized irradiated allografts to augment hamstring tendon autografts with small diameter. This may be one of the main reasons for the equivalent or inferior results of hybrid grafts demonstrated in most of these studies, in comparison to a hamstring autograft. Only nonirradiated, aseptically procured allografts were used in this study, which may contribute to the improved hybrid graft outcomes demonstrated in relation to previous studies. In addition, the older age of the patients included in this study (average 36.0 years) may also provide a rationale for the improved outcomes and low risk of revision surgery following ACLR with a hybrid graft.

Studies have shown that hamstring autografts with a small diameter (often less than 8 mm) are at increased risk of graft failure after ACLR in younger patients.[18–21] Furthermore, Boniello et al[22] recently showed significant differences

Table 1 Outcome scores

Outcome score	Hamstring autograft ($n = 83$)	Hybrid graft ($n = 65$)	*p*-Value
Change in activity level (preinjury to follow-up)	−0.8 ± 1.4 (−5 to 3)	−0.9 ± 1.8 (−6 to 4)	0.70
KOOS symptoms	85.3 ± 15.3 (20–100)	87.2 ± 13.5 (45–100)	0.43
KOOS stiffness	89.9 ± 13.6 (50–100)	89.6 ± 14.4 (0–100)	0.90
KOOS function, daily living	96.1 ± 7.8 (62–100)	96.5 ± 7.0 (65–100)	0.76
KOOS sports	80.1 ± 18.5 (17–100)	82.9 ± 17.8 (17–100)	0.35
KOOS QOL	76.3 ± 19.2 (19–100)	75.6 ± 21.7 (6–100)	0.84
SANE	88.3 ± 13.4 (30–100)	88.4 ± 13.6 (40–100)	0.99
SF-12 physical	53.5 ± 6.9 (28–64)	52.7 ± 7.9 (23–64)	0.52
SF-12 mental	51.5 ± 9.9 (16–67)	54.2 ± 6.8 (32–67)	0.054
Subjective IKDC	77.7 ± 12.7 (38–93)	77.2 ± 13.6 (34–93)	0.82

Abbreviations: IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; QOL, quality of life; SANE, Single Assessment Numeric Evaluation; SD, standard deviation; SF-12, 12-Item Short-Form Health Survey.
Note: Data presented include all completed patient surveys. Data are given as a mean ± SD (range).

Table 2 Matched-pair comparison

Outcome score	Hamstring autograft ($n = 36$)	Hybrid graft ($n = 36$)	*p*-Value
Change in activity level (preinjury to follow-up)	−0.8 ± 1.4 (−5 to 3)	−0.8 ± 1.7 (−6 to 2)	0.80
KOOS symptoms	81.4 ± 15.1 (40–100)	87.6 ± 13.5 (45–100)	0.067
KOOS stiffness	88.2 ± 15.5 (50–100)	91.0 ± 11.8 (63–100)	0.41
KOOS function, daily living	94.8 ± 9.3 (62–100)	97.4 ± 6.3 (72–100)	0.12
KOOS sports	75.9 ± 19.9 (17–100)	84.0 ± 17.6 (33–100)	0.10
KOOS QOL	69.6 ± 19.5 (19–100)	79.2 ± 21.8 (6–100)	**0.028**
SANE	83.2 ± 15.9 (30–100)	91.4 ± 10.3 (60–100)	**0.015**
SF-12 physical	52.3 ± 7.9 (32–64)	53.6 ± 8.1 (23–64)	0.52
SF-12 mental	50.7 ± 12.0 (16–67)	52.3 ± 8.0 (32–67)	0.46
Subjective IKDC	72.6 ± 13.5 (38–93)	79.7 ± 12.5 (37–93)	**0.031**

Abbreviations: IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; QOL, quality of life; SANE, Single Assessment Numeric Evaluation; SD, standard deviation; SF-12, 12-Item Short-Form Health Survey.
Note: Data are given as a mean ± SD (range). Statistically significant findings are in bold ($p < 0.05$).

in load to failure between hamstring grafts of 6 mm versus 7 mm in diameter, and suggested that increasing tendon diameter by 1 to 2 mm may dramatically affect graft strength. As a result, many study groups have attempted to find ways to predict the diameter of a two- or four-strand hamstring autograft prior to surgery.[18,23–26] The patients in this study who underwent ACLR with a hamstring autograft had an average hamstring tendon diameter of 7.5 mm, compared with 9.1 mm among the hybrid graft cohort. In fact, it was not possible to match patients from both groups based on graft diameter within 0.5 mm. The difference in average graft diameter between the groups in this study likely resulted in significant differences in ultimate tensile strength of the grafts.[22] Supplementation of hamstring autograft with an allograft may minimize the loss of hamstring function. Furthermore, by preoperatively planning for the use of a hybrid graft for ACLR, it is only necessary to harvest the semitendinosus tendon, which has been shown to result in less donor-site morbidity compared with harvesting both the semitendinosus and gracilis tendons,[27] though may not have a clinically significant impact on isokinetic and isometric hamstring strength postoperatively.[28]

The strengths of this study include the first clinical outcomes analysis of ACLR with a preoperatively planned hybrid graft. In addition, the sample size is significantly larger than previous studies on hybrid graft use for the purpose of graft size augmentation. The limitations of this study should also be noted. This study was retrospective. Revision risk was calculated by review of patient charts and completed surveys, and therefore patients who had revision ACLR at another institution were not available for this calculation. In addition, 23% of patients could not be reached for follow-up. Finally, patients were not assessed at follow-up with objective outcomes such as imaging or KT-1000 testing.

Conclusion

While hybrid grafts have previously been indicated for ACLR only in patients with inadequate or damaged hamstring tendons, a preoperatively planned hybrid graft may also be used for this procedure. By preoperatively planning for a hybrid graft, it is only necessary to harvest the semitendinosus tendon, which may result in reduced donor-site morbidity postoperatively compared with harvesting both the semitendinosus and gracilis tendons. Planned hybrid grafts also have a significantly higher graft diameter on average compared with a semitendinosus-gracilis autograft, which may reduce the risk of postoperative graft failure. A preoperatively planned hybrid graft, with use of a fresh-frozen, nonirradiated allograft, should be considered as a viable alternative for primary ACLR in older patients.

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