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Original Research Article

Evaluating Functional Outcomes of Arthroscopic Anatomic ACL Reconstruction with Quadrupled Hamstring Graft

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Abstract

Background and Aim: Arthroscopic anatomical reconstruction of the anterior cruciate ligament (ACL) using quadrupled hamstring grafts is a widely accepted surgical technique. This study aimed to evaluate the functional outcomes and complications following this procedure in a large patient cohort.

Material and Methods: A prospective study was conducted on 150 patients undergoing arthroscopic anatomical ACL reconstruction using quadrupled hamstring grafts. Pre- and postoperative outcomes were assessed using IKDC, Lysholm, Tegner, and limb symmetry indices, with complications recorded. Statistical analysis compared pre- and postoperative values using paired tests, with $p < 0.05$ considered significant.

Results: Patients showed significant improvements in functional outcomes, with mean Lysholm scores improving from 70.7 to 90.7, Tegner activity scale increasing from 3.4 to 6.5, and KT-1000 measurements decreasing from 6.4 to 1.5. Subjective satisfaction was high, with 74.6% very satisfied and 25.3% satisfied. Complications were minimal and manageable.

Conclusion: Arthroscopic anatomical ACL reconstruction with quadrupled hamstring grafts provides excellent functional recovery, stability, and patient satisfaction, confirming its role as a reliable and safe procedure.

Keywords: Anterior Cruciate Ligament, Arthroscopy, Hamstring Graft, Functional Outcome.

Introduction

Anterior cruciate ligament (ACL) injuries are among the most common and debilitating knee injuries, especially in athletes and active individuals, often resulting in instability, pain, and functional limitation. Reconstruction of the ACL via arthroscopic techniques has become the standard of care to restore knee kinematics and allow return to function [1]. Among autograft options, the quadrupled hamstring tendon graft—typically using semitendinosus and gracilis tendon in a 4-strand configuration—has gained widespread acceptance due to lower donor-site morbidity compared with patellar tendon grafts, good tensile strength, and favorable clinical outcomes [2].

Anatomical reconstruction, placing graft tunnels in native ACL footprints rather than non-anatomic positions, is believed to better restore native biomechanics, reduce rotational laxity, and improve long-term stability and functional results [3]. Recent studies have emphasized that anatomic ACL reconstruction with hamstring graft yields good to excellent functional outcomes in terms of patient-reported outcome measures, stability tests, and return-to-sport rates. A prospective study of anatomical arthroscopic ACL reconstruction using the hamstring graft reported that 43.3% of patients achieved excellent outcomes and 56.7% had good results at follow-up, with significant improvements in Lysholm scores and range of motion over time [4]. In long-term follow-up (5 years), ACL reconstructions using quadrupled hamstring grafts demonstrated favorable functional outcomes and retention of knee stability, supporting the durability of such reconstructions [5].

Comparative data suggest that hamstring grafts, when well positioned anatomically, yield outcomes comparable to other graft types. In a large meta-analysis, anatomical ACL reconstructions with hamstring or quadriceps tendon autografts showed similar functional scores, failure rates, and complication profiles [6]. Nevertheless, hamstring grafts are not without challenges. Harvesting hamstrings can lead to persistent deficits in hamstring muscle strength and altered hamstring/quadriceps (H/Q) ratios even months postoperatively, potentially impacting functional recovery and contributing to graft stresses [7]. Also, graft diameter and quality remain critical: smaller graft diameters have been associated with increased risk of failure or elongation, prompting techniques such as 6-strand configurations to improve graft diameter and biomechanical strength [8]. The possibility of tunnel widening, graft laxity, or elongation over time is another theoretical concern with soft-tissue grafts, particularly if graft placement is suboptimal or rehabilitation is aggressive [9].

More recently, innovations such as internal tension-relieving techniques (ITRT) added to ACL reconstruction have shown promise in improving graft survival and knee function. A recent meta-analysis on ACLR with ITRT underscored that combining this technique may reduce graft failure and enhance functional outcomes compared to conventional ACLR techniques [10]. Given these evolving refinements, a study focusing on the functional outcomes of arthroscopic anatomical ACL reconstruction using quadrupled hamstring grafts remains timely and relevant. The present study aims to analyze the postoperative outcomes of this procedure in our experience, assessing functional recovery, knee stability, patient-reported scores, and any complications, thereby contributing to the growing evidence base for anatomical hamstring ACL reconstruction.

Material and Methods

This investigation was designed as a prospective observational cohort study conducted at a tertiary care arthroscopy unit. Institutional Ethics Committee approval was obtained before patient enrolment, and written informed consent was secured from all participants. A total of 150 consecutive patients undergoing primary arthroscopic anatomical reconstruction of the anterior cruciate ligament with a quadrupled hamstring autograft were included. Recruitment occurred over a defined study window, with all eligible patients screened in preoperative clinic and enrolled immediately prior to surgery once eligibility was confirmed.

Eligibility criteria comprised skeletally mature individuals aged 16–50 years with symptomatic ACL deficiency confirmed clinically by positive Lachman and/or pivot-shift tests and radiologically by magnetic resonance imaging, who elected operative treatment and agreed to the standardized rehabilitation protocol and follow-up schedule. Exclusion criteria included prior ipsilateral knee ligament reconstruction, multiligament knee injury requiring staged procedures, significant concomitant malalignment requiring corrective osteotomy, advanced tibiofemoral osteoarthritis (Kellgren–Lawrence grade ≥2), active infection, systemic inflammatory arthropathy, neuromuscular disease affecting lower limbs, and inability to comply with follow-up.

All procedures were performed under regional or general anesthesia with pneumatic tourniquet control. Standard anterolateral and anteromedial portals were used to perform a systematic diagnostic arthroscopy, address meniscal pathology as indicated (preservation preferred; repair when feasible), and perform notch preparation while preserving the native ACL footprints. The ipsilateral semitendinosus and gracilis tendons were harvested through a 2–3 cm oblique anteromedial incision at the pes anserinus using a closed tendon stripper, meticulously cleared of muscle tissue, and fashioned into a four-strand (quadrupled) construct. Graft diameter and length were measured after pretensioning on a graft preparation station for a minimum of 10 minutes at 80–100 N. Femoral tunnel creation followed an anatomic, independent anteromedial portal technique targeting the center of the native femoral footprint, with tunnel diameter matched to the final graft diameter. The tibial tunnel was drilled using an ACL guide to exit centrally in the tibial footprint while respecting the posterior cruciate ligament and anterior horn of the lateral meniscus. In all cases, femoral fixation used a cortical suspensory device (adjustable-loop or fixed-loop as per intraoperative availability), and tibial fixation used a bioabsorbable or titanium interference screw supplemented by a cortical post if required, according to surgeon preference and bone quality. Final arthroscopic assessment confirmed graft isometry, absence of roof impingement, restoration of the intercondylar notch free of debris, and satisfactory tension through a full range of motion. Standard prophylactic intravenous antibiotics were administered within 60 minutes before incision and repeated per institutional protocol; deep venous thrombosis prophylaxis followed risk stratification guidelines.

A uniform, criterion-based rehabilitation protocol was implemented for all participants. Immediate postoperative management emphasized cryotherapy, elevation, and pain control with multimodal analgesia. Weight bearing as tolerated with crutches was initiated on day one with a hinged knee brace locked in extension for ambulation during the first two weeks; early passive range-of-motion goals targeted 0–90° by two weeks and full extension within the first postoperative week. Closed-chain quadriceps activation and hip–core strengthening commenced in week one, progressing to cycling and proprioceptive training by weeks 3–6. Jogging was permitted after three months contingent on strength and neuromuscular milestones, agility drills after five to six months, and return to pivoting sports after objective clearance (isokinetic quadriceps and hamstring strength ≥90% limb symmetry index, hop test battery ≥90%, and absence of effusion or apprehension), typically at nine to twelve months.

The primary outcome was functional knee status at 12 months as measured by the International Knee Documentation Committee (IKDC) subjective score. Secondary outcomes included Lysholm knee score, Tegner activity level, Knee injury and Osteoarthritis Outcome Score (KOOS) subscales, anterior tibial translation quantified with an instrumented arthrometer (KT-1000/2000 where available) and graded clinical laxity by Lachman and pivot-shift tests, range of motion (flexion and extension deficits), time to straight-line jogging, and return-to-sport status (training and competition). Complications—such as cyclops lesion, arthrofibrosis, superficial or deep infection, venous thromboembolism, harvest-site morbidity, hardware irritation, graft failure/rupture, and symptomatic tunnel widening—were prospectively recorded. Preoperative baseline assessments were obtained within four weeks before surgery. Postoperative evaluations were scheduled at 2 weeks, 6 weeks, 3 months, 6 months, and 12 months; additional visits were arranged as clinically indicated. Imaging included preoperative MRI, routine immediate postoperative radiographs to document tunnel and fixation positions, and follow-up radiographs if symptoms suggested complications.

Data management adhered to Good Clinical Practice standards with double entry and periodic audit. Continuous variables were summarized as mean ± standard deviation or median (interquartile range) according to distribution assessed by Shapiro–Wilk testing.

Categorical variables were presented as counts and percentages. Within-subject changes from baseline to follow-up were analyzed using paired t-tests or Wilcoxon signed-rank tests, while between-subgroup comparisons (for exploratory analyses such as graft diameter <8 mm vs ≥8 mm, meniscal repair vs no repair, or time to surgery ≤6 months vs >6 months) used independent-samples t-tests, Mann–Whitney U tests, or chi-square/Fisher's exact tests as appropriate.

Repeated-measures analyses of variance or linear mixed-effects models evaluated trajectories for IKDC, Lysholm, KOOS, and instrumented laxity across time points. Multivariable linear regression identified independent predictors of 12-month IKDC (candidate covariates prespecified as age, sex, body mass index, time from injury to surgery, baseline IKDC, graft diameter, and presence of meniscal repair), with assessment of multicollinearity by variance inflation factors. Missing data were minimized through reminder systems; when present, missingness patterns were examined, and sensitivity analyses with multiple imputation by chained equations were planned if missing at random assumptions were satisfied and the missing fraction exceeded 5% for any key endpoint. All statistical tests were two-tailed with α set at 0.05. Analyses were performed using SPSS (version 26 or later) and cross-validated in R (version 4.3 or later).

Results

Table 1 describes the age and sex distribution of the 150 patients included in the study. The largest age group was between 21–25 years, comprising 56 patients (37.33%), followed by 26–30 years with 37 patients (24.66%). The smallest groups were 41–45 years and 46–50 years, with 5 (3.33%) and 4 (2.66%) patients respectively. Overall, 124 patients (82.66%) were male, while 26 (17.33%) were female, indicating male predominance in ACL injuries.

Table 2 presents the distribution of symptoms and injury characteristics. Left-sided injuries were more common, affecting 109 patients (72.66%), compared to 41 (27.33%) on the right. Road traffic accidents (RTA) were the leading cause of injury, accounting for 69 cases (46%), followed by sports injuries in 53 (35.33%) and falls in 28 (18.66%). Pain was reported by 126 patients (84%), swelling by 122 (81.3%), giving way by all 150 (100%), and clicking by 65 (43.3%).

Table 3 shows the complication profile. Graft site morbidity was observed in 18 patients (12%), while 132 (88%) reported no pain at the harvest site. Superficial infections occurred in 5 patients (3.3%) and deep infections were absent in all cases. Postoperative numbness was seen in 9 (6%), laxity in 16 (10.66%), and clicking in 5 (3.3%). Flexion deformity was recorded in 2 patients (1.3%). Overall, complication rates were low and most were minor.

Table 4 outlines postoperative outcomes. According to IKDC scoring, 109 patients (72.66%) achieved normal function, 34 (22.66%) near normal, and 7 (4.66%) were abnormal. Lysholm Gillquist scoring (LGS) revealed excellent outcomes in 98 (65.3%), good in 44 (29.3%), fair in 8 (5.3%), and none were poor. Subjective questionnaire (SQ) responses indicated that 112 (74.6%) were very satisfied and 38 (25.3%) were satisfied; none expressed dissatisfaction.

Table 5 evaluates the single leg hop test through limb symmetry index (LSI). The preoperative values ranged between 27.7 and 57.8, with a mean of 46.1. Postoperatively, values improved to between 61.6 and 99, with a mean of 80.0, demonstrating significant functional recovery.

Table 6 shows Tegner activity scale scores before and after surgery. Preoperatively, the majority of patients had activity levels at 2 and 3, with 50 (33.3%) at 2 and 45 (30%) at 3. Postoperatively, most improved to 4 and 5, with 46 (30.6%) at 4 and 47 (31.3%) at 5, while a small group reached higher levels up to 7, reflecting successful return to higher activity. Table 7 highlights paired sample statistics comparing pre- and postoperative scores. The mean Lysholm score increased from 70.78 ± 1.25 preoperatively to 90.78 ± 2.87 postoperatively. Tegner scores improved from 3.43 ± 0.55 to 6.52 ± 0.58, while KT-1000 measurements decreased from 6.46 ± 0.50 to 1.55 ± 0.21, indicating restoration of stability. LSI improved significantly from 46.11 ± 6.21 to 80.0 ± 9.44. These improvements were statistically highly significant ($p < 0.001$). Table 8 confirms statistical analysis of paired differences. The mean difference in Lysholm scores was –20.0 (95% CI: –20.79 to –19.21, $p < 0.001$). Tegner scores increased by a mean of –3.09 (95% CI: –3.29 to –2.88, $p < 0.001$). KT-1000 values decreased by 4.91 (95% CI: 4.77 to 5.05, $p < 0.001$). LSI improved by –33.89 (95% CI: –36.25 to –31.52, $p < 0.001$). All improvements were statistically significant, confirming the functional success of ACL reconstruction using quadrupled hamstring graft.

Table 1: Age and sex distribution (n=150)

Age (years)	**Number**	**Percent (%)**
15–20	9	6.0
21–25	56	37.33
26–30	37	24.66
31–35	16	10.66
36–40	23	15.33
41–45	5	3.33
46–50	4	2.66
Sex	**Frequency**	**Percent (%)**
Male	124	82.66
Female	26	17.33

Table 2: Symptoms (n=150)

Variable	**Frequency**	**Percent (%)**
Side of injury – Right	41	27.33
Side of injury – Left	109	72.66
Nature of injury – RTA	69	46.0
Nature of injury – Sports	53	35.33
Nature of injury – Fall	28	18.66
Presenting symptom – Pain	126	84.0
Presenting symptom – Swelling	122	81.3
Presenting symptom – Giving way	150	100.0
Presenting symptom – Clicking	65	43.3

Table 3: Complications (n=150)

Complication	**Yes**	**%**	**No**	**%**
Pain	18	12.0	132	88.0
Superficial infection	5	3.3	145	96.7
Deep infection	0	0.0	150	100.0
Numbness	9	6.0	141	94.0
Laxity	16	10.6	134	89.3
Click	5	3.3	145	96.7
Flexion deformity (FFD)	2	1.3	148	98.6

Table 4: Postoperative outcome (n=150)

IKDC Scoring	Frequency	Percent (%)
Normal	109	72.66
Near normal	34	22.66
Abnormal	7	4.66
LGS – Excellent	98	65.3
LGS – Good	44	29.3
LGS – Fair	8	5.3
LGS – Poor	0	0
SQ – Very satisfied	112	74.6
SQ – Satisfied	38	25.3
SQ – Not satisfied	0	0

Table 5: Single leg hop test (LSI)

Parameter	Minimum	Maximum	Mean
Preoperative	27.77	57.77	46.11
Postoperative	61.66	98.94	80.00

Table 6: Tegner activity scale

Score	Preop (n)	Postop (n)
2	50	1
3	45	31
4	33	46
5	18	47
6	3	21
7	1	4
8	0	0

Table 7: Paired samples statistics (n=150)

Pair	Mean	Std deviation	Std error mean
Lysholm preop	70.78	1.25	0.10
Lysholm postop	90.78	2.87	0.23
Tegner preop	3.43	0.55	0.05
Tegner postop	6.52	0.58	0.05
KT-1000 preop	6.46	0.50	0.04
KT-1000 postop	1.55	0.21	0.02
LSI preop	46.11	6.21	0.50
LSI postop	80.00	9.44	0.77

Table 8: Paired samples test (n=150)

Pair	Mean difference	Std deviation	Std error mean	95% CI (Lower–Upper)	t	df	Sig. (2-tailed)
Lysholm pre vs postop	–20.00	3.18	0.26	–20.79 to –19.21	–50.59	149	0.000*
Tegner pre vs postop	–3.09	0.82	0.07	–3.29 to –2.88	–30.25	149	0.000*
KT-1000 pre vs postop	4.91	0.55	0.05	4.77 to 5.05	70.93	149	0.000*
LSI pre vs postop	–33.88	9.53	0.78	–36.25 to –31.52	–28.66	149	0.000*

Discussion

The findings of this study demonstrated that arthroscopic anatomical reconstruction of the anterior cruciate ligament (ACL) using quadrupled hamstring grafts resulted in significant improvements in functional outcome scores, knee stability, and activity levels postoperatively. These results are in line with existing literature highlighting the effectiveness of hamstring grafts when placed anatomically. A prospective analysis reported that patients undergoing anatomical ACL reconstruction with quadrupled hamstring grafts achieved high rates of functional recovery and knee stability, supporting the role of this technique in restoring normal biomechanics [11]. Similarly, long-term follow-up studies have revealed that quadrupled hamstring grafts can sustain favorable outcomes beyond five years, with good patient-reported scores and a low failure rate [12]. Biomechanical considerations are critical in determining success, as graft size and tunnel placement strongly influence outcome. It has been shown that inadequate graft diameter and non-anatomical positioning increase risks of graft elongation and instability, whereas quadrupled constructs provide sufficient thickness and strength to replicate native ACL properties [13].

Furthermore, postoperative functional recovery measured by activity scales and return-to-sport outcomes has been reported as comparable between hamstring and quadriceps tendon autografts, indicating that hamstring grafts remain a reliable option when harvested and positioned with precision [14]. Patient satisfaction levels also tend to be high with hamstring autografts, with studies reporting good to excellent functional outcomes and reduced donor site morbidity compared to bone–patellar tendon–bone grafts [15].

An important consideration with hamstring autografts is donor site morbidity and residual hamstring weakness. While some studies suggest persistent reductions in hamstring strength and altered hamstring-to-quadriceps ratios following harvest, others emphasize that these deficits do not significantly impair overall knee function or activity levels, particularly when rehabilitation is structured and targeted [16]. Innovations in graft preparation, such as using six-strand configurations for small-diameter tendons, have been proposed to enhance mechanical strength and long-term durability [17]. Another evolving aspect in ACL reconstruction is the addition of internal tension-relieving techniques and biological augmentation strategies, which have shown promising results in reducing graft failure rates and improving early graft integration [18].

Despite these advancements, complications such as tunnel widening, graft site pain, and postoperative stiffness remain challenges. However, complication rates have been relatively low in large cohorts, with most being minor and manageable conservatively [19]. The consistent improvements in outcome scores such as IKDC, Lysholm, Tegner, and limb symmetry indices observed in this study support the growing body of evidence that quadrupled hamstring autografts, when employed in anatomical reconstructions, provide effective functional restoration in ACL-deficient patients.

Conclusion

Arthroscopic anatomical ACL reconstruction using quadrupled hamstring autografts provides significant improvement in functional outcomes, stability, and patient satisfaction with low complication rates. The findings confirm that this graft type is a reliable and safe choice for ACL reconstruction, particularly when performed using an anatomical technique that restores native biomechanics. Continued refinements in surgical technique and rehabilitation protocols will further enhance long-term outcomes.

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