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Functional outcomes of anatomical anterior cruciate ligament reconstruction using single-bundle quadruple hamstring graft: a prospective study using the Lysholm score and single hop test

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ABSTRACT

Background: Anterior cruciate ligament (ACL) injuries are among the most common sports-related knee injuries. Anatomical reconstruction techniques have evolved to restore native knee kinematics. This study aimed to evaluate the functional outcomes of anatomical ACL reconstruction using a single-bundle quadruple hamstring tendon graft.
Methods: A prospective study was conducted involving 30 patients with isolated ACL tears confirmed clinically and radiologically. All patients underwent anatomical single-bundle ACL reconstruction using a quadruple hamstring graft with femoral fixation via an Endobutton and tibial fixation with an interference screw. Functional outcomes were assessed using Lysholm Knee Scoring Scale and the Single Hop Test preoperatively and at 6 months postoperatively.
Results: The mean preoperative Lysholm score improved from 54.46 to 91.06 at 6 months, indicating statistically significant improvement ($p<0.001$). The Single Hop Test showed a marked increase in limb symmetry index from a preoperative mean of 44.35% to 83.50% postoperatively, reflecting substantial functional recovery. No major postoperative complications were reported.
Conclusions: Anatomical ACL reconstruction using a single-bundle quadruple hamstring graft provides excellent short-term functional outcomes with minimal morbidity. This technique offers reliable restoration of knee function and stability, with promising results in active patients.

Keywords: ACL reconstruction, hamstring graft, anatomical single bundle, knee function, Lysholm score, single hop test

INTRODUCTION

Injury to the anterior cruciate ligament (ACL) is one of the most prevalent causes of knee instability, especially among athletes and individuals involved in pivoting sports such as football, basketball and wrestling. The ACL serves a crucial biomechanical role in maintaining anterior stability of the tibia relative to the femur and in controlling rotational movements of the knee joint.[1] Disruption of this ligament can lead to recurrent giving way of the knee, pain, functional limitations and an increased likelihood of early-onset osteoarthritis if left untreated.[2] Surgical reconstruction has become the standard of care for functionally unstable ACL-deficient knees, especially in young and active patients.

Among the various graft options available, bone–patellar tendon–bone (BPTB) and hamstring tendon autografts are the most commonly employed. The BPTB graft offers the advantage of robust bone-to-bone healing and early graft incorporation; however, it has been associated with donor site morbidity, anterior knee pain and increased risk of

patellar fractures or tendinitis.[3,4] On the other hand, quadruple hamstring grafts, which use the semitendinosus and gracilis tendons, have gained popularity owing to their reduced donor site complications, smaller incision and adequate graft length and strength.[5]

Biomechanical studies have shown that quadrupled hamstring tendon constructs can provide ultimate tensile strength ranging from 4000 to 4600 N, which exceeds that of the native ACL (approximately 2160 N) and is also superior to that of the BPTB graft.[6,7] Additionally, hamstring grafts allow for greater flexibility in tunnel placement and are better suited for anatomical single-bundle reconstructions, especially with the modern use of the anteromedial portal for femoral tunnel drilling. This technique allows for more precise graft placement at the native footprint of the ACL, thereby improving rotational stability and potentially reducing the risk of graft failure.[8]

Functional outcomes following ACL reconstruction are typically assessed through a combination of subjective and objective measures. The Lysholm Knee Scoring Scale, a validated 100-point instrument, evaluates a range of knee symptoms and functional limitations, including pain, swelling, instability, stair climbing and squatting. It is widely used in both clinical practice and research to assess patient-reported knee function.[9] In parallel, performance-based assessments such as the single-leg hop test are used to measure lower limb strength, power and functional symmetry between the injured and uninjured limbs. A limb symmetry index (LSI) of ≥90% is often used as a benchmark for readiness to return to sport and indicates near-normal functional recovery.[10]

Despite the global focus on ACL reconstruction, studies evaluating functional outcomes in the Indian population remain relatively limited. Factors such as body habitus, activity level, surgical preferences and access to postoperative rehabilitation can significantly affect clinical outcomes and must be considered when choosing the most appropriate surgical technique. There is a need for prospective studies in Indian settings that assess modern anatomical reconstruction techniques and correlate them with functional and performance-based outcomes. This prospective study aims to evaluate the functional outcomes of anatomical ACL reconstruction using a single-bundle quadruple hamstring autograft.

Functional assessment was conducted using the Lysholm Knee Score and the single-leg hop test at defined postoperative intervals. The findings from this study are expected to contribute valuable data on the efficacy and outcomes of this surgical approach within the Indian demographic and help guide future clinical decisions and patient counselling. The specific objectives of this study were to assess the functional outcome of anatomical ACL reconstruction using a single-bundle quadruple hamstring tendon graft, to determine correlation between patient satisfaction and outcome and to analyze the relationship of the functional test (single-leg hop test) with clinical outcome.

METHODS

This study was conducted as a prospective observational analysis at Khurshitji Beharamji Bhabha Municipal General Hospital between September 2021 and September 2022. The primary objective was to assess the functional outcomes of anatomical single-bundle ACL reconstruction using quadruple hamstring tendon grafts. All surgeries were performed by experienced orthopaedic surgeons with standardized surgical and rehabilitation protocols. The study was conducted in accordance with the ethical guidelines outlined in the Declaration of Helsinki and written informed consent was obtained from all participants.

A total of 30 patients who underwent ACL reconstruction using single-bundle quadrupled hamstring graft were enrolled. The inclusion criteria were patients of both sexes aged between 18 and 50 years, diagnosed with isolated post-traumatic ACL tears confirmed via clinical examination and MRI and willing to participate and comply with follow-up protocol. Exclusion criteria included patients younger than 18 years or older than 50 years, those with multi-ligamentous injury or associated bony fractures of the involved or contralateral knee, evidence of osteoarthritic changes in the involved joint, prior surgery on either knee, use of graft types other than hamstring tendons such as BPTB or peroneus longus and patients unwilling or medically unfit for surgery.

All patients underwent detailed clinical and radiological assessments including Lachman test, anterior drawer test and pivot shift test. Functional scoring was done using the Lysholm Knee Score and Single Hop Test preoperatively. MRI was used to confirm the diagnosis of isolated ACL rupture and to exclude associated injuries.

All procedures were performed under spinal anaesthesia. The patients were positioned supine with the involved limb slightly flexed at the knee. A pneumatic tourniquet was applied to the proximal thigh and inflated after limb exsanguination. Prophylactic intravenous antibiotics (Ceftriaxone 1 g) were administered before incision. A standard diagnostic arthroscopy was initially performed to confirm ACL tear and rule out other intra-articular pathology. Harvesting of the semitendinosus and gracilis tendons was performed via a small incision over the pes anserinus insertion. The tendons were cleaned of muscle tissue, measured and quadrupled to prepare the graft. A minimum graft length of 28 cm was targeted to allow 2 cm fixation within femoral and tibial tunnels and 3 cm intra-articular length.

The femoral tunnel was created via the anteromedial portal technique to replicate the anatomical footprint of the native ACL. The tibial tunnel was drilled in line with the tibial ACL footprint using a tibial guide set at 55°. The graft was

passed using shuttle sutures, ensuring appropriate positioning. Femoral fixation was done using an Endo button and tibial fixation was achieved using an interference screw. Graft tensioning was verified at 30° knee flexion (Figure 1). Postoperatively, sterile dressings and compression bandaging were applied. All patients were immobilized in a long knee brace. Early isometric quadriceps exercises were initiated, followed by gradual range-of-motion exercises according to the American Academy of Orthopaedic Surgeons (AAOS) ACL rehabilitation protocol.[11] Sutures were removed at two weeks and patients were encouraged to progress to full weight-bearing as tolerated. At 6-month follow-up, functional recovery was assessed using the Lysholm Knee Scoring Scale, which evaluates pain, instability, locking, stair climbing and other functional parameters.[9] Additionally, a single-leg hop test was performed to objectively assess strength and limb symmetry. The test was deemed valid only if the patient landed with control and maintained balance for at least 2 seconds. Unsuccessful attempts such as loss of balance or use of the contralateral limb were repeated (Figure 2).

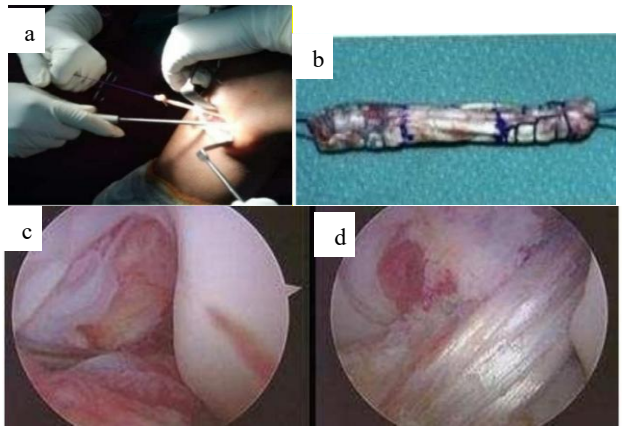


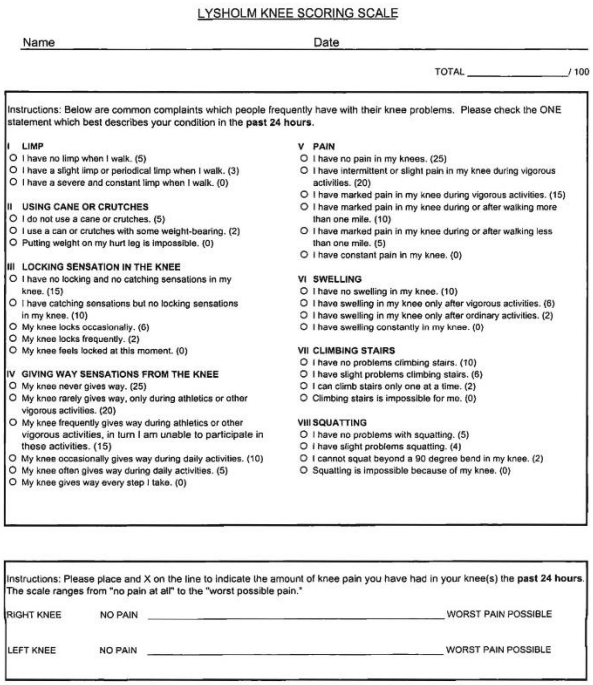
Figure 1 (a-d): Graft harvesting, quadrupled hamstring graft, torn anterior cruciate ligament, reconstructed anterior cruciate ligament with quadrupled hamstring graft.

Statistical analysis

The data was entered in Microsoft Excel 2010 and analysed using SPSS software version 21.0. Statistical tests such as the paired t-test and chi-square test were used. Chi-square analysis was applied for comparing the sex distribution, mode of injury, MRI grading of ACL tear, tests for ligament laxity at 6 months and the Lysholm knee scores of the two groups. The independent t-test was used to compare the age distribution and knee range of motion of patients in both groups. A p-value of <0.05 was considered statistically significant for all tests.

RESULTS

This prospective clinical study involved a cohort of 30 patients who underwent anatomical single-bundle ACL reconstruction using a quadruple hamstring tendon autograft. The study aimed to assess both functional and clinical outcomes over a minimum follow-up period of six months using objective examination, functional performance tests and validated outcome scores. The age of patients ranged from 18 to 40 years, with a mean age of 29.4 years.



LYSHOLM KNEE SCORING SCALE

Name _____ Date _____

TOTAL _____ / 100

Instructions: Below are common complaints which people frequently have with their knee problems. Please check the ONE statement which best describes your condition in the **past 24 hours**.

I LIMP
- ○ I have no limp when I walk. (5)
- ○ I have a slight limp or periodical limp when I walk. (3)
- ○ I have a severe and constant limp when I walk. (0)

II USING CANE OR CRUTCHES
- ○ I do not use a cane or crutches. (5)
- ○ I use a can or crutches with some weight-bearing. (2)
- ○ Putting weight on my hurt leg is impossible. (0)

III LOCKING SENSATION IN THE KNEE
- ○ I have no locking and no catching sensations in my knee. (15)
- ○ I have catching sensations but no locking sensations in my knee. (10)
- ○ My knee locks occasionally. (6)
- ○ My knee locks frequently. (2)
- ○ My knee feels locked at this moment. (0)

IV GIVING WAY SENSATIONS FROM THE KNEE
- ○ My knee never gives way. (25)
- ○ My knee rarely gives way, only during athletics or other vigorous activities. (20)
- ○ My knee frequently gives way during athletics or other vigorous activities, in turn I am unable to participate in these activities. (15)
- ○ My knee occasionally gives way during daily activities. (10)
- ○ My knee often gives way during daily activities. (5)
- ○ My knee gives way every step I take. (0)

V PAIN
- ○ I have no pain in my knees. (25)
- ○ I have intermittent or slight pain in my knee during vigorous activities. (20)
- ○ I have marked pain in my knee during vigorous activities. (15)
- ○ I have marked pain in my knee during or after walking more than one mile. (10)
- ○ I have marked pain in my knee during or after walking less than one mile. (5)
- ○ I have constant pain in my knee. (0)

VI SWELLING
- ○ I have no swelling in my knee. (10)
- ○ I have swelling in my knee only after vigorous activities. (6)
- ○ I have swelling in my knee only after ordinary activities. (2)
- ○ I have swelling constantly in my knee. (0)

VII CLIMBING STAIRS
- ○ I have no problems climbing stairs. (10)
- ○ I have slight problems climbing stairs. (6)
- ○ I can climb stairs only one at a time. (2)
- ○ Climbing stairs is impossible for me. (0)

VIII SQUATTING
- ○ I have no problems with squatting. (5)
- ○ I have slight problems squatting. (4)
- ○ I cannot squat beyond a 90 degree bend in my knee. (2)
- ○ Squatting is impossible because of my knee. (0)

Instructions: Please place and X on the line to indicate the amount of knee pain you have had in your knee(s) the **past 24 hours**. The scale ranges from "no pain at all" to the "worst possible pain."

RIGHT KNEE NO PAIN _____ WORST PAIN POSSIBLE

LEFT KNEE NO PAIN _____ WORST PAIN POSSIBLE

Figure 2: Lysholm knee scoring scale.

Table 1: Distribution of study subjects by age group.

Age group (in years)	Frequency	%
18–25	9	30.0
26–30	7	23.3
31–35	11	36.7
36–40	3	10.0
Total	30	100.0

The most commonly represented age group was 31–35 years comprising 11 patients (36.7%), followed by 9 patients (30%) in the 18–25 age group. The remaining participants were distributed between 26–30 years (23.3%) and 36–40 years (10%). These findings reflect a trend toward ACL injuries occurring most frequently in young, active adults, particularly those in their third and fourth decades of life, consistent with existing literature on ACL epidemiology (Table 1). The study population was overwhelmingly male, with 27 male patients (90%) and only 3 female patients (10%), resulting in a male-to-female ratio of 9:1. This sex distribution may be attributable to greater male participation in high-risk physical activities and manual occupations, which predispose them to traumatic knee injuries. In terms of laterality, the injury distribution was equal, with 15 patients (50%) sustaining ACL tears in the left knee and the remaining 15 (50%) in

the right knee, indicating no side dominance in injury occurrence. The most common mechanism of injury was a fall-related trauma (36.7%), closely followed by road traffic accidents (33.3%) and sports-related injuries (30%). The high incidence of trauma-related injuries further supports the association between ACL injuries and sudden twisting or deceleration mechanisms common in sports or vehicular accidents. Regarding chronicity, 23 patients (77.7%) presented with chronic ACL injuries (defined as symptoms persisting >14 days post-injury), while only 7 patients (23.3%) were categorized as acute presentations. This may reflect delayed access to orthopaedic care or initial underdiagnosis.

Table 2: Comparison of clinical stability tests before and after ACL reconstruction.

Test	Pre-op (positive)	Post-op (positive)
ADT	30 (100%)	0 (0%)
Lachman	30 (100%)	0 (0%)
Pivot Shift	8 (26.7%)	0 (0%)

All patients exhibited clinical evidence of ACL deficiency preoperatively. Standard diagnostic tests such as the sADT, lachman test and pivot shift test were utilized. ADT and Lachman tests were positive in all 30 patients (100%) before surgery, while pivot shift test was positive in 8 patients (26.7%), typically associated with higher-grade instability. Postoperatively, all patients exhibited a negative ADT, Lachman and Pivot Shift test, indicating complete restoration of knee stability in terms of clinical evaluation (Table 2).

Table 3: Postoperative functional outcome based on Lysholm knee scoring scale.

Lysholm score category	Frequency	%
Excellent (≥95)	17	56.7
Good (84–94)	11	36.7
Fair (65–83)	2	6.6
Poor (<65)	0	0

Functional recovery was evaluated using the Lysholm knee score (LKS). The mean preoperative score was 44.35±5.27, reflecting significant functional limitation. At final follow-up (6 months postoperatively), the mean Lysholm score improved to 83.42±6.61, a statistically significant difference ($p<0.001$) (Table 3). A total of 93.4% of patients fell within the "excellent" or "good" category, showing marked improvement in pain, instability, locking, stair-climbing and squatting capacity. This result aligns with recent meta-analyses supporting the efficacy of hamstring tendon autografts in restoring functional stability post-ACL reconstruction.

The single hop test was employed to assess dynamic knee function and limb symmetry. The limb symmetry index (LSI) was used to calculate performance differences between the operated and non-operated legs. Preoperatively, the mean LSI was 44.35% (range=22.72%–57.14%). Postoperatively, the mean LSI improved to 83.50% (range=66.36%–93.33%). This nearly twofold increase in LSI values postoperatively reflects significant recovery in neuromuscular control, strength and confidence in the reconstructed limb. Return-to-sport criteria often recommend an LSI≥85%, which most patients approached by 6 months. Subjective satisfaction was assessed using a self-reported questionnaire. A total of 66.7% of patients rated their experience as "very satisfied," while the remaining 33.3% were "satisfied." No patients expressed dissatisfaction, demonstrating the overall acceptability and effectiveness of this surgical technique. The complication rate was low.

One patient (3.3%) developed superficial wound infections, which were effectively managed with oral antibiotics and wound care. One patient (3.3%) reported postoperative mechanical symptoms (clicking), though this did not correlate with instability on clinical testing. There were no cases of deep infection, neurovascular complications, graft failure or re-injury noted during the follow-up period. A significant correlation (Kendall's tau-b=0.799, $p<0.001$) was found between Lysholm Score outcomes and subjective satisfaction levels.

This highlights the reliability of the Lysholm scoring system as a surrogate for patient-perceived recovery, reinforcing its utility in clinical follow-up protocols. In summary, clinical tests normalized in 100% of patients postoperatively, the mean Lysholm score improved from 44.35 to 83.42, the single hop test LSI improved from 44.35% to 83.50% and all patients reported being satisfied or very satisfied with their outcomes.

Complications were minor, with no long-term sequelae. These outcomes strongly suggest that anatomical ACL reconstruction using a quadruple hamstring graft provides excellent restoration of function and stability in a young, active population over a short-to-intermediate term follow up.

DISCUSSION

ACL injuries are one of the most frequently encountered knee pathologies in young and physically active individuals. Reconstruction of the ACL using autografts remains the gold standard for restoring knee stability and function. This study prospectively analysed the clinical and functional outcomes of anatomical ACL reconstruction utilizing a single-bundle quadruple hamstring tendon graft in 30 patients, with a follow-up period of six months. The findings strongly support the effectiveness of this method, demonstrating high rates of patient satisfaction, objective functional recovery and minimal complications. In the study cohort, males constituted the vast majority (90%), which aligns with existing literature suggesting higher exposure to activities associated with ACL injuries such as contact sports, road traffic accidents and occupational hazards.[12,14] Similar

gender distribution trends have been observed in studies by Mahir et al and Kumar et al, where the male population was predominantly represented due to greater participation in high-risk activities.[15,16] The average age of the patients was 28.5 years, predominantly falling within the 26–35 years age group.

This demographic is recognized as having the highest incidence of ACL injuries, likely due to peak physical activity levels during these years.[17] These findings are consistent with global data indicating that ACL tears are most common in individuals in their second and third decades of life.[18] In terms of laterality, injuries were evenly distributed between the left and right knees. This symmetry is also reflected in other clinical studies, supporting the notion that side dominance does not significantly influence the likelihood of ACL rupture.[19] Falls and road traffic accidents were the most common modes of injury in our sample, accounting for 36.7% and 33.3%, respectively.

Sports-related injuries made up the remaining 30%. This distribution reflects patterns often observed in developing countries, where high-impact trauma from accidents and domestic falls can be as prevalent as sports-related mechanisms.[20] Significant improvements in knee stability and function were noted postoperatively, with the Lysholm knee scoring scale serving as the principal measure of functional recovery. The mean score increased from a preoperative value of 44.35 to 83.42 postoperatively. Notably, 93% of the patients were classified as having excellent or good outcomes based on their Lysholm scores, a result that is in close agreement with earlier studies conducted by Riley et al, Mahir et al and Kumar et al who reported mean Lysholm scores ranging from 90 to 93.5 following ACL reconstruction using hamstring grafts.[15,16,21] These improvements were also reflected in the single-leg hop test. The limb symmetry index (LSI) improved from a preoperative mean of 44.35% to 83.50% postoperatively, indicating a substantial restoration of limb strength and neuromuscular control. The use of functional performance tests like the hop test has been endorsed in prior studies as a reliable metric for evaluating postoperative recovery and determining readiness to return to sport (Table 4).[22] Patient-reported outcomes are vital for assessing the overall success of surgical interventions. In our study, 66.7% of patients reported being "very satisfied," while the remaining 33.3% were "satisfied."

Table 4: Comparison of postoperative Lysholm scores across different studies on ACL reconstruction.

Study	Year	Subjects	Male:Female	Mean age (in years)	Average Lysholm score
Riley et al[21]	2004	85	59% male	33	91
Mahir et al[15]	2005	62	100 % male	24	93.5
Kumar et al[16]	2016	34	97.1% male	27	90
Authors study	2024	30	90% male	28.5	91.9

This high level of satisfaction correlates with the improved clinical and functional parameters, highlighting the importance of individualized rehabilitation and patient-centered care in orthopaedic surgery.[13] These findings reinforce the relative safety of using quadruple hamstring grafts for ACL reconstruction, as reported in broader systematic reviews and meta-analyses.[23,24] The findings align with those of previous studies in terms of graft selection, patient outcomes and complication rates. Quadrupled hamstring grafts offer several advantages, including greater graft length, better tensile strength and lower donor site morbidity compared to patellar tendon grafts.[25] The present study's postoperative Lysholm scores and functional test results confirm the utility of this technique in achieving satisfactory knee stability and function over short- to mid-term follow-up.

The study is unique in being, to the best of our knowledge, the only prospective Indian study that evaluates functional outcomes of anatomical ACL reconstruction using a single-bundle quadruple hamstring graft with both the Lysholm score and the single hop test. Very few studies in India have specifically assessed this graft choice and even fewer have incorporated an objective functional test alongside a subjective scoring system.

The study is limited by a small sample size and short follow-up duration. Although six months is sufficient to assess early outcomes, long-term follow-up is necessary to evaluate graft longevity, return to sport and development of post-traumatic osteoarthritis. Additionally, the study was not comparative; future randomized trials comparing hamstring and patellar tendon autografts or evaluating single versus double-bundle reconstructions, would provide more comprehensive insights.

CONCLUSION

This prospective study demonstrates that anatomical ACL reconstruction using a single-bundle quadruple hamstring tendon graft results in excellent functional outcomes, high patient satisfaction and minimal complications. The procedure is particularly suitable for young and active individuals, offering a reliable option for restoring knee stability and function. With structured rehabilitation and adherence to post-operative protocols, most patients can expect favourable recovery within six months.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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