Original Article

DOI: 10.7860/JCDR/2026/82393.24157

Functional Outcomes of Arthroscopic ACL Reconstruction with a Bone-patellar Tendon-bone Graft using the Femoral Press-fit Fixation Technique: A Prospective Observational Study

Orthopaedics Section

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ABSTRACT

Introduction: Anterior Cruciate Ligament (ACL) injuries are common, particularly among athletes, and require surgical intervention to restore knee stability and function. The Bone-Patellar Tendon-Bone (BPTB) graft is a widely used graft for ACL reconstruction, known for its biomechanical strength and favourable outcomes. The femoral press fit fixation technique was developed to avoid disadvantages related to hardware and other fixation devices.

Aim: To evaluate the functional outcomes of arthroscopic ACL reconstruction using the BPTB graft with the femoral press-fit fixation technique, and to review the associated complications and rehabilitation protocols.

Materials and Methods: A prospective observational study was conducted at A J Institute of Medical Sciences, Mangalore, India, from July 2022 to March 2024. It was conducted among 21 patients who underwent arthroscopic ACL reconstruction with a BPTB graft and femoral press-fit fixation. Clinical outcomes such as range of motion, postoperative complications, and graft failure were assessed using the IKDC (International Knee Documentation Committee) and Lysholm scoring systems. Repeated Measures ANOVA was utilised to compare mean IKDC scores and Lysholm's scores across time points. A p-value of <0.05 was considered significant.

Results: All patients included belonged to class III modified Kuppuswamy scale. The use of BPTB grafts in ACL reconstruction produced positive functional outcomes, including significant improvements in ($p<0.01$) knee stability and patient-reported outcomes. However, the study identifies potential problems, such as donor site morbidity in one patient among 21 (4.8%) and anterior knee pain in 9 (42.9%) patients out of 21.

Conclusion: Arthroscopic ACL reconstruction using BPTB grafts with the femoral press-fit technique is an effective method for restoring knee function. Despite certain risks, the advantages of bone-to-bone healing, cost-effectiveness, avoiding hardware-associated complications and clinical outcomes make it a preferred choice for ACL reconstruction.

Keywords: Donor site morbidity, Grafts, International knee documentation committee, LYSHOLM's Score

INTRODUCTION

The ACL injuries are prevalent, particularly among athletes, often resulting from sports-related incidents or traumatic events. Among the surgical options, arthroscopic ACL reconstruction using a BPTB graft has emerged as a highly effective technique [1].

The ACL injuries can severely impact the quality of life by limiting mobility and increasing the risk of developing long-term joint issues, such as osteoarthritis. Surgical reconstruction of the ACL aims to restore knee stability and function, thereby improving patient outcomes and quality of life. Various graft options are available for ACL reconstruction, including autografts (patient's tissue), allografts (donor tissue), and synthetic grafts. Among these, the BPTB graft is highly regarded for its biomechanical strength and favourable clinical outcomes [2]. Arthroscopic ACL reconstruction involves minimally invasive surgical techniques, allowing for precise graft placement and reduced recovery times. The BPTB graft, harvested from the central third of the patellar tendon, includes bone blocks from the patella and tibia, providing a strong and biologically compatible graft option [3].

Patient outcomes following arthroscopic ACL reconstruction with a BPTB graft are generally favourable, with high rates of return to pre-injury levels of activity. Rehabilitation protocols play a crucial role in optimising functional recovery, emphasising early mobilisation, strength training, and proprioceptive exercises. Studies consistently reported that patients undergoing ACL reconstruction with BPTB grafts achieve substantial improvements in knee stability, strength, and overall function [1-3]. Despite the overall positive outcomes, potential complications such as graft site morbidity, anterior knee pain, and patellar fractures necessitate careful patient selection and surgical technique. Advances in surgical methods and postoperative care continue to enhance the success rates of ACL reconstruction procedures [4].

Autograft (mainly patellar or hamstring tendons) or allograft (allogenic human tissue of various types) is used in surgical reconstruction for primary isolated ACL lesions, while synthetic ligaments have recently gained acceptance again after being abandoned in the past due to a high failure rate. According to multiple studies involving surgeons from various countries, the selection of a technique is determined by clinical and biomechanical standards, tradition and surgeon experience [5,6].

Hertel P and Behrend H described the first implant-free procedures for ACL reconstruction, which is a press-fit technique of ACL graft reconstruction, and the outcomes were good [7]. The advantages include minimal expenses and ease of revision.

The ACL's structure and design are closely related to its function as a joint mobility constraint. The complicated design of the ACL reflects its importance to knee function, as evidenced by its orientation inside the joint and the microanatomy of its insertion [8].

The present study aimed to assess the functional outcome of arthroscopic ACL reconstruction using bone- patellar tendon-bone graft using the femoral press fit fixation technique.

MATERIALS AND METHODS

A prospective observational study was conducted at AJ Institute of Medical Sciences, Mangalore, from July 2022 to March 2024 on patients admitted at AJIMS in the orthopaedic department. IEC number- AJEC/REV/143/2022.

Inclusion criteria:

- Clinically diagnosed traumatic ACL tear of the knee joint;
- ACL tear with a positive Lachman test;
- MRI confirmation of ACL rupture;
- Both acute and chronic ACL-deficient knees;
- ACL tear associated with meniscal and chondral injuries;
- Age group between 18 and 45 years, including both males and females.

Exclusion criteria:

- Patients with osteoarthritic changes of the knee;
- Patients with overlying skin infections around the knee;
- Patients with patellar fractures;
- Multiligament injury associated with ACL tear;
- Bilateral ACL tear;
- ACL tear patients with more than Grade II pivot shift [9].

Sample size calculation: The sample size was estimated using the standard formula for proportions:

$$Z^2P\cdot(1-P)L^2n$$

Where:

Z = 1.96 for 95% confidence interval

P = expected proportion of favourable functional outcome

L (allowable error) = 20%

As there is limited literature reporting a uniform proportion for combined IKDC and pivot shift outcomes using press-fit fixation, the expected proportion (P) was assumed to be 0.5. This assumption provides the maximum sample size and is considered statistically conservative in the absence of reliable prior estimates.

Substituting the values:

$$n = \frac{(1.96)2 \times 0.5 \times 0.5}{(0.20)^2}$$

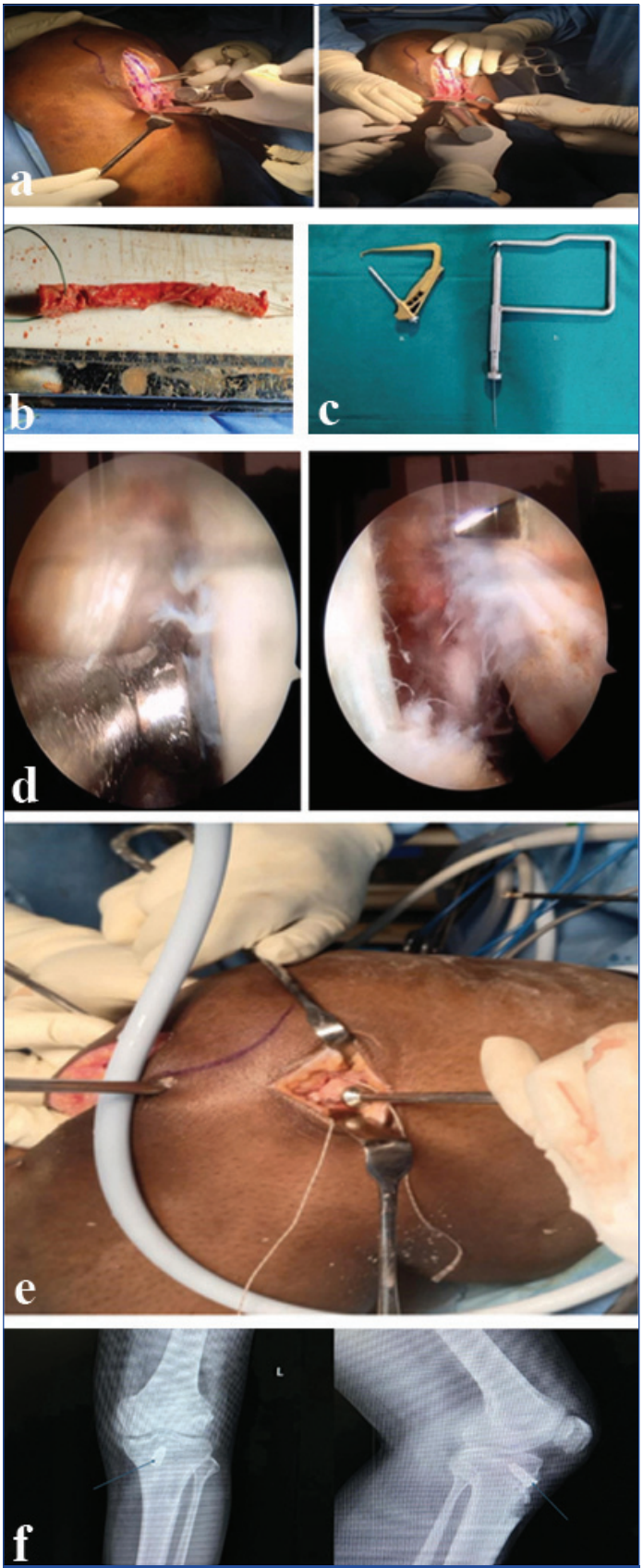
$$n = \frac{3.8416 \times 0.25}{0.04}$$

$$n = \frac{0.9604}{0.04} = 24.01$$

Thus, the calculated sample size was approximately 24 patients. However, due to feasibility constraints and the pilot nature of the study, a total of 21 patients were included.

The patient was positioned supine under general, spinal, or epidural anaesthesia. The operative limb was prepared with a high-thigh tourniquet and lateral thigh support for 90° knee flexion. Anterolateral and anteromedial portals were used to confirm the ACL rupture. A 4 to 5 cm midline incision was made from the inferior pole of the patella to the tibial tuberosity, and the central third of the patellar tendon was harvested along with 10 mm width bone plugs from the patella and tibia. The plugs were prepared and wrapped in vancomycin soaked gauze. After arthroscopic debridement, the femoral tunnel was created using an outside-in technique with a 7-mm offset jig, reamed up to 10 mm. The tibial tunnel was made using a guide set at 55 to 65°, also reamed to 10 mm.

The graft was passed from the femur to the tibia, with the patellar bone plug rotated 90° to mimic the native ACL orientation. Femoral fixation was achieved with the tibial plug under press-fit, while tibial fixation used an 8-mm screw at 30° of knee flexion. Graft position and impingement were checked arthroscopically, and the donor site was closed in layers [Table/Fig-1a-f].



[Table/Fig-1]: ACL reconstruction with BPTB graft using femoral press- fit fixation technique. a) Harvesting patellar tendon along with tibial and patellar bone plugs; b) BPTB graft with trapezoidal tibial block and a rectangular patellar block secured by fibre wire sutures; c) Standard tibial and outside-in femoral ACL jig; d) arthroscopic image of outside-in ACL jig inserted through the antero-medial portal and placed over the anatomical insertion site of ACL and guide pin inserted through the jig and visualised arthroscopically; e) Distal trapezoid part of tibial bone block punched to make it a press fit until the external mouth of femoral tunnel; f) Postoperative radiographs showing femoral implant free press fit fixation (blue arrow shows PEEK screw fixation of BPTB graft to tibial tunnel).

All patients underwent the same rehabilitation program after surgery. In the first week, a long extension knee brace was applied, and patients walked with a walker, bearing partial weight on their toes. Immediate quadriceps and Hamstring (HS) isometric exercises, hip abductor strengthening, ankle movements, and straight leg raises with the brace were initiated. By the tenth postoperative day, 0°-60° closed-chain flexion was allowed, while open-chain knee extension was avoided for up to three months.

At three weeks, patients performed knee flexion between 0° and 90° and bore weight as tolerated with crutches. By the fourth week, the brace was removed, full weight-bearing was permitted, and isotonic HS contraction, hip abductor strengthening, and swimming were introduced.

At six weeks, complete flexion and bicycle riding were allowed. After eight weeks, patients exercised through the full range of motion, extended knees against resistance, and cycled; by 12 weeks, unrestricted isotonic quadriceps and HS strengthening, outdoor cycling, and half-speed jogging on level ground were permitted.

Between three and nine months, patients continued cycling, jogging, and swimming; at four months, straight-line running was allowed. Sports participation was resumed between six and eight months if patients achieved 90% isokinetic strength compared to the contralateral knee, had no effusion, and maintained full range of motion. Returning to sports after nine months required the same criteria. IKDC [10] and Lysholm [11] scores were used to assess outcomes during follow-up (post-op 3 weeks, post-op 3 months, 6 months and 9 months).

STATISTICAL ANALYSIS

Statistical analysis was performed using repeated measures ANOVA to compare mean IKDC scores and Lysholm scores across different time points. When the overall ANOVA was significant post-hoc pairwise comparision were confirmed using baseline as the reference. The analysis was conducted using IBM SPSS Statistics version 25.0. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 21 patients were included in the study. The age of the participants ranged from 18 to 45 years. with a mean age of 30.32 years and a standard deviation of 7.181 years.

The study population was predominantly male, 12 patients (57.1%) had the right-side affected, while nine patients (42.9%) had the left-side affected [Table/Fig-2].

Age group (years)	n (%)
18-20	1 (4.71)
21-25	5 (23.8)
26-30	3 (14.28)
31-35	5 (23.8)
36-40	4 (19.04)
41-45	3 (14.28)
Gender	n (%)
Male	19 (90.5%)
Female	2 (9.5%)
Anterior Cruciate Ligament (ACL) Injury affected side	
Left	9 (42.9%)
Right	12 (57.1%)

[Table/Fig-2]: Demographic details of the participants.

Among 21 patients with ACL tear, one patient was underweight (4.8%), 12 patients had normal BMI (57.1%), seven patients were overweight (33.3%), and one patient (female) was obese (4.8%).

The International Knee Documentation Committee (IKDC) scores showed significant improvements over time (p<0.001) [Table/Fig-3].

IKDC	Minimum	Maximum	Mean	Std. Deviation	p-value
Pre-operative	31	37	34.21	1.512	-
3 weeks	50	55	52.63	1.012	<0.001
3 months	71	73	72.16	0.765	<0.001
6 months	85	88	86.53	1.219	<0.001
9 months	90	92	91.05	1.026	<0.001

[Table/Fig-3]: IKDC score evaluation at baseline, 3 weeks, 3 months, 6 months and 9 months.
Repeated Measures ANOV , (F(4,80) = 9250.9, p<0.001).

Similarly, the Lysholm scores also demonstrated substantial progress. Suggesting consistent and meaningful recovery over the study period [Table/Fig-4].

LYSHOLM	Minimum	Maximum	Mean	Std. Deviation	p-value
Pre-op	20	28	25.47	2.195	-
3 weeks	40	43	41.68	0.946	<0.001
3 months	60	63	62.16	0.834	<0.001
6 months	84	86	84.84	0.765	<0.001
9 months	92	97	94.21	1.813	<0.001

[Table/Fig-4]: Lysholm score evaluation from baseline to nine months.
Statistical analysis was performed using Repeated Measures ANOVA. (F(4,80) = 8444.0, p<0.001); Post-hoc comparision using pre-operative as baseline

Donor-site morbidity was observed in one out of 21 patients (4.8%). Anterior knee pain was reported in nine out of 21 patients (42.9%) during the follow-up period. The anterior knee pain was primarily noted during activities such as kneeling and stair climbing and was mild to moderate in severity in most cases.

DISCUSSION

The ACL reconstruction continues to evolve around a central tension: mechanical stability versus biological and functional outcomes. While numerous graft options exist, no single technique has demonstrated universal superiority, making contextual interpretation of outcomes essential rather than optional.

The study population was socioeconomically homogeneous, with all participants classified as Class III on the Modified Kuppuswamy [12] scale. While this reduces confounding related to healthcare access and rehabilitation compliance, it introduces a selection bias and restricts external validity. Socioeconomic factors are known to influence treatment-seeking behaviour, adherence to rehabilitation, and overall recovery; however, their impact could not be evaluated in the present study due to lack of variability in socioeconomic status [13].

Previous studies comparing BPTB and HS grafts reveal a nuanced balance between stability and morbidity. Defazio MW reported superior return to strenuous activity in the BPTB group, suggesting enhanced biomechanical stability [14]. However, this apparent superiority is tempered by complication profiles; Ravikumar V et al., documented a 30% incidence of anterior knee pain in the BPTB group, a finding consistently echoed across the literature [15].

This aligns with findings from Razi M et al., where higher proportions of good-to-excellent IKDC scores were observed in BPTB graft recipients over longer follow-up [16]. Beynnon BD et al., further complicate the narrative by demonstrating that while objective stability (laxity and pivot shift) favours BPTB grafts, patient-reported outcomes and satisfaction remain comparable between graft types [17]. This divergence suggests that mechanical superiority does not necessarily translate into meaningful functional advantage- an observation that must frame the interpretation of our results.

In contrast to these studies, the present investigation- focused on BPTB autografts with press-fit fixation- demonstrates substantial functional improvement without implant-related complications. However, the absence of a comparator group (e.g., HS grafts or interference screw fixation) limits direct inference regarding relative efficacy.

Although statistically significant improvements were observed in both IKDC and Lysholm scores, the clinical relevance warrants closer scrutiny. The increase in IKDC scores from 34.21 preoperatively to 91.05 at nine months suggests a transition from severely impaired to near-normal knee function. Similarly, Lysholm score improvements indicate restoration of stability, pain reduction, and improved activity levels.

However, these scores- while validated- do not fully capture return-to-sport rates, activity intensity, or patient satisfaction, which are often the outcomes of greatest importance to patients. Studies such as Boda HS C et al., have reported up to 87% return to pre-injury activity levels, a metric absent in the present study [18]. Therefore, while functional scores suggest favourable recovery, the extent to which patients resumed pre-injury athletic performance remains uncertain.

Donor-site morbidity, particularly anterior knee pain, remains a defining limitation of BPTB grafts. While our results acknowledge its presence. Reported rates of anterior knee pain in BPTB grafts range from 10% to 40% across studies [19].

The clinical implications extend beyond discomfort; anterior knee pain may impair kneeling, stair climbing, and occupational activities, particularly in populations requiring frequent squatting. Potential mitigation strategies described in the literature include:

- Minimising patellar tendon harvest width;
- Careful paratenon closure;
- Early rehabilitation focusing on quadriceps strength;
- Avoidance of aggressive early loading.

The absence of a detailed analysis of these factors in the present study limits the ability to contextualise morbidity outcomes.

Although BMI and gender distribution were reported, their potential influence on outcomes was not explored. Existing literature suggests that higher BMI may be associated with increased graft stress and delayed rehabilitation, while gender-related factors such as generalised joint laxity may influence injury risk and possibly recovery trajectories [20].

In the present study, the predominance of male patients and largely normal-to-overweight

BMI distribution preclude meaningful subgroup analysis. However, the lack of observed variability in outcomes may reflect either true uniformity or insufficient statistical power- an ambiguity that warrants acknowledgment.

A notable limitation of the present study is the relatively short follow-up period of 9 months. In contrast, studies such as those by Widuchowski W et al., [21].

Similarly Biazzo A et al., demonstrated a statistically significant advantage of femoral press-fit fixation over screw fixation in ACL reconstruction using bone- patellar tendon- bone autograft. At final follow-up, 64% of patients in the press-fit group achieved excellent IKDC scores compared to 28% in the screw fixation group, while good outcomes were more frequent in the screw group (66% vs. 32%) [22]. This suggests that press-fit fixation may provide superior functional recovery and knee stability. These findings are consistent with reports emphasising the biological integration and avoidance of hardware-related complications associated with press-fit techniques, while differing from studies that found no significant outcome differences between fixation methods. The relatively high proportion of excellent outcomes in the press-fit group underscores its potential as a reliable alternative to screw fixation, though the loss to follow-up (9.2%) and absence of long-term graft survival data warrant cautious interpretation. Short-term improvements in functional scores, while encouraging, may not reliably predict long-term success. Graft failure, tunnel widening, and degenerative joint changes often manifest beyond the first postoperative year. Therefore, extrapolating long-term efficacy from the present findings would be premature.

The present study observed donor-site morbidity in 4.8% of patients and anterior knee pain in 42.9% of cases. The incidence of anterior knee pain is comparable to existing literature on bone–patellar tendon-bone grafts, where rates ranging from 10% to 40% have been reported. This complication is clinically relevant, as it may affect activities such as kneeling and stair climbing, thereby influencing patient satisfaction despite favourable functional outcomes. Similar findings have been reported by Ravikumar V et al., who observed anterior knee pain in 30% of patients in the BPTB group at six months follow-up [16]. The relatively higher incidence in the present study may be attributed to differences in rehabilitation protocols, patient activity levels, or subjective reporting. These findings highlight the trade-off between graft stability and donor-site morbidity associated with BPTB grafts.

Limitation(s)

The findings of this study should be interpreted in light of several important limitations. The relatively small sample size (n = 21) limits the statistical power of the analysis and reduces the generalisability of the results to broader patient populations. In addition, the single-center design may introduce institutional bias, thereby affecting the external validity of the findings. The absence of randomisation and a control group further limits the ability to draw definitive comparative conclusions regarding treatment efficacy. Moreover, the follow-up duration of nine months is relatively short and may be insufficient to adequately assess long-term clinical and functional outcomes. Finally, the study did not include assessments of return-to-sport rates or patient satisfaction, which restricts the interpretation of functional recovery and patient reported outcomes.

CONCLUSION(S)

This study evaluated the functional outcomes of arthroscopic ACL reconstruction using a BPTB graft with femoral press-fit fixation. Significant improvements were observed in both IKDC and Lysholm scores from the preoperative period to the postoperative follow-up, indicating substantial recovery of knee function. The findings demonstrated consistent improvement across all follow-up intervals up to nine months after surgery. These results suggest that this surgical technique is effective in restoring knee stability and functional performance. However, further studies with larger sample sizes and longer follow-up periods are necessary to confirm the long-term effectiveness of this approach.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Aug 13, 2025
- Manual Googling: May 28, 2026
- iThenticate Software: May 30, 2026 (2%)

ETYMOLOGY: Author Origin

EMENDATIONS: 10

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Jul 29, 2025**
Date of Peer Review: **Dec 15, 2025**
Date of Acceptance: **Jun 02, 2026**
Date of Publishing: **Aug 01, 2026**