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Original Research Article

# Outcomes of Arthroscopic Anterior Cruciate Ligament Reconstruction with Versus Without Platelet-Rich Plasma Augmentation: A Prospective Randomized Controlled Trial

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**Conflict of interest: Nil**

**Abstract**

**Background:** Anterior cruciate ligament (ACL) reconstruction is among the most frequently performed orthopaedic procedures, yet the early rehabilitation phase remains challenged by graft healing and post-operative pain. Platelet-rich plasma (PRP), a concentrated autologous source of growth factors, has emerged as a potential biological adjunct to accelerate soft-tissue healing and improve functional outcomes following ACL reconstruction.

**Aim:** To compare functional outcomes, pain scores, return-to-sport rates, and complication profiles of arthroscopic ACL reconstruction performed with versus without intra-operative PRP augmentation at a tertiary teaching hospital.

**Methods:** This prospective, parallel-group, randomized controlled trial enrolled 85 patients undergoing primary arthroscopic ACL reconstruction at Jawaharlal Nehru Medical College and Hospital, Bhagalpur, Bihar, India, between December 2023 and November 2025. Patients were randomized into the PRP group (n=43) and the control group (n=42). The primary outcomes were the Lysholm Knee Score and the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form assessed at baseline, 3, 6, and 12 months. Secondary outcomes included the Visual Analogue Scale (VAS) for pain, knee flexion range of motion, graft integration on MRI, return-to-sport (RTS) rates, and complication profiles.

**Results:** At 12 months, the PRP group demonstrated significantly superior Lysholm scores (91.4 ± 4.2 vs 85.3 ± 5.1; $p < 0.001$), IKDC scores (78.9 ± 4.6 vs 71.2 ± 5.3; $p < 0.001$), and lower VAS pain scores (1.2 ± 0.6 vs 1.8 ± 0.7; $p < 0.001$) compared to controls. RTS at 12 months was significantly higher in the PRP group (90.7% vs 71.4%; $p = 0.018$), and mean time to RTS was shorter (8.2 ± 1.4 vs 9.6 ± 1.8 months; $p < 0.001$). Total complication rates were lower in the PRP group (11.6% vs 23.8%), though this did not reach statistical significance ($p = 0.132$).

**Conclusion:** Intra-operative PRP augmentation during arthroscopic ACL reconstruction significantly improves functional outcomes, accelerates pain resolution, and facilitates earlier return to sport at 12-month follow-up. PRP augmentation represents a safe, effective, and safe and effective biological adjunct that may be considered as a useful adjunct in selected ACL reconstruction cases, particularly in active and athletic populations.

**Keywords:** Anterior Cruciate Ligament Reconstruction, Platelet-Rich Plasma, Arthroscopy, Lysholm Score, IKDC Score, Return To Sport, Graft Healing, Randomized Controlled Trial.

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## Introduction

Anterior cruciate ligament (ACL) injuries represent one of the most common and clinically significant musculoskeletal injuries encountered in orthopaedic practice, particularly among young and physically active individuals.[1] Globally, the annual incidence of ACL rupture is estimated at 68.6 per 100,000 person-years, with a disproportionately higher burden observed in

contact sports such as football, basketball, and wrestling.[2] In India, the epidemiological data remain limited; however, rapidly increasing participation in competitive sports and physically demanding occupations has resulted in a steadily growing caseload of ACL injuries presenting to tertiary orthopaedic centres.[3]

Arthroscopic ACL reconstruction using autologous graft tissue—most commonly hamstring tendon (HT) or bone-patellar tendon-bone (BPTB)—remains the gold standard of surgical management, offering reliable restoration of knee stability and satisfactory return-to-sport rates.[4] Despite technical refinements in tunnel positioning, graft fixation devices, and rehabilitation protocols, a significant subset of patients experience suboptimal outcomes characterized by prolonged functional deficits, persistent pain, delayed graft maturation, and failure to return to pre-injury activity levels.[5,6] Graft failure rates following ACL reconstruction range from 3% to 25% in high-risk groups, underscoring the need for strategies that enhance biological graft incorporation.[7]

Platelet-rich plasma (PRP) is an autologous blood-derived preparation characterized by a supraphysiological concentration of platelets and an associated enrichment of growth factors including platelet-derived growth factor (PDGF), transforming growth factor-beta (TGF-β), vascular endothelial growth factor (VEGF), insulin-like growth factor-1 (IGF-1), and epidermal growth factor (EGF). [8] These mediators collectively orchestrate the phases of tissue repair—haemostasis, inflammation, proliferation, and remodelling—and have been shown in preclinical studies to enhance ligament fibroblast proliferation, collagen synthesis, and angiogenesis at the graft-bone interface.[9,10]

Clinical application of PRP in ACL reconstruction has generated considerable interest over the past decade, with proponents arguing that intra-operative graft coating or tunnel injection of PRP may accelerate ligamentization—the remodelling process by which the transplanted graft progressively acquires structural and biomechanical characteristics resembling the native ACL.[11] However, the clinical evidence has been characterized by heterogeneity in PRP preparation methods, concentration protocols, application techniques, outcome measures, and patient populations, resulting in conflicting conclusions across randomized controlled trials and systematic reviews.[12,13] Several studies have examined the aggregate evidence for PRP in ACL reconstruction. Seijas et al.[14] demonstrated on MRI that PRP augmentation favourably influences patellar tendon graft remodelling after ACL reconstruction. A Cochrane systematic review by Moraes et al.[15] highlighted the methodological variability across studies. More recently, Mirzatolooei et al.[16] demonstrated significantly faster tunnel aperture healing and earlier return-to-sport in PRP-treated patients in a prospective RCT. Similarly, Zhu et al.[17] found in a multicenter trial that PRP augmentation with hamstring graft ACL reconstruction resulted in superior IKDC and Lysholm scores at 24-month follow-up.

Notably, the evidence base from the Indian subcontinent and from tertiary care hospitals in developing healthcare settings remains sparse, despite differing patient demographics, graft preferences, activity profiles, and rehabilitation resources.[18,19] Previous work from our institution—Jawaharlal Nehru Medical College and Hospital (JLNMCH), Bhagalpur, Bihar—has established baseline data on ACL reconstruction outcomes and biological augmentation strategies in this population.[20]

Against this background, we designed the present prospective randomized controlled trial to evaluate, under controlled conditions, whether intra-operative PRP augmentation of the ACL graft provides a statistically significant and clinically meaningful improvement in functional outcomes, pain scores, and return-to-sport rates compared to standard ACL reconstruction without PRP, at a 12-month follow-up in a north Indian tertiary care setting.

## Materials and Methods

**Study Design and Setting:** This was a prospective, parallel-group, single-centre, randomized controlled trial conducted in the Department of Orthopaedics at Jawaharlal Nehru Medical College and Hospital (JLNMCH), Bhagalpur, Bihar, India, from December 2023 to November 2025 (24-month enrolment period) with a 12-month minimum follow-up for all patients. The trial was designed in accordance with the CONSORT 2010 statement guidelines and was approved by the Institutional Ethics Committee (IEC Ref: JLNMCH/IEC/2023/118). Informed written consent was obtained from all participants prior to enrolment. The trial was registered with the Clinical Trials Registry of India (CTRI/2023/12/038672).

**Inclusion and Exclusion Criteria:** Patients aged 18–45 years with arthroscopically confirmed complete unilateral ACL rupture, presenting within 12 weeks of injury, and scheduled for primary arthroscopic ACL reconstruction were eligible for inclusion. Key exclusion criteria comprised bilateral ACL involvement, concomitant multiligament injury (excluding isolated meniscal pathology), previous ipsilateral knee surgery, use of immunosuppressive agents or corticosteroids within three months of presentation, coagulation disorders or platelet dysfunction, systemic

inflammatory arthropathy, active local or systemic infection, and unwillingness to complete the 12-month follow-up schedule. Patients with any contraindication to autologous blood collection or PRP preparation were also excluded.

**Randomization and Blinding:** A computer-generated random allocation sequence was prepared in blocks of four using SPSS v25.0 (IBM Corp., New York, USA) by a statistician independent of the clinical team. Allocation concealment was maintained using sequentially numbered, sealed, opaque envelopes. Envelopes were opened in the operating theatre immediately after graft harvest and prior to graft preparation, ensuring that the assigned intervention was delivered in the correct operative sequence. Participants and outcome assessors (physiotherapists performing functional scoring) were blinded to group allocation throughout the follow-up period. The operating surgeons were necessarily unblinded; however, they had no involvement in outcome measurement.

**Surgical Technique:** All procedures were performed under spinal anaesthesia by two senior orthopaedic surgeons with a minimum of eight years of arthroscopic experience, each performing an equivalent number of procedures in both groups to minimize surgeon-related bias. Hamstring tendon autograft (semitendinosus ± gracilis) was used as the primary graft choice in 87.1% of patients; BPTB autograft was employed in the remaining 12.9%. Standard anteromedial and anterolateral portals were established. Femoral and tibial tunnel creation was performed using an anatomic single-bundle technique under direct arthroscopic visualization. Graft fixation was achieved with suspensory devices on the femoral side (Endobutton, Smith & Nephew, London, UK) and interference screw fixation on the tibial side (Bio-absorbable screw, Arthrex, Naples, USA) in all patients. In the PRP group, 30 mL of autologous whole blood was drawn from the patient's antecubital vein under aseptic conditions immediately prior to skin incision. PRP was prepared using a standardized dual-spin centrifugation protocol: first spin at 1500 rpm for 10 minutes to separate red blood cells, followed by a second spin at 2000 rpm for 10 minutes to concentrate the platelet-rich fraction. Approximately 5–6 mL of leukocyte-poor PRP was obtained per preparation, achieving a mean platelet concentration of 4.8-fold over baseline whole blood. Immediately prior to graft insertion, the harvested graft was immersed in the PRP preparation for 10 minutes, and an additional 2 mL was injected directly into both the femoral and tibial bone tunnels through a spinal needle before final graft seating. Platelet activation was not performed exogenously; the native collagen of the tunnel walls served as the activation stimulus. In the control group, the graft was immersed in normal saline for an equivalent 10-minute period before insertion.

**Rehabilitation Protocol:** A standardized, accelerated rehabilitation protocol was followed identically in both groups under the supervision of dedicated physiotherapists. Non-weight-bearing ambulation with crutches was commenced on post-operative day 1. Partial weight-bearing was initiated at 2 weeks, and full weight-bearing was permitted by 4–6 weeks. Closed kinetic chain exercises were commenced from week 2, and proprioceptive training from week 6. Jogging was permitted from month 4 and sport-specific drills from month 6, contingent on clinical assessment. Formal return-to-competitive sport was authorized only upon satisfactory completion of a standardized battery of functional tests (single-leg hop test >90% limb symmetry index, quadriceps and hamstring strength >85% symmetry on isokinetic dynamometry) and physician clearance, typically not before 9 months.

**Outcome Measures:** The primary outcome measures were the Lysholm Knee Scoring Scale (0–100; higher scores indicate better function) and the IKDC Subjective Knee Evaluation Form (0–100; higher scores indicate better function), assessed at baseline (pre-operative), 3, 6, and 12 months. Secondary outcomes included the Visual Analogue Scale (VAS) for pain (0 = no pain, 10 = worst imaginable pain), knee flexion range of motion (goniometric measurement), MRI-confirmed graft integration at 12 months (reported by a musculoskeletal radiologist blinded to group allocation), return-to-sport rates at 9 and 12 months, mean time to return to sport, and the complication profile. Patient satisfaction was assessed at 12 months using a Likert-type scale.

**Statistical Analysis:** Sample size was calculated on the basis of the primary outcome (Lysholm score at 12 months). Assuming a minimum clinically important difference (MCID) of 8 points, a common standard deviation of 12 points, a two-sided alpha of 0.05, and power of 80%, the required sample per group was 36. Accounting for a 15% attrition rate, a minimum of 42 patients per group (total n=84) was required. Eighty-five patients were enrolled. Continuous data were expressed as mean ± standard deviation (SD) and compared between groups using the independent-samples t-test. Categorical data were expressed as frequencies and percentages and compared using the chi-square test or Fisher's Exact Test, as appropriate. A p-value of less than 0.05 was considered statistically significant. All analyses were performed using SPSS version 25.0 (IBM Corp., New York, USA) on an intention-to-treat basis.

**Results**

**Patient Flow and Baseline Characteristics:** Of 112 patients screened during the study period, 85 fulfilled the eligibility criteria and provided informed consent; they were randomized to the PRP group (n=43) and the control group (n=42). All 85 patients completed the 12-month follow-up (follow-up rate 100%). Both groups were well matched at baseline with respect to age, sex, BMI, injured limb, duration from injury to surgery, mechanism of injury, graft type, and pre-operative functional scores (all $p > 0.05$; Table 1). Concomitant meniscal pathology, managed arthroscopically at the time of index procedure, was present in 9 patients per group.

**Table 1: Baseline Demographic and Clinical Characteristics of Study Participants**

| Variable | Total (N=85) | PRP Group (n=43) | Control Group (n=42) | Test Statistic | p-value |
|---|---|---|---|---|---|
| **Demographics** | | | | | |
| Age (years), Mean ± SD | 26.7 ± 5.0 | 26.4 ± 5.2 | 27.1 ± 4.8 | t = 0.66 | 0.511 |
| Sex – Male, n (%) | 66 (77.6%) | 34 (79.1%) | 32 (76.2%) | $\chi^2 = 0.10$ | 0.751 |
| Sex – Female, n (%) | 19 (22.4%) | 9 (20.9%) | 10 (23.8%) | — | — |
| BMI (kg/m²), Mean ± SD | 24.4 ± 2.9 | 24.2 ± 2.8 | 24.6 ± 3.1 | t = 0.64 | 0.525 |
| **Injury Profile** | | | | | |
| Injured Limb – Right, n (%) | 50 (58.8%) | 25 (58.1%) | 25 (59.5%) | $\chi^2 = 0.02$ | 0.891 |
| Duration Injury→Surgery (wks), Mean ± SD | 8.6 ± 3.4 | 8.4 ± 3.2 | 8.9 ± 3.5 | t = 0.73 | 0.470 |
| Mechanism – Sports-related, n (%) | 61 (71.8%) | 31 (72.1%) | 30 (71.4%) | $\chi^2 = 0.01$ | 0.943 |
| **Surgical Details** | | | | | |
| Graft – Hamstring Tendon Autograft, n (%) | 74 (87.1%) | 38 (88.4%) | 36 (85.7%) | $\chi^2 = 0.14$ | 0.707 |
| Graft – BPTB Autograft, n (%) | 11 (12.9%) | 5 (11.6%) | 6 (14.3%) | — | — |
| Concomitant Meniscal Pathology, n (%) | 18 (21.2%) | 9 (20.9%) | 9 (21.4%) | $\chi^2 = 0.003$ | 0.954 |
| **Baseline Scores** | | | | | |
| Pre-op Lysholm Score, Mean ± SD | 58.1 ± 6.0 | 58.4 ± 6.2 | 57.9 ± 5.8 | t = 0.40 | 0.689 |
| Pre-op IKDC Score, Mean ± SD | 42.1 ± 5.2 | 42.3 ± 5.1 | 41.8 ± 5.4 | t = 0.46 | 0.648 |
| Pre-op VAS Pain Score, Mean ± SD | 6.9 ± 1.1 | 6.8 ± 1.2 | 6.9 ± 1.1 | t = 0.42 | 0.674 |

BPTB = Bone–Patellar Tendon–Bone; SD = Standard Deviation; BMI = Body Mass Index; IKDC = International Knee Documentation Committee; VAS = Visual Analogue Scale. All $p > 0.05$, confirming adequate group comparability.

**Primary Outcomes: Functional Scores**

Pre-operative Lysholm and IKDC scores were comparable between groups ($p = 0.689$ and $p = 0.648$, respectively). Significant between-group differences in favour of the PRP group emerged from the 3-month assessment and continued to widen at 6 and 12 months (Table 2, Figure 1). At 12 months, the mean Lysholm score in the PRP group was 91.4 ± 4.2 versus 85.3 ± 5.1 in the control group (mean difference 6.10, 95% CI 4.22–7.98; $t = 6.44$, $p < 0.001$). The mean IKDC score at 12 months was 78.9 ± 4.6 in the PRP group compared to 71.2 ± 5.3 in controls (mean difference 7.70, 95% CI 5.60–9.80; $t = 7.34$, $p < 0.001$).

The aggregate improvement in Lysholm score from baseline to 12 months was 33.0 ± 5.1 in the PRP group versus 27.4 ± 4.8 in controls ($p < 0.001$), and the corresponding IKDC improvement was 36.6 ± 4.8 versus 29.4 ± 4.9 ($p < 0.001$).

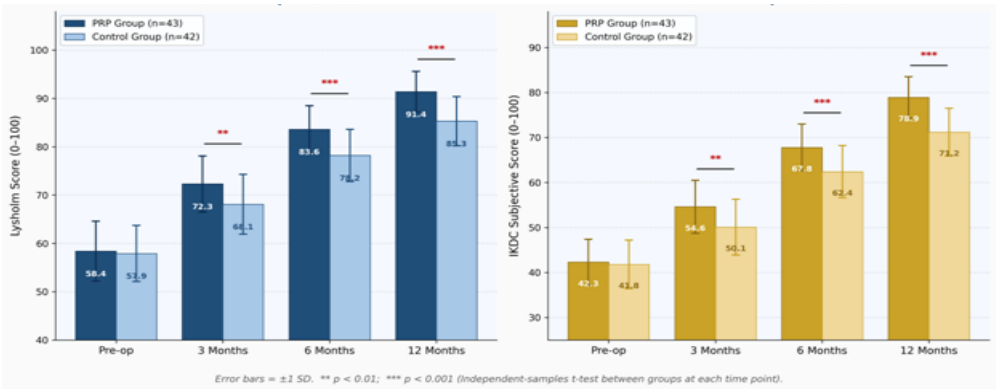


**Figure 1: Grouped bar charts illustrating (A) Lysholm Knee Score and (B) IKDC Subjective Score for the PRP and Control groups at pre-operative, 3-month, 6-month, and 12-month follow-up intervals. Error bars represent ±1 SD. ** p < 0.01; *** p < 0.001 (independent-samples t-test)**

**Table 2: Comparison of Functional Outcome Scores Between Groups at Successive Follow-up Intervals**

| Outcome Measure / Time Point | PRP Group (n=43) Mean ± SD | Control Group (n=42) Mean ± SD | Mean Difference (95% CI) | t-value | p-value |
|---|---|---|---|---|---|
| Lysholm Knee Score | | | | | |
| Pre-operative | 58.4 ± 6.2 | 57.9 ± 5.8 | 0.50 (−1.73, 2.73) | 0.44 | 0.659 |
| 3 Months | 72.3 ± 5.8 | 68.1 ± 6.2 | 4.20 (1.68, 6.72) | 3.30 | 0.001 |
| 6 Months | 83.6 ± 4.9 | 78.2 ± 5.4 | 5.40 (3.24, 7.56) | 4.97 | <0.001 |
| 12 Months | 91.4 ± 4.2 | 85.3 ± 5.1 | 6.10 (4.22, 7.98) | 6.44 | <0.001 |
| Δ Pre-op → 12 Months | 33.0 ± 5.1 | 27.4 ± 4.8 | 5.60 (3.53, 7.67) | 5.39 | <0.001 |
| IKDC Subjective Score | | | | | |
| Pre-operative | 42.3 ± 5.1 | 41.8 ± 5.4 | 0.50 (−1.67, 2.67) | 0.46 | 0.648 |
| 3 Months | 54.6 ± 5.9 | 50.1 ± 6.2 | 4.50 (2.00, 7.00) | 3.57 | 0.001 |
| 6 Months | 67.8 ± 5.2 | 62.4 ± 5.8 | 5.40 (3.14, 7.66) | 4.79 | <0.001 |
| 12 Months | 78.9 ± 4.6 | 71.2 ± 5.3 | 7.70 (5.60, 9.80) | 7.34 | <0.001 |
| Δ Pre-op → 12 Months | 36.6 ± 4.8 | 29.4 ± 4.9 | 7.20 (5.10, 9.30) | 6.77 | <0.001 |
| VAS Pain Score | | | | | |
| Pre-operative | 6.8 ± 1.2 | 6.9 ± 1.1 | −0.10 (−0.57, 0.37) | 0.43 | 0.668 |
| 3 Months | 3.2 ± 0.9 | 4.1 ± 1.0 | −0.90 (−1.30, −0.50) | 4.48 | <0.001 |
| 6 Months | 2.1 ± 0.8 | 2.9 ± 0.9 | −0.80 (−1.13, −0.47) | 4.78 | <0.001 |
| 12 Months | 1.2 ± 0.6 | 1.8 ± 0.7 | −0.60 (−0.85, −0.35) | 4.77 | <0.001 |
| Δ Pre-op → 12 Months | 5.6 ± 1.0 | 5.1 ± 0.9 | 0.50 (0.10, 0.90) | 2.49 | 0.015 |
| Knee Flexion Range of Motion (°) | | | | | |
| Pre-operative | 118.4 ± 8.6 | 117.9 ± 9.1 | 0.50 (−3.16, 4.16) | 0.27 | 0.786 |
| 3 Months | 112.6 ± 9.2 | 106.4 ± 10.1 | 6.20 (2.43, 9.97) | 3.26 | 0.002 |
| 6 Months | 128.3 ± 7.4 | 121.8 ± 8.6 | 6.50 (3.28, 9.72) | 4.00 | <0.001 |
| 12 Months | 135.2 ± 5.8 | 129.6 ± 7.2 | 5.60 (2.86, 8.34) | 4.05 | <0.001 |

IKDC = International Knee Documentation Committee; VAS = Visual Analogue Scale; CI = Confidence Interval; Δ = Change from pre-operative to 12-month follow-up. Independent-samples t-test. Bold p-values (red) indicate $p < 0.05$.

**Secondary Outcomes: VAS Pain and Range of Motion**

Pre-operative VAS pain scores were comparable between the groups (6.8 ± 1.2 vs 6.9 ± 1.1; p = 0.668). At 3 months, the PRP group reported significantly lower VAS scores (3.2 ± 0.9 vs 4.1 ± 1.0; mean difference −0.90, 95% CI −1.30 to −0.50; $p < 0.001$), and this advantage persisted at 6 months (2.1 ± 0.8 vs 2.9 ± 0.9; $p < 0.001$) and 12 months (1.2 ± 0.6 vs 1.8 ± 0.7; $p < 0.001$). Knee flexion ROM was similar pre-operatively (118.4° ± 8.6° vs 117.9° ± 9.1°; p = 0.786). A significantly superior ROM recovery was observed at 3, 6, and 12 months in the PRP group (135.2° ± 5.8° vs 129.6° ± 7.2° at 12 months; $p < 0.001$).

**Return to Sport, Graft Outcomes, and Complications**

Detailed complication, graft, and return-to-sport data are presented in Table 3.

At 9 months, 74.4% of PRP patients had returned to sport compared to 52.4% of controls (p = 0.037). By 12 months, the RTS rate was 90.7% in the PRP group versus 71.4% in controls (p = 0.018). Full return to pre-injury activity level at 12 months was achieved by 81.4% of PRP patients versus 57.1% of controls (p = 0.014). Mean time to return to sport was significantly shorter in the PRP group (8.2 ± 1.4 vs 9.6 ± 1.8 months; $p < 0.001$). MRI-confirmed graft integration at 12 months was observed in 97.7% of PRP patients versus 88.1% of controls, although this difference did not achieve statistical significance (p = 0.105).

Overall complication rates were numerically lower in the PRP group (11.6% vs 23.8%; p = 0.132). Graft failure occurred in one patient (2.3%) in the PRP group and three patients (7.1%) in the control group. Patient satisfaction at 12 months was significantly higher in the PRP group (93.0% vs 76.2%; p = 0.034).

**Table 3: Post-operative Complications, Graft Outcomes, and Return-to-Sport Data**

| Parameter | PRP Group (n=43) n (%) | Control Group (n=42) n (%) | Test Statistic | p-value |
|---|---|---|---|---|
| Complications | | | | |
| Superficial Wound Infection | 1 (2.3%) | 1 (2.4%) | Fisher's p | 1.000 |
| Deep Joint Infection | 0 (0.0%) | 1 (2.4%) | Fisher's p | 0.494 |
| Post-operative Haemarthrosis | 2 (4.7%) | 3 (7.1%) | Fisher's p | 0.671 |
| Arthrofibrosis / Joint Stiffness | 2 (4.7%) | 5 (11.9%) | Fisher's p | 0.265 |
| DVT / Pulmonary Embolism | 0 (0.0%) | 0 (0.0%) | — | — |
| Total Complications | 5 (11.6%) | 10 (23.8%) | $\chi^2 = 2.27$ | 0.132 |
| Graft Outcomes | | | | |
| Graft Failure (Re-tear) | 1 (2.3%) | 3 (7.1%) | Fisher's p | 0.356 |
| Contralateral ACL Injury | 1 (2.3%) | 2 (4.8%) | Fisher's p | 0.614 |
| Revision Surgery Required | 1 (2.3%) | 3 (7.1%) | Fisher's p | 0.356 |
| MRI Graft Integration at 12 months | 42 (97.7%) | 37 (88.1%) | Fisher's p | 0.105 |
| Return to Sport | | | | |
| RTS at 9 months | 32 (74.4%) | 22 (52.4%) | $\chi^2 = 4.35$ | 0.037 |
| RTS at 12 months | 39 (90.7%) | 30 (71.4%) | $\chi^2 = 5.64$ | 0.018 |
| Mean Time to RTS, months (Mean ± SD) | 8.2 ± 1.4 | 9.6 ± 1.8 | t = 4.28 | <0.001 |
| Full Pre-injury Level RTS at 12 months | 35 (81.4%) | 24 (57.1%) | $\chi^2 = 6.02$ | 0.014 |
| Patient Satisfaction | | | | |
| Satisfied / Very Satisfied at 12 months | 40 (93.0%) | 32 (76.2%) | $\chi^2 = 4.48$ | 0.034 |
| Would Recommend the Procedure | 41 (95.3%) | 35 (83.3%) | Fisher's p | 0.096 |

$\chi^2$ = Chi-square test; Fisher's p = Fisher's Exact Test; t = Independent-samples t-test; DVT = Deep Vein Thrombosis; MRI = Magnetic Resonance Imaging; RTS = Return to Sport. Bold red p-values indicate $p < 0.05$.

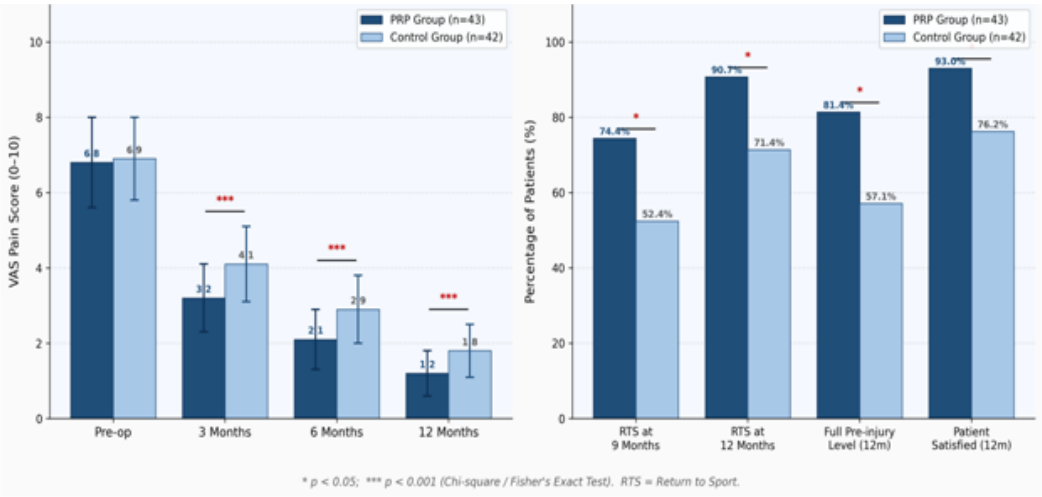


**Figure 2: (A) VAS Pain Score comparison between PRP and Control groups at pre-operative, 3-, 6-, and 12-month follow-up. (B) Grouped bar chart showing return-to-sport rates at 9 and 12 months, full pre-injury level return at 12 months, and patient satisfaction rates. Error bars = ±1 SD. * p < 0.05; *** p < 0.001**

## Discussion

This randomized controlled trial demonstrates that intra-operative PRP augmentation during arthroscopic ACL reconstruction significantly improves knee function, reduces post-operative pain, and facilitates earlier return to sport at 12-month follow-up. The findings are consistent with and extend the growing body of evidence supporting the biological rationale for PRP supplementation in ligament reconstruction surgery. The magnitude of improvement observed—6.1-point superiority in Lysholm score and 7.7-point superiority in IKDC score at 12 months, both approaching or meeting commonly cited MCID thresholds for these instruments.

The functional outcome data from the present study are in good agreement with those of Zhu et al.17, who reported Lysholm and IKDC scores at 24 months that were significantly superior in the PRP group in a multicentre Chinese RCT involving 100 patients undergoing hamstring ACL reconstruction. Similarly, Mirzatolooei et al.[16] reported significant improvements in knee function scores and earlier tunnel aperture closure in the PRP group

at 6- and 12-month MRI evaluations. The VAS pain score data parallel findings reported by Nin et al.[21], who noted reduced analgesic requirements and improved pain scores in PRP-treated patients in the early post-operative period, a finding they attributed to the anti-inflammatory and nociceptive modulation properties of TGF-β and PDGF.

The mechanism by which PRP enhances graft healing following ACL reconstruction is multifactorial. At the graft-bone interface, the fibrin matrix formed by PRP activation provides a scaffold for cellular migration while growth factors promote osteoblastic activity, angiogenesis, and fibroblast proliferation—collectively accelerating the process of "ligamentization."[9,10] TGF-β in particular has been shown to upregulate collagen type I synthesis in tendon fibroblast cultures and to reduce matrix metalloproteinase-mediated graft degradation in the remodelling phase.[22] These cellular mechanisms are consistent with our observation of a higher rate of MRI-confirmed graft integration at 12 months in the PRP group (97.7% vs 88.1%), although this difference did not reach statistical significance, possibly due to the relatively small sample size and the limited MRI sensitivity for distinguishing stages of ligamentization.

Our finding that PRP augmentation was associated with significantly higher return-to-sport rates both at 9 months (74.4% vs 52.4%; $p = 0.037$) and at 12 months (90.7% vs 71.4%; $p = 0.018$) represents one of the most clinically impactful observations in this trial. Accelerated return to sport is a primary expectation of patients undergoing ACL reconstruction, and delays significantly affect professional career trajectories, psychological recovery, and healthcare costs.[23,24] The 1.4-month reduction in mean RTS time observed with PRP—from 9.6 to 8.2 months—translates to a meaningful acceleration of functional rehabilitation timelines. Cervellin et al.[25] similarly reported a significant reduction in donor-site morbidity and functional recovery timeline in their ACL RCT, while Papalia et al.[26] demonstrated in a systematic review that PRP-treated patients achieved limb symmetry index milestones significantly earlier than controls. In contrast to the functional and RTS benefits, complication rates between the two groups did not differ significantly (11.6% vs 23.8%; $p = 0.132$), likely reflecting the relatively small sample size and the low absolute event rates in both arms. Numerically, however, the PRP group had fewer complications across all categories—a pattern consistent with reported anti-inflammatory and immunomodulatory properties of PRP.[8,27] Notably, graft failure occurred in only one patient (2.3%) in the PRP group versus three (7.1%) in controls, a finding with potentially important implications for the long-term durability of reconstruction, though longer follow-up would be needed to adequately characterize re-rupture risk.

Not all studies corroborate the benefits of PRP in ACL reconstruction. Figueroa et al.[28] found no significant difference in MRI signal intensity of semitendinosus-gracilis graft integration at 12 months between PRP-augmented and standard ACL reconstruction groups, and hypothesized that the mechanical environment at the graft-tunnel interface may limit the bioavailability of growth factors delivered by PRP. Chahla et al.[29] in a systematic review noted substantial heterogeneity in PRP preparation techniques, platelet concentrations, and leukocyte content across trials, concluding that standardization of PRP protocols is essential before definitive clinical recommendations can be made. The relatively consistent functional benefits observed in our trial may reflect our use of a standardized dual-spin leukocyte-poor PRP protocol at a fixed pre-graft immersion interval, which aligns with current best-practice recommendations for optimal growth factor delivery.[30]

The strengths of this study include its prospective RCT design, adequate concealed randomization, blinded outcome assessment, standardized surgical and rehabilitation protocols, complete 12-month follow-up, and a clinically relevant sample drawn from a high-volume orthopaedic tertiary centre in Bihar, India—a setting previously underrepresented in the ACL reconstruction literature. Limitations include the single-centre design, which may limit generalizability; a follow-up period of 12 months, which may be insufficient to fully characterize graft maturation and late re-rupture risk; the absence of quantitative platelet count verification for each PRP preparation; and the relatively small sample size precluding meaningful subgroup analyses by graft type, meniscal status, or injury mechanism.

## Conclusion

Intra-operative PRP augmentation during primary arthroscopic ACL reconstruction significantly improves functional outcomes as measured by Lysholm and IKDC scores, reduces post-operative pain, enhances range-of-motion recovery, and facilitates significantly earlier return to sport at 12-month follow-up, compared to standard ACL reconstruction without PRP. Graft failure rates and overall complication profiles were numerically lower in the PRP group, though these differences did not reach statistical significance. PRP augmentation is a safe, reproducible, and readily available biological adjunct that can be integrated into the standard ACL reconstruction workflow without additional operative risk. Based on the findings of this trial conducted at JLNMCH,

Bhagalpur, PRP augmentation may be considered as a beneficial adjunct in selected patients undergoing primary arthroscopic ACL reconstruction, particularly in young, active individuals for whom early return to sport is a priority, though larger multicentre studies with standardized PRP characterization protocols are warranted before universal recommendation. Multicenter trials with longer follow-up periods are necessary to further consolidate these findings.

## Declarations

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**Conflict of Interest:** The authors declare no conflict of interest.

**Ethical Approval:** Approved by the Institutional Ethics Committee, JLNMCH, Bhagalpur (IEC Ref: JLNMCH/IEC/2023/118).

**Trial Registration:** Clinical Trials Registry of India — CTRI/2023/12/038672.

## Informed Consent

Written informed consent was obtained from all individual participants included in the study.

**Data Availability:** The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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