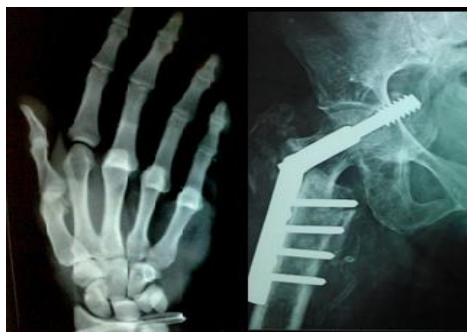




International Journal of Orthopaedics Sciences

E-ISSN: 2395-1958

P-ISSN: 2706-6630

Impact Factor (RJIF): 6.72

IJOS 2025; 11(3): 276-281

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www.orthopaper.com

Received: 24-06-2025

Accepted: 28-07-2025

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Incidence of post-operative complications in early versus delayed ACL reconstruction

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DOI: <https://www.doi.org/10.22271/ortho.2025.v11.i3d.3815>

Abstract

Background: Anterior cruciate ligament (ACL) injuries are common in active populations and can lead to joint instability, secondary cartilage damage, and long-term functional impairment. The timing of ACL reconstruction-early versus delayed remains controversial, with potential implications for post-operative complications and functional outcomes.

Aim of the study: To compare the incidence of early and late post-operative complications, as well as functional outcomes, in patients undergoing early (≤ 6 weeks) versus delayed (>12 weeks) ACL reconstruction.

Methods: This prospective comparative study was conducted from September 2022 to March 2025 in the Department of Orthopedic Surgery at BMU, Shahbagh, Dhaka. Forty-four patients with isolated ACL injuries were enrolled and divided into early ($n=22$) and delayed ($n=22$) reconstruction groups. Baseline demographic and clinical characteristics, post-operative complications (early ≤ 6 weeks and late >3 months), functional outcomes including Lysholm score, Tegner Activity Score, knee range of motion, return to pre-injury activity, and time to return to sport were assessed. Multivariate logistic regression was used to identify risk factors for complications.

Result: Baseline characteristics were comparable between groups. Early reconstruction was associated with lower incidences of early complications such as arthrofibrosis (9.09% vs. 4.55%) and hemarthrosis (4.55% vs. 13.64%), as well as late complications including residual pain (13.64% vs. 27.27%) and persistent instability (9.09% vs. 18.18%). Delayed surgery was identified as a significant independent risk factor for post-operative complications (adjusted OR = 2.10, 95% CI: 1.05-4.18, $p = 0.03$). Functional outcomes favored early reconstruction, with significantly higher Lysholm scores (90.1 ± 3.8 vs. 82.5 ± 8.7 , $p = 0.0008$) and shorter time to return to sport (8.2 ± 1.9 vs. 9.6 ± 2.3 months, $p = 0.033$), while Tegner Activity Score and knee range of motion were similar between groups.

Conclusion: Early ACL reconstruction is associated with reduced post-operative complications, improved functional outcomes, and faster return to sport compared to delayed reconstruction. Timing of surgery is a critical determinant of surgical success, underscoring the benefits of early intervention in active patients.

Keywords: Anterior cruciate ligament, ACL reconstruction, early reconstruction, delayed reconstruction, post-operative complications, functional outcomes

Introduction

Anterior cruciate ligament (ACL) injuries are a significant global health concern, with an estimated annual incidence of 68.6 per 100,000 person-years ^[1]. These injuries are particularly common among athletes involved in high-demand sports such as football, basketball, and skiing, where rapid changes in direction, sudden deceleration, pivoting, and jumping substantially increase the risk of ligament damage ^[2]. ACL injuries can be classified based on severity, including partial or complete tears, and according to the mechanism of injury, such as contact versus non-contact trauma, with non-contact mechanisms often resulting from abrupt movements or incorrect landings being more prevalent in sports-related cases ^[3-5]. The functional consequences of ACL injury extend beyond immediate joint instability, as they predispose individuals to secondary complications such as meniscal tears, progressive cartilage degeneration, and long-term development of knee osteoarthritis, underscoring the clinical

importance of prompt and effective management [6, 7]. ACL reconstruction surgery remains the gold standard treatment for restoring knee stability, enhancing functional outcomes, and reducing the risk of chronic joint degeneration. This procedure involves replacing the torn ligament with a graft, which may be an autograft harvested from the patient's own tissue most commonly the hamstring tendon or patellar tendon or an allograft obtained from a donor [8]. Various surgical techniques are employed, including single-bundle and double-bundle reconstruction approaches, each designed to closely replicate the native ACL anatomy and biomechanical properties, thereby optimizing joint stability and improving long-term functional recovery [9]. The timing of ACL reconstruction early versus delayed has been widely debated, as it can significantly influence postoperative outcomes, rehabilitation potential, and the overall risk of complications. Early reconstruction is performed to rapidly restore knee stability, minimize secondary joint damage, and facilitate a timely return to sports or physical activity, whereas delayed reconstruction allows for resolution of initial inflammation, comprehensive management of associated injuries, and optimization of patient readiness for surgery, which may help reduce intraoperative technical challenges [10]. Postoperative complications following ACL reconstruction are varied and can include graft failure, joint stiffness, arthrofibrosis, infection, or residual instability. The incidence of these complications is influenced by multiple factors, including the chosen surgical technique, type of graft used, rehabilitation protocols, and patient-specific characteristics such as age, baseline activity level, and presence of comorbidities [11, 12]. Theoretical considerations suggest that early surgery may be associated with a higher risk of arthrofibrosis due to persistent inflammation, whereas delayed reconstruction could increase the likelihood of secondary meniscal or cartilage injuries as a result of prolonged joint instability [13, 14]. Understanding the interplay between surgical timing, graft choice, rehabilitation, and patient-specific factors is critical for minimizing complications and optimizing functional outcomes. This study aims to compare the incidence of postoperative complications in early versus delayed ACL reconstruction, providing valuable evidence to guide clinical decision-making, optimize surgical timing, and improve long-term knee function.

Methodology and Materials

This prospective comparative study was conducted from September 2022 to March 2025 in the Department of Orthopedic Surgery at Bangladesh Medical University (BMU), Shahbagh, Dhaka. Patients presenting to the outpatient department with an isolated ACL injury within the study period were assessed for eligibility. Purposive sampling was employed to enroll participants. A total of 44 patients were included and categorized into two groups according to timing of surgery:

- **Early reconstruction group (n = 22):** ACL reconstruction performed within 3 weeks of injury.
- **Delayed reconstruction group (n = 22):** ACL reconstruction performed after 3 weeks of injury.

Inclusion Criteria

- Age between 18 and 45 years.
- Diagnosed isolated ACL injury.
- Undergoing arthroscopic ACL reconstruction within defined timeframes (Group A: ≤ 3 weeks; Group B: > 3 weeks).

Exclusion Criteria

- Old ACL injuries (> 1 year) or multi-ligament knee injuries.
- Associated meniscal, chondral injuries, or fractures around the knee (femoral condyle, tibial plateau, patella).
- Prior knee surgery or diagnosed knee osteoarthritis.
- Knee sepsis or loss of motion due to acute injury.
- Patients unfit for surgery or who declined consent.

Surgical Procedure

All surgeries were performed by a single senior orthopedic surgeon using standard arthroscopic ACL reconstruction techniques. Graft selection (hamstring or quadriceps tendon autograft) was based on surgeon preference. Femoral tunnels were created via anteromedial portal technique, with tibial fixation using interference or suspensory methods. Concomitant meniscal tears were addressed with repair or partial meniscectomy. Standardized perioperative antibiotics, thromboprophylaxis, and post-operative rehabilitation protocols, including supervised physiotherapy and staged return-to-sport criteria, were applied to all patients.

Outcomes

The primary outcomes were the incidence of early post-operative complications (≤ 6 weeks) and late post-operative complications (> 3 months) after ACL reconstruction. Early complications included wound infection (superficial and deep), hemarthrosis requiring aspiration or re-intervention, arthrofibrosis/stiffness requiring manipulation under anaesthesia or prolonged physiotherapy, and early graft failure. Late complications included persistent clinical instability, recurrent joint effusion, persistent/residual knee pain, graft rupture, and need for revision surgery. "Any early complication" and "any late complication" were prespecified composite endpoints and designated as the study's principal incidence measures.

Secondary outcomes included patient-reported and objective functional outcomes: Lysholm knee score, Tegner activity score, knee range of motion (ROM in degrees), proportion returning to pre-injury activity level, and time (months) to return to sport. Functional assessments were performed preoperatively and at standard postoperative intervals (6 weeks, 3 months, 6 months and final follow-up). For the purposes of this analysis, functional outcomes reported refer to the last available follow-up visit (minimum 6 months).

Data Collection

Baseline demographics and clinical variables (age, sex, BMI, involved side, mechanism of injury, time from injury to surgery) were recorded. Complications were assessed at 2 weeks, 6 weeks, 3 months, and 6 months, and additional visits as required. Functional outcomes were evaluated at 6 months by a blinded assessor.

Statistical Analysis

Continuous variables were reported as mean $\pm$ SD and compared using independent t-test or Mann-Whitney U test. Categorical variables were expressed as counts and percentages, with comparisons via Chi-square or Fisher's exact test for small counts. Absolute risk reduction (ARR) and number needed to treat (NNT) were calculated for complications. Multivariate logistic regression was used to identify potential risk factors, with adjusted odds ratios (ORs) and 95% confidence intervals (CIs) reported. Statistical

significance was defined as $p < 0.05$. Analyses were performed using SPSS version 26 (IBM Corp., Armonk, NY, USA).

Ethical Considerations

The study adhered to the Declaration of Helsinki. Written informed consent was obtained from all participants, and confidentiality was strictly maintained.

Result

Table 1 summarized the baseline demographic and clinical characteristics of the study population ($n=44$). The mean age was comparable between early and delayed groups (30.14 ± 5.89 vs. 29.41 ± 7.02 years, $p=0.549$), with most patients in the 20-30 year range (50.0% vs. 59.1%). Males predominated in both groups (81.82% vs. 90.91%, $p=0.380$). Mean BMI was nearly identical (23.95 ± 2.22 vs. 23.98 ± 2.27 , $p=0.972$). Right-sided involvement was more frequent in the early group (68.18%), whereas the left side was more common in the delayed group (45.45%, $p=0.353$). Notably, the mean interval from injury to surgery was significantly shorter in the early group (13.32 ± 3.37 vs. 106.00 ± 56.20 days, $p=0.001$). Figure 1 showed the mechanism of injury, with sports activity being the most common cause (45.45% vs. 50.00%), followed by road traffic accidents (36.34% vs. 40.91%) and domestic accidents (18.18% vs. 9.09%). Early

post-operative complications (≤ 6 weeks, Table 2) were generally higher in the delayed group, though not statistically significant. Arthrofibrosis occurred in 9.09% versus 4.55%, hemarthrosis in 13.64% versus 4.55%, and superficial wound infection in 13.64% versus 9.09%. Early graft failure was slightly more frequent in the delayed group (0.00% vs. 4.55%). Late complications (> 3 months) also tended to be higher with delayed surgery. Residual pain (27.27% vs. 13.64%) and persistent instability (18.18% vs. 9.09%) were most frequent, followed by recurrent effusion (13.64% vs. 4.55%), late graft rupture (0.00% vs. 4.55%), and revision surgery (9.09% vs. 4.55%). None reached statistical significance (Table 3). Functional outcomes favored early reconstruction. Lysholm scores were significantly higher in the early group (90.1 ± 3.8 vs. 82.5 ± 8.7 , $p=0.0008$), and return to sport was earlier (8.2 ± 1.9 vs. 9.6 ± 2.3 months, $p=0.033$). Tegner activity scores (5.91 ± 1.02 vs. 5.86 ± 0.71 , $p=0.85$), knee ROM ($134.77^\circ \pm 3.27$ vs. $134.09^\circ \pm 2.94$, $p=0.47$), and rates of return to pre-injury activity (72.7% vs. 50.0%, $p=0.481$) were similar (Table 4). Multivariate logistic regression (Table 5) identified delayed surgery (> 12 weeks) as a significant risk factor for post-operative complications (OR=2.10, 95% CI: 1.05-4.18, $p=0.03$). Age > 30 years, male sex, and BMI > 25 kg/m² showed no significant association.

Table 1: Baseline Demographic and Clinical Characteristics of Patients Undergoing ACL Reconstruction (N= 44)

Variable	Early Reconstruction (n = 22)		Delayed Reconstruction (n = 22)		p-value
	n	%	n	%	
Age (years)					
20-30	11	50.00	13	59.09	0.598*
31-40	10	45.45	7	31.82	
41-45	1	4.55	2	9.09	
Mean ±SD	30.14±5.89		29.41±7.02		0.549**
Gender					
Male	18	81.82	20	90.91	0.380*
Female	4	18.18	2	9.09	
BMI (kg/m²)					
Mean ±SD	23.95±2.22		23.98±2.27		0.972**
Involved site					
Right	15	68.18	12	54.55	0.353*
Left	7	31.82	10	45.45	
Time from injury to surgery (days)					
Mean ±SD	13.32±3.37		106.00±56.20		0.001*

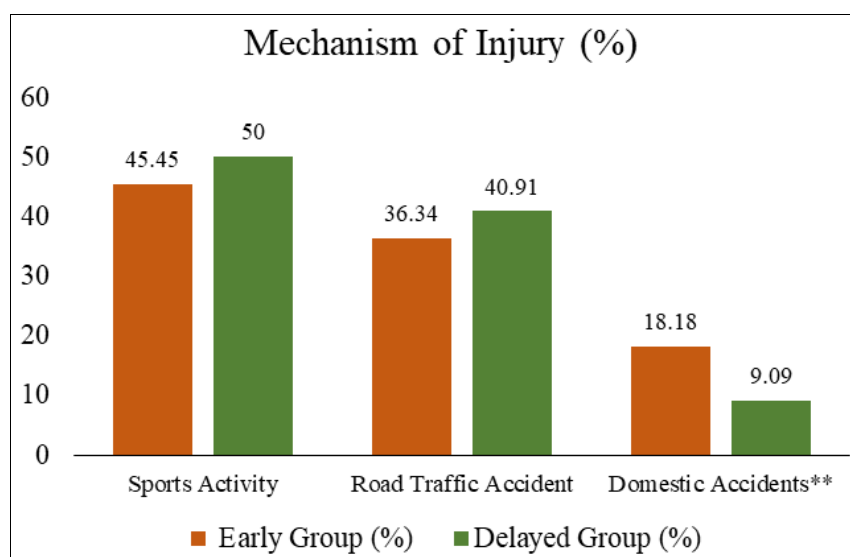


Fig 1: Distribution of patients according to Mechanism of Injury

Table 2: Early Post-Operative Complications of the Study Population (≤ 6 weeks)

Complication	Early Reconstruction (n = 22)	Delayed Reconstruction (n = 22)	ARR (%)	NNT	p-value
Superficial wound infection	2 (9.09)	3 (13.64)	4.5	22	0.64†
Hemarthrosis	1 (4.55)	3 (13.64)	9.1	11	0.30†
Arthrofibrosis/stiffness	2 (9.09)	1(4.55)	13.6	7	0.24†
Graft failure (early)	0 (0.00)	1(4.55)	4.5	22	0.55†

Table 3: Late Post-Operative Complications of the Study Population (>3 months)

Complication	Early Reconstruction (n = 22)	Delayed Reconstruction (n = 22)	ARR (%)	NNT	p-value
Persistent instability	2 (9.09)	4 (18.18)	9.1	11	0.41
Recurrent effusion	1 (4.55)	3 (13.64)	9.1	11	0.30
Residual pain	3 (13.64)	6 (27.27)	13.6	7	0.25
Graft rupture (late)	0(0.00)	1(4.55)	4.5	22	0.55
Revision surgery	0 (4.55)	1 (9.09)	4.5	22	0.55

Table 4: Functional Outcomes of the Study Population

Outcome Measure	Early Group (n=22)	Delayed Group (n=22)	Mean Difference (95% CI)	p-value
Lysholm score (mean $\pm$ SD)	90.1 $\pm$ 3.8	82.5 $\pm$ 8.7	7.6 (3.51-11.69)	0.0008*
Tegner Activity Score (points)	5.91 $\pm$ 1.02	5.86 $\pm$ 0.71	0.05 (-0.49-0.59)	0.85
Knee ROM ($^{\circ}$)	134.77 $\pm$ 3.27	134.09 $\pm$ 2.94	0.68 (-1.21-2.57)	0.47
Return to pre-injury activity, n (%)	16 (72.73)	11 (50.00)	RR = 1.35 (0.96-1.90)	0.481
Time to return to sport (months, mean $\pm$ SD)	8.2 $\pm$ 1.9	9.6 $\pm$ 2.3	-1.4 (-2.69 to -0.12)	0.033*

Table 5: Multivariate logistic regression analysis of risk factors for post-operative complications

Variable	Adjusted OR (95% CI)	p-value
Delayed surgery (>12 weeks)	2.10 (1.05-4.18)	0.03*
Age > 30 years	1.42 (0.70-2.86)	0.32
Male gender	0.91 (0.44-1.87)	0.8
BMI > 25 kg/m 2	1.56 (0.76-3.19)	0.22

Discussion

Anterior cruciate ligament (ACL) injuries represent one of the most frequent and debilitating injuries in young and physically active individuals, with considerable implications for long-term knee stability, athletic performance, and quality of life [15]. The timing of ACL reconstruction has been a subject of ongoing debate, with studies suggesting that early reconstruction may prevent secondary joint damage and improve functional outcomes, while delayed surgery could allow for preoperative rehabilitation but may increase the risk of complications [16]. This clinical dilemma has prompted multiple comparative studies exploring complication rates, functional outcomes, and long-term joint preservation [16]. In our study, the majority of patients (54.6%) were between 20 and 30 years of age, with no significant intergroup differences ($p = 0.598, 0.549$). Chen *et al.* (2015) similarly reported mean ages of 29.4 years for early and 31.9 years for delayed reconstruction [17]. Male predominance was observed (81.8% vs. 90.9%, $p = 0.380$), consistent with findings by Salahuddin *et al.* (2023) [18]. The mean injury-to-surgery interval differed significantly (13.32 ± 3.37 vs. 106.00 ± 56.20 days, $p = 0.001$), corroborating reports by Bottoni *et al.* (2008) [19]. Sports-related activities accounted for 47.7% of ACL injuries, with road traffic accidents and domestic incidents contributing 38.6% and 13.6%, respectively. These findings align with previous reports indicating sports as the primary mechanism in 40-78% of cases [20-21], reflecting a predominantly young, student population engaged in recreational sports and the rising incidence of two-wheeler-related knee trauma. Our analysis of early post-operative outcomes indicates a clinical advantage of prompt ACL reconstruction. Superficial wound infections occurred in 9.1% of early cases compared to 13.6% in delayed cases, while hemarthrosis was observed in 4.55% versus 13.64%, respectively. Although these differences did

not reach statistical significance, the absolute risk reduction underscores the potential benefit of early intervention. Consistent with prior studies, early ACL reconstruction is associated with reduced joint effusion and a lower incidence of acute peri-operative complications, likely due to stabilization of the knee before the onset of a pro-inflammatory environment. Biomarker and synovial-fluid analyses further demonstrate a time-dependent rise in cytokines and degradative mediators after ACL injury, supporting the biological rationale for timely surgical management [16, 22-23]. Moreover, arthrofibrosis was notably higher in the delayed reconstruction group (22.73% vs. 9.09%), consistent with prior evidence that prolonged knee instability predisposes to fibrosis and limits post-operative range of motion [24]. Comparative analyses further indicate that delayed ACL reconstruction increases the risk of secondary meniscal and chondral injuries, whereas carefully selected early interventions do not elevate arthrofibrosis risk [25]. Late complications were also higher in patients undergoing delayed reconstruction. Persistent instability, recurrent effusion, residual pain, and graft rupture were more common in the delayed group, with delayed surgery identified as a significant independent risk factor (adjusted OR = 2.10, 95% CI: 1.05-4.18, $p = 0.03$). These results support earlier work by Magnussen *et al.* (2012), who demonstrated that postponing ACL reconstruction increases the likelihood of secondary meniscal and chondral injuries, predisposing patients to long-term morbidity [26]. In contrast, demographic variables such as age, BMI, and gender did not significantly influence complication rates in our cohort, emphasizing that timing of surgery is a key determinant of post-operative outcomes. In the present study, functional outcomes favored early anterior cruciate ligament (ACL) reconstruction. Patients undergoing early surgery demonstrated significantly

higher Lysholm scores (90.1 ± 3.8 vs. 82.5 ± 8.7 , $p = 0.0008$), indicating better knee function and patient satisfaction. Although Tegner Activity Scores and range of motion were comparable between groups, early reconstruction facilitated a quicker return to pre-injury activity and sport (8.2 ± 1.9 vs. 9.6 ± 2.3 months, $p = 0.033$), in line with Liu *et al.* (2023) [27]. These results corroborate the COMPARE randomized trial, which reported superior Lysholm and KOOS Sport scores and higher return-to-sport rates in early reconstruction [28]. Retrospective studies in young athletes similarly observed shorter return-to-play intervals and higher activity scores [29]. While some long-term analyses, including Frobell *et al.* (2013), reported minimal differences beyond five years, short-term evidence consistently supports early reconstruction for faster functional recovery and enhanced patient-reported outcomes [30-31].

Limitations of the study: Every hospital-based study has some limitations and the present study undertaken is no exception to this fact. The study did not account for variations in rehabilitation adherence or subtle differences in surgical technique, which may have influenced outcomes. Additionally, unmeasured factors such as pre-existing joint health, activity level, and concomitant minor injuries could have affected post-operative complications and functional recovery. These factors may limit the broader applicability of the findings to diverse patient populations.

Conclusion and Recommendations

This study demonstrates that early anterior cruciate ligament (ACL) reconstruction confers significant clinical advantages over delayed surgery. Patients undergoing early reconstruction experienced lower rates of both early and late post-operative complications, including arthrofibrosis, hemarthrosis, persistent instability, and residual pain. Functional outcomes were superior in the early group, evidenced by higher Lysholm scores and shorter time to return to sport, while Tegner Activity Scores and knee range of motion remained comparable. Multivariate analysis identified delayed surgery as an independent risk factor for complications. These findings underscore the critical importance of early surgical intervention in optimizing patient outcomes and minimizing morbidity in ACL injuries.

Funding: No funding sources

Conflict of interest: None declared

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

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How to Cite This Article

Rasul A, Dey D, Diba ANR, Islam MN, Ferdous MGS, Al-Nisa F, Khan S, Rahman MN. Incidence of post-operative complications in early versus delayed ACL reconstruction. *International Journal of Orthopaedics Sciences*. 2025;11(3):276-281

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