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IMPACT OF EARLY VERSUS DELAYED WEIGHT-BEARING AFTER ARTHROSCOPIC ACL RECONSTRUCTION WITH HAMSTRING TENDONS.

DR. SUGIN GLEN BAISIL J[1], DR. K. C. MATHEW[2], DR. KAVIN RAJA S[3], DR. MIDHUN BABU[4]*, DR. GOWTHAM RAJ G[5], DR. ZAKIR HUSSAIN MOHAMED[6], DR. ROHIN G[7].

[1,3,5,6,7] Postgraduate Resident, DEPARTMENT OF ORTHOPAEDICS, SREE MOOKAMBIKA INSTITUTE OF MEDICAL SCIENCES, KULASEKHARAM, KANYAKUMARI - 629161, TAMILNADU, INDIA.

[2]Professor and Head of the department, DEPARTMENT OF ORTHOPAEDICS, SREE MOOKAMBIKA INSTITUTE OF MEDICAL SCIENCES, KULASEKHARAM, KANYAKUMARI - 629161, TAMILNADU, INDIA.

[4]Assistant Professor, DEPARTMENT OF ORTHOPAEDICS, SREE MOOKAMBIKA INSTITUTE OF MEDICAL SCIENCES, KULASEKHARAM, KANYAKUMARI - 629161, TAMILNADU, INDIA.

Correspondence:
Dr. Midhun Babu.
Assistant Professor, Department of Orthopaedics, Sree Mookambika Institute of Medical Sciences, Kulasekharam, Kanyakumari - 629161, Tamilnadu, India.

Email:
drmidhunbabu@gmail.com

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Abstract

Background: Rehabilitation after anterior cruciate ligament (ACL) reconstruction is a critical factor in the recovery process and the ability to return to activity. While the early weight-bearing protocol has become more popular, issues of graft healing and stability still exist and affect rehabilitation. ***Aim:*** To compare the clinical, functional, and second-look arthroscopic outcomes between early and delayed weight-bearing rehabilitation protocols following arthroscopic ACL reconstruction using hamstring tendon autograft ***Materials and Methods:*** This is a prospective randomized comparative study carried out in the Department of Orthopaedics, Sree Mookambika Institute of Medical Sciences from February 2024 to May 2025. There were 88 patients who had arthroscopic ACL reconstruction with hamstring tendon autograft who were included and were split into two groups. Group A followed a delayed weight bearing rehabilitation protocol, group B started with partial weight bearing in the first week postoperatively. The International Knee Documentation Committee (IKDC) score, Lysholm knee score, knee range of motion and thigh circumference difference were assessed at 3, 6 and 12 months. Graft synovial coverage, tension and integrity were evaluated at second-look arthroscopy at a minimum of 12 months after surgery. ***Results:*** The two groups had similar demographic data at baseline. Patients in the early weight-bearing group had significantly improved IKDC and Lysholm scores at 3 and 6 months after surgery. In the first follow up period, the recovery of knee range of motion was also quicker in Group B. There was a significantly smaller thigh circumference difference at all follow-up measurements in the early weight bearing group, reflecting decreased muscle wasting. The functional scores and range of motion at 12 months were similar for each group. There was no difference in graft synovial coverage, graft tension or graft integrity at second-look arthroscopy between the two rehabilitation protocols. ***Conclusion:*** Partial weight-bearing after hamstring tendon autograft ACL reconstruction was correlated with higher early functional scores, better knee motion, and better maintenance of thigh muscle bulk, without negative effects on ACL graft morphology at 1-year follow-up. These results justify the implementation of an early weight-bearing rehabilitation protocol for uncomplicated ACL reconstruction that is supervised and gradually advanced. These effects are long-lasting, but more long-term studies are necessary to assess their persistence.

Keywords: Anterior cruciate ligament reconstruction, ACL rehabilitation, Early weight-bearing, Hamstring tendon autograft, Second-look arthroscopy.

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INTRODUCTION

Anterior cruciate ligament (ACL) injury is one of the most commonly encountered ligament injuries of the knee, particularly among physically active individuals involved in sports requiring pivoting, jumping, and sudden changes in direction [1]. ACL deficiency can result in recurrent knee instability, reduced functional performance, limitation of activity, and an increased risk of secondary meniscal and chondral injury [1]. ACL reconstruction is therefore widely performed with the aim of restoring knee stability and enabling return to pre-injury activity levels [1].

Despite advances in arthroscopic surgical techniques and graft fixation methods, postoperative rehabilitation continues to play a major role in determining recovery following ACL reconstruction [1, 2]. Restoration of knee range of motion, quadriceps strength, proprioception, neuromuscular control, and gait pattern depends largely on a structured and effective rehabilitation programme [2]. Among the different aspects of rehabilitation, the appropriate timing for initiation of postoperative weight-bearing remains controversial [2, 3].

Conventional rehabilitation protocols have traditionally favoured delayed weight-bearing during the early postoperative period in an attempt to protect the healing graft and reduce excessive stress across the reconstruction site [3, 4]. However, prolonged restriction of weight-bearing may contribute to quadriceps weakness, muscle wasting, delayed gait recovery, and postoperative knee stiffness [2, 5]. In contrast, recent rehabilitation approaches increasingly advocate early mobilization and progressive weight-bearing to facilitate earlier recovery of knee function and muscle strength [2, 4].

The recent Aspetar Clinical Practice Guideline on rehabilitation after ACL reconstruction recommends early progressive weight-bearing and early joint mobilization following isolated ACL reconstruction as part of criterion-based rehabilitation strategies [4]. The guideline also emphasizes the considerable heterogeneity among currently available rehabilitation protocols and the limited certainty of evidence regarding optimal progression criteria after ACL reconstruction [4].

Despite increasing interest in accelerated rehabilitation protocols, there remains no clear consensus regarding the optimal timing for initiation of postoperative weight-bearing after ACL reconstruction [2-4]. Variability in rehabilitation protocols, progression criteria, outcome assessment methods, and duration of follow-up has contributed to inconsistent conclusions in the available literature [3-5]. Furthermore, relatively few studies have simultaneously evaluated both functional recovery and second-look arthroscopic graft characteristics following different postoperative weight-bearing protocols [2].

The present study was undertaken to compare clinical and functional outcomes between early and delayed weight-bearing rehabilitation protocols following arthroscopic ACL reconstruction using hamstring tendon autograft. The study aimed to compare knee function, range of motion, thigh circumference, and second-look arthroscopic findings between the two rehabilitation protocols over a 12-month follow-up period and to determine whether early initiation of weight-bearing influences postoperative recovery following ACL reconstruction.

MATERIALS AND METHODS

Study design and setting

This prospective randomized comparative study was conducted in the Department of Orthopaedics at Sree Mookambika Institute of Medical Sciences from February 2024 to May 2025. Ethical clearance for the study was obtained from the Institutional Ethics Committee before commencement. All patients provided written informed consent before participation.

Study population

Patients presenting with unilateral anterior cruciate ligament (ACL) injury and planned for arthroscopic ACL reconstruction using hamstring tendon autograft were consecutively included during the study period. Diagnosis was established based on clinical examination, magnetic resonance imaging (MRI), and intraoperative arthroscopic findings.

Patients aged 18 to 50 years with symptomatic ACL deficiency and positive Lachman and anterior drawer tests were included. Patients with bilateral knee involvement, associated with multiple ligament injuries, recurrent ACL tears, inflammatory arthritis, advanced chondral damage, meniscal repair procedures, or poor compliance with rehabilitation and follow-up were excluded from the study.

Initially, 100 patients were enrolled. During follow-up, seven patients were lost to follow-up and five patients sustained reinjury following surgery. A final total of 88 patients were included for analysis.

Group allocation

The included patients were randomly divided into two groups using a computer-generated randomization method.

- Group A (n = 45) followed a delayed weight-bearing rehabilitation protocol.
- Group B (n = 45) followed an early weight-bearing rehabilitation protocol.

The demographic profile and baseline clinical characteristics were comparable between the two groups.

Surgical technique

All surgeries were performed arthroscopically by the same surgical team under general anaesthesia using a standardized operative technique.

Diagnostic arthroscopy was initially carried out through standard anteromedial and anterolateral portals to confirm complete ACL rupture and identify associated intra-articular pathology. Hamstring tendon grafts were harvested through a small oblique incision over the proximal medial tibia.

The femoral tunnel was created using the anteromedial portal technique with the lateral intercondylar ridge used as the anatomical landmark. The tibial tunnel was positioned at the centre of the native ACL footprint. Femoral fixation was achieved using an Endobutton device, while tibial fixation was performed using an interference screw with additional fixation where required.

Rehabilitation protocol

The postoperative rehabilitation programme was similar in both groups except for the timing of initiation of weight-bearing activities.

All patients were mobilized using a long knee brace locked in extension during the first postoperative week. Cryotherapy, quadriceps isometric exercises, ankle pump exercises, straight leg raising, and gradual knee range-of-motion exercises were initiated early after surgery.

In Group A, partial weight-bearing with the help of a unilateral axillary crutch was started at the third postoperative week and gradually progressed to full weight-bearing by the sixth week.

In Group B, partial weight-bearing was initiated during the first postoperative week and advanced to full weight-bearing by the fourth postoperative week.

Progressive strengthening exercises, stationary cycling, treadmill walking, and closed-chain exercises were introduced according to patient tolerance. Jogging was permitted after three months, while return to sports involving pivoting or jumping activities was allowed after six months.

Clinical assessment

Patients were evaluated clinically at 3, 6, and 12 months following surgery by the same investigators.

Outcome measures included the International Knee Documentation Committee (IKDC) subjective knee score, Lysholm knee score, knee range of motion, and thigh circumference difference.

Knee flexion and extension were measured using a standard goniometer with the patient in the supine position. Thigh circumference was measured at a fixed point proximal to the joint line in both limbs, and the side-to-side difference was recorded to assess postoperative muscle wasting.

Second-look arthroscopic assessment

Second-look arthroscopy was performed in patients who consented to implant removal after a minimum postoperative period of 12 months.

During arthroscopic evaluation, graft healing was assessed based on synovial coverage, graft tension, and graft integrity. Synovial coverage was graded as poor, fair, or good according to the extent of graft coverage. Graft tension was categorized as taut, slightly lax, or lax on probe assessment. Graft integrity was recorded as intact, partially torn, or completely torn.

Statistical analysis

Data analysis was carried out using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean ± standard deviation and analysed using the independent-samples t-test. Categorical variables were analysed using the Pearson chi-square test. Arthroscopic findings between the two groups were compared using the chi-square test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The demographic characteristics of patients included in both study groups are summarized in Table 1. A total of 88 patients were included in the study, with 44 patients in each group. The mean age was 32.4±8.5 years in Group A and 34.7±9.1 years in Group B. Male patients predominated in both groups, with male-to-female ratios of 26:18 in Group A and 23:21 in Group B. The mean height and weight were comparable between the two groups. Sports-related injuries constituted the most common cause of ACL injury in both groups, accounting for 35 cases in Group A and 36 cases in Group B. No statistically significant difference was observed between the groups with respect to baseline demographic parameters (Table 1).

Table 1: Patient's demographics

Parameter	Group A	Group B	P value
N. of cases	44	44	
Age (years)	32.4±8.5	34.7±9.1	0.58
Gender (F/M)	44 (18/26)	44 (21/23)	0.47
Height (cm)	170.8±8.1	169.1±8.4	0.55
Weight (kg)	69.52±12.8	68.77±13.0	0.70
Cause of injury			
Sports activity	35	36	
Accidents or others	9	8	

The results of clinical examination at various follow-ups are presented in Table 2. IKDC and Lysholm scores before the surgery were equal between the two groups. At 3 and 6 months after surgery, Group B patients' mean IKDC and Lysholm scores were better than those in Group A; the differences were statistically significant. Twelve-month IKDC and Lysholm scores were improved for both groups with no significant difference between the groups. The mean difference in the thigh circumference value was comparable for the two groups before the procedure. In the course of postoperative follow-up, smaller thigh circumference difference values were seen in Group B at 3, 6, and 12 months; the differences were statistically significant at each point. Assessment of knee range of motion showed higher mean extension and flexion values in Group B at both 3 and 6 months postoperatively, with statistically significant differences between the groups. At 12 months after the operation, the mean extension and flexion values were similar in the two groups, and there was no statistically significant difference (Table 2).

Table II: Clinical assessment results

Tool	Timepoint	Group A	Group B	P value
IKDC	Preop.	47.92±8.84	46.18±9.95	0.42
	3 months	69.74±8.66	74.88±6.91	0.01
	6 months	77.56±7.82	82.47±6.98	0.02
	12 months	86.24±7.43	88.15±5.86	0.21
Lysholm Score	Preop.	56.18±6.74	55.42±6.88	0.57
	3 months	71.63±5.11	79.14±3.68	0.00
	6 months	80.47±3.22	86.13±2.84	0.00
	12 months	93.84±4.92	95.28±4.17	0.18
Difference value in thigh circumference (cm)	Preop.	2.04±0.78	2.16±0.58	0.31
	3 months	4.12±0.98	2.38±0.69	0.00
	6 months	2.56±0.74	1.36±0.57	0.00
	12 months	1.42±0.65	0.71±0.41	0.00
Extension (°)	3 months	0.62±2.41	2.34±2.06	0.00
	6 months	3.94±1.42	4.73±0.79	0.01
	12 months	5.36±0.88	5.29±0.84	0.79
Flexion (°)	3 months	109.42±5.84	117.18±3.26	0.00
	6 months	118.84±3.55	122.04±2.46	0.00
	12 months	124.73±2.14	125.18±1.73	0.22

Arthroscopic results at second-look arthroscopy in both groups are shown in Table 3. Good, fair, and poor synovial coverage were reported in 28, 13, and one patient in Group A and 25, 19, and zero patient in Group B, respectively. Graft tension assessment indicated that taut grafts existed in 25 and 29 patients, slightly lax grafts in 16 and 15 patients in Group A and Group B, respectively, and one lax graft in Group A.

Graft status assessment revealed that there were 34 and 36 intact grafts in Group A and Group B, respectively. Eight partial tears were recorded for both groups but no total graft tear in either group. There was no statistical difference between the two groups regarding the second-look arthroscopic evaluation of synovial coverage, graft tension, and graft status (Table 3).

Table III: Second-look arthroscopic findings in the study groups

Finding	Group A	Group B	P value
Synovial coverage (good/fair/poor)	28/13/1	25/19/0	0.27
Tension (taut/slightly lax/lax)	25/16/1	29/15/0	0.38
Status of graft (intact/partial tear/total tear)	34/8/0	36/8/0	0.82

DISCUSSION

This study yielded two principal findings. Patients who initiated partial weight-bearing one week after hamstring autograft ACL reconstruction demonstrated significantly better early functional recovery, as reflected by IKDC scores, Lysholm scores, knee flexion, and thigh circumference measurements, compared with patients in whom weight-bearing was delayed until three weeks postoperatively. However, second-look arthroscopic evaluation at 12 months demonstrated no significant differences between the groups with respect to graft synovial coverage, graft tension, or graft integrity. These findings

suggest that early axial loading may facilitate improved short-term functional recovery without adversely affecting graft healing during the first postoperative year.

The superior functional recovery observed in the early weight-bearing group at 3 and 6 months is consistent with the established role of controlled mechanical loading in reducing arthrogenic muscle inhibition and promoting neuromuscular recovery after ACL reconstruction. By 12 months, however, IKDC and Lysholm scores were comparable between the two groups, with no statistically significant difference observed. A similar pattern has been reported in previous studies evaluating accelerated rehabilitation following ACL reconstruction. Deichsel et al. reported comparable long-term Lysholm, IKDC, and Tegner scores between accelerated and conservative rehabilitation protocols at a mean follow-up of five years [6]. Likewise, Fan et al., in a systematic review and meta-analysis, observed improved short-term IKDC outcomes without sustained long-term differences in Lysholm scores following accelerated weight-bearing protocols [7]. The absence of long-term intergroup differences does not reduce the clinical relevance of improved early recovery, particularly in physically active individuals and athletes requiring earlier restoration of functional capacity.

Knee flexion was significantly greater in Group B at 3 and 6 months postoperatively, whereas extension and flexion measurements at 12 months were comparable between the two groups. Delayed mobilization following ACL reconstruction has been associated with periarticular fibrosis, quadriceps inhibition, and delayed recovery of joint motion, all of which may adversely affect postoperative rehabilitation. Earlier restoration of flexion observed with progressive axial loading may be related to improved synovial fluid circulation and reduced intra-articular adhesion formation during the early postoperative phase. Pamboris et al., in a systematic review, reported that earlier progressive loading protocols were associated with improved quadriceps strength during the early postoperative period following ACL reconstruction [8].

The smaller thigh circumference difference observed in Group B at all postoperative assessments, including 12 months, suggests a sustained beneficial effect of early loading on preservation of thigh muscle bulk. Persistent quadriceps weakness remains a major barrier to successful return to sport following ACL reconstruction and has been associated with increased risk of reinjury. Buckthorpe et al. emphasized that minimizing early quadriceps inhibition through progressive loading strategies plays an important role in subsequent strength recovery after ACL reconstruction [9]. In patients with significant postoperative muscle atrophy, adjunctive rehabilitation approaches may also be beneficial. Wengle et al., in a meta-analysis evaluating blood flow restriction training after knee surgery, demonstrated significant improvement in postoperative quadriceps muscle bulk with the use of blood flow restriction-based rehabilitation protocols [10].

The second-look arthroscopic findings represent an important component of the present study, as relatively few comparative studies evaluating postoperative weight-bearing protocols have included direct assessment of graft morphology. No significant differences were observed between the two groups with respect to synovial coverage, graft tension, or graft integrity, suggesting that initiation of partial weight-bearing at one week postoperatively did not adversely affect graft healing. Experimental evidence has also demonstrated the importance of controlled mechanical loading during the early healing phase. Camp et al. reported superior tendon-to-bone healing in animals allowed loading after a short period of immobilization compared with immediate loading or prolonged immobilization [11]. Similarly, Lee et al. demonstrated that synovial coverage observed during second-look arthroscopy correlates with graft maturation following ACL reconstruction using hamstring autografts [12]. Comparable synovial coverage grades between the two groups in the present study therefore suggest that earlier loading did not negatively influence graft ligamentization.

Concerns regarding the potential effect of accelerated rehabilitation on tunnel widening and graft laxity have been described in previous literature [7]. However, several earlier studies evaluating accelerated protocols involved immediate or near-immediate full weight-bearing, which differs from the graduated partial weight-bearing protocol used in the present study. Experimental findings by Nakagawa et al. further demonstrated that short-term immobilization during the early postoperative phase may reduce matrix metalloproteinase activity at the graft-bone interface compared with prolonged immobilization [13]. The comparable graft tension and structural integrity observed at one-year follow-up in the present study are consistent with these findings and suggest that initiation of partial weight-bearing after one week may provide an adequate balance between graft protection and functional rehabilitation.

These findings have important clinical implications for the development of postoperative rehabilitation protocols following ACL reconstruction. Contemporary rehabilitation strategies increasingly favor criterion-based progression rather than strictly time-based advancement, with rehabilitation progression tailored according to individual patient recovery and functional status. Kyritsis et al. reported a significantly higher risk of graft rupture among athletes who returned to sport without meeting objective discharge criteria, emphasizing the importance of structured rehabilitation progression following ACL reconstruction [14]. Within this context, the findings of the present study support initiation of partial weight-bearing with assisted ambulation at the end of the first postoperative week following uncomplicated single-bundle hamstring autograft ACL reconstruction. Nevertheless, factors such as graft diameter, fixation stability, postoperative inflammatory

response, and patient compliance should be considered when implementing rehabilitation protocols. The variability among currently available rehabilitation guidelines further highlights the need for additional prospective comparative studies to establish standardized rehabilitation pathways following ACL reconstruction [15].

The present study has several strengths. The prospective randomized design and comparable baseline demographic characteristics between the groups minimized selection bias. Surgical technique, fixation methods, and postoperative rehabilitation protocols were standardized across both groups, thereby reducing confounding related to operative variability. An additional strength of the study was the inclusion of second-look arthroscopy as an objective method for assessment of graft morphology, as many previous comparative studies evaluating postoperative weight-bearing protocols have relied primarily on clinical or patient-reported outcomes. Furthermore, validated functional assessment tools, including IKDC score, Lysholm score, goniometric range of motion assessment, and thigh circumference measurements, were applied uniformly at all follow-up intervals.

Certain limitations of the present study should be acknowledged. The follow-up duration of 15 months does not allow assessment of long-term outcomes such as osteoarthritic progression or graft rerupture rates. Graft laxity was assessed clinically rather than with instrumented arthrometric evaluation, which may have introduced examiner-dependent variability and limited detection of subtle differences in anterior tibial translation. Patients with meniscal repair, significant chondral lesions, and bilateral knee pathology were excluded from the study, which may limit the generalizability of the findings to more complex injury patterns. In addition, factors such as graft diameter and injury-to-surgery interval were not stratified during analysis, although both may influence postoperative recovery. Second-look arthroscopy was performed only in patients who consented to hardware removal, and therefore the possibility of selection bias cannot be completely excluded.

In summary, initiation of partial weight-bearing at one week following ACL reconstruction with hamstring tendon autograft was associated with earlier improvement in knee range of motion, functional scores, and preservation of thigh muscle bulk during the first six postoperative months, without evidence of adverse effects on graft morphology at one-year follow-up. These findings support the incorporation of appropriately supervised early weight-bearing into rehabilitation protocols following uncomplicated hamstring autograft ACL reconstruction. Further long-term studies using objective laxity assessment methods are required to evaluate the durability of these outcomes.

CONCLUSION

Early initiation of partial weight-bearing following hamstring tendon autograft ACL reconstruction was associated with improved early functional recovery, greater knee range of motion, and reduced thigh muscle wasting during the initial postoperative months, without evidence of adverse effects on graft morphology at one-year follow-up. Although functional outcomes between the two groups became comparable at later follow-up, patients undergoing early weight-bearing demonstrated faster recovery during the early rehabilitation phase. These findings suggest that a supervised and progressively advanced early weight-bearing protocol may be safely incorporated into postoperative rehabilitation following uncomplicated ACL reconstruction. Nevertheless, rehabilitation progression should remain individualized according to patient characteristics, graft stability, and clinical recovery. Further prospective studies with longer follow-up duration and objective assessment of graft laxity are required to determine the long-term functional and structural outcomes of accelerated rehabilitation protocols.

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