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Original Research Article

TEMPORAL TRENDS IN PAIN, STIFFNESS, AND PHYSICAL FUNCTION FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING A QUADRUPLED HAMSTRING GRAFT: A PROSPECTIVE 12-MONTH STUDY USING THE WOMAC INDEX

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ABSTRACT

Background: Anterior cruciate ligament (ACL) injury is a common cause of knee instability and functional limitation in physically active individuals. Arthroscopic ACL reconstruction using hamstring tendon grafts has become a widely accepted procedure for restoring knee stability and improving functional outcomes. The objective is to evaluate temporal trends in pain, stiffness, and physical function following arthroscopic ACL reconstruction using a quadrupled hamstring tendon graft over a 12-month follow-up period.

Materials and Methods: This prospective observational study was conducted in 51 patients with ACL injury who underwent arthroscopic ACL reconstruction at a tertiary care center between January 2017 and October 2018. Patients aged 18–55 years with ACL injury, with or without associated meniscal injury, were included. Functional outcomes were assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Serial assessments of pain, stiffness, physical function, and total WOMAC scores were performed pre-operatively and during follow-up at 10 days, 1.5 months, 3 months, 6 months, 9 months, and 12 months post-operatively.

Results: Progressive improvement in WOMAC scores was observed during serial follow-up. Mean WOMAC pain scores improved from 58.08 ± 8.23 pre-operatively to 14.53 ± 8.05 at 12 months. Mean stiffness scores improved from 60.05 ± 9.98 to 10.49 ± 7.26, while physical function scores improved from 54.22 ± 6.83 to 16.66 ± 6.90. Total WOMAC scores also demonstrated significant reduction during follow-up ($p < 0.001$).

Conclusion: Arthroscopic ACL reconstruction using a quadrupled hamstring tendon graft provides significant improvement in pain, stiffness, and functional recovery over a 12-month period when combined with structured rehabilitation.

Keywords: Anterior cruciate ligament reconstruction; Hamstring graft; WOMAC index; Arthroscopy; Knee function; Rehabilitation.

INTRODUCTION

Anterior cruciate ligament (ACL) injury is one of the most frequently encountered ligamentous injuries of the knee joint and represents a significant cause of disability among young and physically active individuals.[1] The incidence of ACL tears has increased substantially over recent decades owing to greater participation in competitive sports, recreational athletic activities, and high-velocity trauma such as road traffic accidents.[2] Patients with ACL deficiency commonly present with knee instability, recurrent giving-way episodes, pain, swelling, stiffness, and impaired functional performance, all of which adversely affect quality of life and physical activity levels.[3]

Persistent instability following ACL rupture may predispose the knee to secondary intra-articular damage, particularly meniscal tears and chondral degeneration, thereby accelerating the development

of early osteoarthritis.[4] Consequently, restoration of knee stability and preservation of long-term joint function have become the primary objectives in the management of ACL injuries. Arthroscopic anterior cruciate ligament reconstruction (ACLR) is currently regarded as the treatment of choice for symptomatic ACL-deficient knees in active patients seeking to return to their pre-injury functional status.[5]

Several graft options have been described for ACL reconstruction, including bone–patellar tendon–bone grafts, hamstring tendon grafts, quadriceps tendon grafts, and allografts. Among these, quadrupled hamstring tendon grafts using semitendinosus and gracilis tendons have gained widespread acceptance because of their favorable biomechanical properties, lower donor-site morbidity, reduced anterior knee pain, and improved cosmetic outcomes.[6] Advances in arthroscopic instrumentation, anatomical tunnel placement, adjustable-loop fixation devices, and structured rehabilitation protocols have further contributed to better clinical and functional outcomes following ACL reconstruction.

Mechanical stability alone is not sufficient to determine surgical success after ACL reconstruction. Patient-reported clinical recovery has become an important component of outcome assessment in contemporary orthopaedic practice. Evaluation of pain, stiffness, and physical function provides valuable insight into the effectiveness of both surgical reconstruction and post-operative rehabilitation. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) is a validated patient-reported outcome measure that assesses these three major domains and has been widely utilized in studies evaluating knee-related functional outcomes.[7]

Recovery after ACL reconstruction is a gradual process that continues over several months. Early post-operative recovery is influenced by pain control, restoration of range of motion, graft incorporation, and muscle strengthening, whereas later recovery depends largely on neuromuscular rehabilitation, proprioceptive training, and return-to-sport conditioning. Hence, serial assessment of patient-reported outcomes is essential for understanding the pattern of recovery following ACL reconstruction.

The present study was conducted to evaluate temporal trends in pain, stiffness, and physical function following arthroscopic anterior cruciate ligament reconstruction using a quadrupled hamstring tendon graft. Functional outcomes were assessed using the WOMAC index over a 12-month follow-up period to evaluate the pattern of recovery and the effectiveness of the surgical technique combined with a structured rehabilitation protocol.

MATERIALS AND METHODS

Study Design and Setting: This prospective observational study was conducted in the Department of Orthopaedics at Amala Institute of medical sciences, Thrissur, Kerala, India, between January 2017 and October 2018. The study evaluated temporal changes in pain, stiffness, and physical function following arthroscopic anterior cruciate ligament reconstruction (ACLR) using a quadrupled hamstring tendon graft. Ethical approval was obtained from the Institutional Ethics Committee prior to commencement of the study. Written informed consent was obtained from all participants included in the study.

Prospective longitudinal assessment enables serial evaluation of patient-reported outcomes following ACL reconstruction.[8]

Study Population

A total of 51 patients diagnosed with anterior cruciate ligament injury and undergoing arthroscopic ACL reconstruction were included in the study. All patients were followed for a period of 12 months after surgery.

Inclusion Criteria

1. Patients with ACL injury with or without associated meniscal injury.
2. Age between 18 and 55 years.
3. Patients willing for regular follow-up assessments.

Exclusion Criteria

1. Revision ACL reconstruction.
2. Previous surgery involving the affected knee.
3. Age below 18 years or above 55 years.
4. Associated fractures or neurovascular injury around the knee.

Pre-operative Evaluation

All patients underwent detailed clinical evaluation including history taking, physical examination, and radiological assessment. Clinical diagnosis of ACL injury was established using Lachman test, anterior drawer test, and pivot shift test. Magnetic resonance imaging (MRI) was performed in all patients to confirm ACL rupture and identify associated meniscal or chondral injuries. MRI is considered the imaging modality of choice for evaluation of ACL injuries because of its high diagnostic accuracy and ability to assess associated intra-articular pathology.[9]

Baseline demographic variables including age, sex, side of injury, mechanism of injury, and associated meniscal injury were recorded prior to surgery.

Surgical Technique

All patients underwent arthroscopic ACL reconstruction under spinal anesthesia in the supine position with the knee flexed to 90 degrees. Standard anterolateral and anteromedial arthroscopic portals were established. Diagnostic arthroscopy was performed to assess the ACL, posterior cruciate ligament, menisci, and articular cartilage.

Semitendinosus and gracilis tendons were harvested through a small anteromedial incision over the proximal tibia. The tendons were prepared after removal of residual muscle fibers and fashioned into a quadrupled hamstring graft using non-absorbable whip stitches. Hamstring tendon autografts are widely used in ACL reconstruction because of their

favorable biomechanical strength and lower donor-site morbidity compared with patellar tendon grafts.[10]

Femoral and tibial tunnels were created arthroscopically according to the anatomical footprint of the native ACL. The prepared graft was passed through the femoral and tibial tunnels and fixed on the femoral side using an adjustable-loop cortical suspension device and on the tibial side using an interference screw. Anatomical graft placement and secure fixation are essential for restoration of knee stability and graft incorporation following ACL reconstruction.[11]

After graft fixation, the knee was cycled several times to ensure appropriate graft tension and range of motion. Wound closure was performed in layers, followed by sterile dressing application and placement of a long knee immobilizer.

Post-operative Rehabilitation Protocol

All patients followed a structured post-operative rehabilitation program supervised by physiotherapists. Intravenous antibiotics and analgesics were administered during the immediate post-operative period. Static quadriceps exercises were initiated on the evening of surgery, followed by heel-slide exercises and straight leg raising exercises from the first post-operative day.

Progressive rehabilitation focused on restoration of knee range of motion, quadriceps strengthening, hamstring stretching, proprioceptive training, gait training, balance exercises, and gradual return to sports-specific activities. A phased rehabilitation approach after ACL reconstruction has been shown to improve functional recovery and facilitate safe return to activity (12). The knee immobilizer was continued for four weeks post-operatively, after which progressive strengthening and sport-specific training were introduced according to patient tolerance and functional recovery.

Outcome Assessment

Functional outcomes were assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Pain, stiffness, physical function, and total WOMAC scores were recorded for each patient.

Assessments were performed pre-operatively and during follow-up at 10 days, 1.5 months, 3 months, 6 months, 9 months, and 12 months post-operatively. WOMAC has demonstrated reliability and responsiveness in evaluating knee-related functional outcomes and patient-reported recovery.[13]

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) software version 23.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequency and percentage. Repeated measures statistical analysis was used to compare WOMAC pain, stiffness, physical function, and total scores during serial follow-up. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Demographic and Baseline Clinical Characteristics

A total of 51 patients who underwent arthroscopic anterior cruciate ligament reconstruction using a quadrupled hamstring tendon graft were included in the study. The mean age of the patients was 33.6 ± 11.5 years. Male patients constituted the majority of the study population, accounting for 66.7%, while females comprised 33.3%.

Right-sided ACL injury was more common than left-sided injury. Twisting injury was the most frequent mechanism of injury, followed by sports-related trauma and road traffic accidents. Associated meniscal injury was identified in a subset of patients undergoing reconstruction [Table 1].

Temporal Changes in WOMAC Pain Scores

Serial evaluation of WOMAC pain scores demonstrated gradual reduction following ACL reconstruction. The mean pre-operative pain score was 58.08 ± 8.23. A transient increase in pain was observed during the immediate post-operative period at 10 days. Subsequently, pain scores decreased steadily during serial follow-up.

A marked reduction in pain scores was observed between the 3-month and 6-month follow-up periods, with continued improvement up to the final 12-month assessment. At one year following surgery, the mean WOMAC pain score had reduced to 14.53 ± 8.05, indicating marked reduction in pain following reconstruction. Repeated measures analysis demonstrated statistically significant reduction in WOMAC pain scores during follow-up ($p < 0.001$) [Table 2].

Temporal Changes in WOMAC Stiffness Scores

WOMAC stiffness scores also demonstrated significant reduction during serial follow-up. The mean pre-operative stiffness score was 60.05 ± 9.98. Increased stiffness was noted during the early post-operative phase, particularly at the 10-day follow-up, likely related to post-surgical inflammation and immobilization. Gradual reduction in stiffness was observed following initiation of rehabilitation and restoration of knee mobility. Improvement became evident after the 3-month follow-up period, with continued reduction in stiffness up to the final 12-month assessment. The final mean WOMAC stiffness score was 10.49 ± 7.26, representing marked reduction compared with baseline values ($p < 0.001$) [Table 3].

Temporal Changes in WOMAC Physical Function Scores

Assessment of WOMAC physical function scores demonstrated gradual recovery of functional capacity following ACL reconstruction. The mean pre-operative physical function score was 54.22 ± 6.83. Early post-operative limitation in physical activity was observed during the initial follow-up period because of pain, stiffness, and restricted weight bearing. With progression of rehabilitation, patients demonstrated steady improvement in mobility,

walking ability, stair climbing, and activities of daily living. Improvement in physical function became more evident after 6 months of follow-up and continued until the final follow-up assessment. At 12 months post-operatively, the mean WOMAC physical function score improved to 16.66 ± 6.90, indicating substantial restoration of knee function following surgery and rehabilitation ($p < 0.001$) [Table 4].

Temporal Changes in Total WOMAC Scores

Total WOMAC scores demonstrated gradual reduction during serial follow-up. The mean pre-operative total WOMAC score was 55.51 ± 6.43. Although early post-operative worsening was observed during the immediate recovery period, subsequent follow-up showed steady reduction in total WOMAC scores. The most substantial reduction occurred between the 3-month and 6-month follow-up intervals, corresponding with progression of rehabilitation exercises. Continued improvement was observed up to the final follow-up period. At 12 months following ACL reconstruction, the mean total WOMAC score had decreased to 15.70 ± 6.32, indicating overall clinical and functional recovery after surgery [Table 5, Figure 1].

Intra-operative and Post-operative Clinical Documentation

Intra-operative clinical photographs demonstrated key operative steps including arthroscopic portal placement, hamstring graft harvesting, graft preparation, tibial tunnel drilling, graft passage into the femoral tunnel, and final reconstructed graft appearance [Figure 2–5]. Post-operative photographs documented wound healing, application of a long knee immobilizer, and post-operative radiographic tunnel positioning following ACL reconstruction [Figure 6 and 7].

Functional Recovery During Follow-up

Gradual functional recovery was observed throughout the study period. Early rehabilitation focused on pain control, restoration of range of motion, and quadriceps activation. Later rehabilitation emphasized strengthening, proprioceptive training, gait correction, and return to functional activities. Most patients achieved satisfactory clinical recovery and improvement in daily functional activities by the end of the 12-month follow-up period. All WOMAC domains demonstrated statistically significant improvement during serial follow-up ($p < 0.001$).

Table 1: Baseline demographic and clinical characteristics of the study population

Variable	Observation
Number of patients	51
Mean age (years)	33.6 ± 11.5
Male	34 (66.7%)
Female	17 (33.3%)
Right-sided injury	29 (56.9%)
Left-sided injury	22 (43.1%)
Isolated ACL injury	35 (68.6%)
ACL with meniscal injury	16 (31.4%)
Twisting injury	27 (52.9%)
Sports injury	17 (33.3%)
Road traffic accident	7 (13.7%)

Table 2: Temporal changes in WOMAC pain scores following ACL reconstruction

Follow-up period	Mean ± SD
Pre-operative	58.08 ± 8.23
10 days	61.34 ± 7.92
1.5 months	49.26 ± 8.41
3 months	37.12 ± 7.88
6 months	25.84 ± 7.36
9 months	18.92 ± 7.11
12 months	14.53 ± 8.05

Table 3: Temporal changes in WOMAC stiffness scores following ACL reconstruction

Follow-up period	Mean ± SD
Pre-operative	60.05 ± 9.98
10 days	64.11 ± 8.86
1.5 months	51.42 ± 8.34
3 months	38.26 ± 7.75
6 months	24.87 ± 7.14
9 months	15.63 ± 6.92
12 months	10.49 ± 7.26

Table 4: Temporal changes in WOMAC physical function scores following ACL reconstruction

Follow-up period	Mean ± SD
Pre-operative	54.22 ± 6.83
10 days	58.46 ± 7.15
1.5 months	47.33 ± 6.88
3 months	36.85 ± 6.42

6 months	27.16 ± 6.14
9 months	20.44 ± 6.58
12 months	16.66 ± 6.90

Table 5: Temporal changes in total WOMAC scores following ACL reconstruction

Follow-up period	Mean ± SD
Pre-operative	55.51 ± 6.43
10 days	60.18 ± 7.12
1.5 months	49.34 ± 6.95
3 months	37.41 ± 6.72
6 months	26.02 ± 6.28
9 months	18.36 ± 6.11
12 months	15.70 ± 6.32

Figure 1: WOMAC score trends during follow-up.

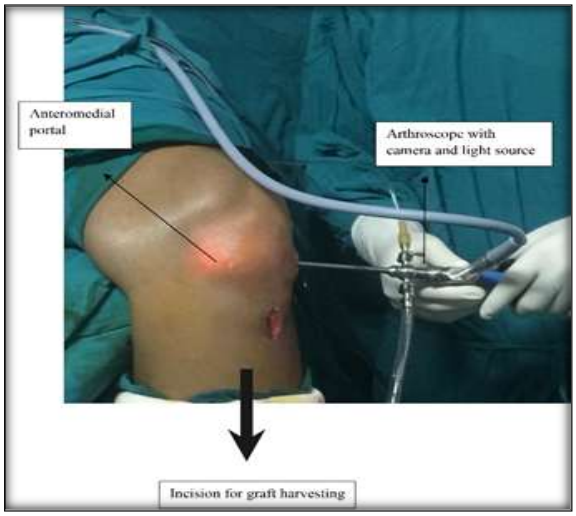

Figure 2: Arthroscopic portals and graft harvest site.

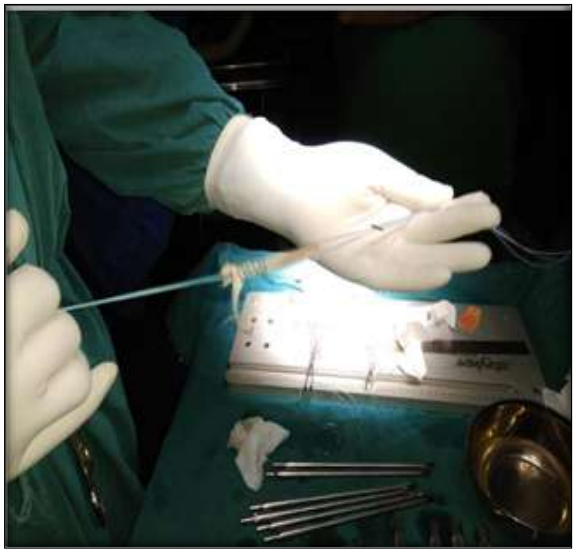

Figure 3: Prepared hamstring graft.

Figure 4: Tibial tunnel drilling and graft passage.

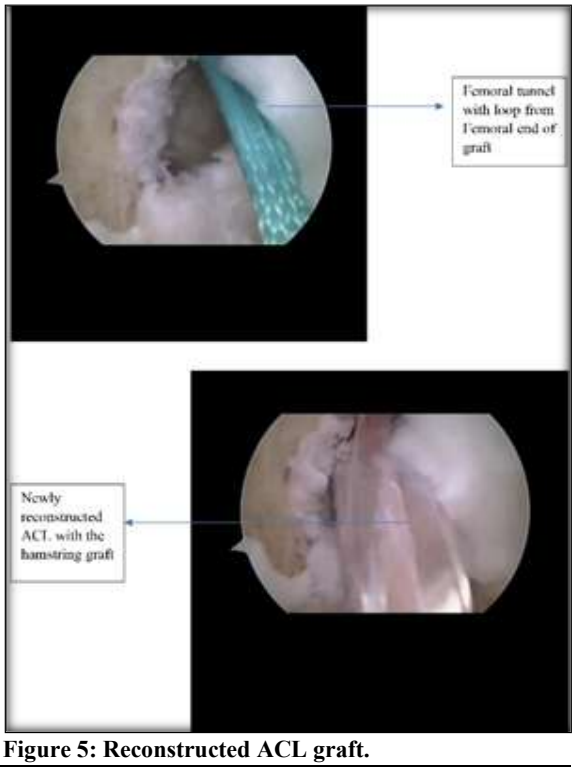

Figure 5: Reconstructed ACL graft.

Figure 6: Post-operative wound and knee immobilizer.

Figure 7: Post-operative X-ray after ACL reconstruction.

DISCUSSION

The present prospective study demonstrated significant improvement in pain, stiffness, physical function, and total WOMAC scores following arthroscopic anterior cruciate ligament reconstruction using a quadrupled hamstring tendon graft over a 12-month follow-up period. Gradual reduction in WOMAC scores was observed during serial follow-up, indicating satisfactory clinical and functional recovery after surgery and rehabilitation. Similar improvement in functional outcomes following ACL reconstruction has been reported in previous studies.[13,14]

Pain and stiffness showed marked reduction after the early post-operative period, which may be attributed to restoration of knee stability, graft incorporation, and structured physiotherapy rehabilitation. Improvement in physical function became more evident after 6 months of follow-up, corresponding with progression of strengthening and proprioceptive exercises. These findings are consistent with previous reports emphasizing the importance of rehabilitation in achieving optimal post-operative recovery.[15]

Hamstring tendon grafts remain widely preferred because of lower donor-site morbidity, reduced anterior knee pain, and satisfactory biomechanical strength compared with other graft options.[16] The gradual decline in total WOMAC scores observed in the present study reflects overall improvement in patient-reported knee function and supports the effectiveness of arthroscopic ACL reconstruction using a quadrupled hamstring graft.

The study has certain limitations including single-center design, relatively modest sample size, and absence of a control group. In addition, WOMAC is not an ACL-specific outcome measure. Nevertheless, the prospective design and serial follow-up assessment strengthen the findings of the present study. The results suggest that arthroscopic ACL reconstruction combined with structured rehabilitation provides satisfactory improvement in pain, stiffness, and physical function over a period of one year.

CONCLUSION

Arthroscopic anterior cruciate ligament reconstruction using a quadrupled hamstring tendon graft resulted in significant improvement in pain, stiffness, physical function, and overall WOMAC scores over a 12-month follow-up period. Gradual functional recovery was observed during serial follow-up, with substantial improvement becoming evident after the early post-operative phase and continuing throughout rehabilitation.

The present study demonstrated that restoration of knee stability through anatomical ACL reconstruction, combined with a structured rehabilitation program, contributes to satisfactory clinical and functional recovery in patients with ACL-deficient knees. Improvement in patient-reported outcomes during follow-up highlights the importance of early mobilization, muscle strengthening, and progressive physiotherapy in achieving optimal post-operative function.

Serial assessment using the WOMAC index proved useful in evaluating temporal changes in symptoms and functional capacity following reconstruction. The findings of the present study support the effectiveness of arthroscopic ACL reconstruction using a quadrupled hamstring tendon graft as a reliable treatment option for improving knee function and quality of life in patients with ACL injury.

Further studies with larger sample sizes, longer follow-up duration, and inclusion of ACL-specific functional scoring systems may provide additional insight into long-term functional recovery following ACL reconstruction.

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