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Original article

Early Functional Recovery and Range of Motion After ACL Reconstruction: A Prospective Study Comparing Bone-Patellar Tendon-Bone *vs.* Hamstring Autografts

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Abstract
Anterior Cruciate Ligament (ACL) reconstruction is commonly performed using either bone-patellar tendon-bone (BPTB) or hamstring autografts. Although long-term outcomes are often comparable, early postoperative recovery, including pain, range of motion, and functional recovery, may differ between graft types. This prospective cohort study compared early functional recovery, pain levels, ROM, and complications between BPTB and hamstring autografts in ACL reconstruction. Fifty patients were included: 30 received hamstring grafts and 20 received BPTB grafts. Early outcomes assessed included pain (visual analog scale, VAS), ability to walk without a limp, kneeling pain, time to return to sport/work, ROM, stiffness, and complication rates. Data were collected via structured questionnaires and clinical follow-up, with statistical analysis performed using independent t-tests and chi-square tests. Both groups exhibited minimal pain at rest (VAS = 0) and low pain during walking (VAS 0.3 vs. 0.5, p = 0.317). A high proportion achieved full extension (97% vs. 90%, p = 0.361) and full flexion (97% vs. 95%, p = 0.728), with no significant intergroup differences. Kneeling pain was slightly more frequent with hamstring grafts (33% vs. 30%, p = 0.815). Return to sport/work was significantly faster in the hamstring group (5.4 vs. 7.2 months, p = 0.048). Complication rates were low and comparable between groups (infection: 3.3% vs. 5%, p = 0.755; residual instability: 6.7% vs. 5%, p = 0.785). Early postoperative outcomes were similar between BPTB and hamstring autografts, with both providing excellent pain control, ROM recovery, and low complication rates. However, the hamstring group demonstrated a statistically faster return to sport/work. Graft selection should consider individual patient factors and surgeon preference.
Keywords. Early Functional Recovery, Range of Motion, Bone-Patellar, Tendon-Bone.

Introduction

Anterior cruciate ligament (ACL) injuries represent one of the most significant challenges in sports medicine and orthopedic practice, with profound implications for knee stability and long-term joint health. These injuries occur with an annual incidence of approximately 68.6 per 100,000 person-years, reflecting their prevalence among athletes and physically active populations [1]. In the United States alone, this translates to about 1 in 3,500 individuals sustaining an ACL injury each year, though recent epidemiological trends suggest these numbers may be increasing due to growing sports participation and enhanced diagnostic capabilities. The consequences of ACL injuries extend beyond the initial trauma, as untreated or improperly managed cases frequently lead to secondary complications such as meniscal damage and early-onset osteoarthritis, which develops in approximately 20% of patients within a decade and affects half of all patients by twenty years post-injury [2].

The surgical management of ACL injuries has evolved significantly, with autograft reconstruction remaining the gold standard for active individuals. Among the various graft options available, the bone-patellar tendon-bone (BPTB) and hamstring tendon (HT) autografts have emerged as the most widely used, each offering distinct advantages and presenting unique challenges. The BPTB graft, harvested from the central third of the patellar tendon, is particularly valued for its robust biomechanical properties. Its bone-to-bone healing characteristics facilitate faster incorporation into the knee joint, while its high initial tensile strength makes it especially suitable for high-demand athletes participating in sports that involve cutting, pivoting, and jumping. However, these benefits come at the cost of increased donor-site morbidity, with approximately 30% of patients reporting persistent anterior knee pain and kneeling discomfort, along with a small but notable risk of patellar fracture [3].

In contrast, HT autografts, typically comprising the semitendinosus and gracilis tendons, present a different set of clinical considerations. These grafts are associated with reduced donor-site morbidity and generally cause less postoperative discomfort, allowing for earlier mobilization and faster return to basic activities. The smaller incision required for HT graft harvest also offers cosmetic advantages that some patients may

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prefer. Nevertheless, HT grafts face their challenges, particularly in the realm of graft healing. The process of ligamentization, where the soft tissue graft gradually transforms into a structure resembling the native ACL, tends to be slower with HT grafts, potentially leading to increased laxity in the early postoperative period. Additionally, some patients experience persistent hamstring weakness, which can affect knee flexion strength and functional performance [4].

The early postoperative period reveals important differences between these two graft types that can influence clinical decision-making and rehabilitation strategies. Patients undergoing BPTB reconstruction typically report higher levels of initial pain, primarily due to the patellar tendon harvest, though this difference generally resolves by the six-month mark. Quadriceps strength recovery tends to be more protracted with BPTB grafts, often requiring nearly a year to achieve optimal symmetry with the unaffected limb. Conversely, HT graft recipients frequently demonstrate quicker restoration of range of motion, often achieving full knee flexion and extension approximately two weeks earlier than their BPTB counterparts. These factors contribute to the observation that HT graft patients may reach certain return-to-sport milestones sooner, though the long-term outcomes between the two graft types ultimately converge [5]. Long-term follow-up studies and meta-analyses have provided valuable insights into the durability and consequences of these surgical choices. At an average of 14.6 years post-reconstruction, both graft types demonstrate similar rates of graft failure and osteoarthritis progression. However, nuanced differences emerge when examining specific joint compartments, with BPTB grafts showing a greater propensity for patellofemoral osteoarthritis development. This finding has led some surgeons to consider alternative graft choices for patients with preexisting patellofemoral joint concerns or those engaged in activities requiring frequent kneeling. Interestingly, some evidence suggests that HT grafts may offer a modest protective effect against contralateral ACL injuries, though this observation requires further investigation [6].

The evolving landscape of ACL reconstruction continues to introduce new considerations and alternatives. The quadriceps tendon autograft has gained attention as a potential middle ground, offering reduced donor-site morbidity compared to BPTB while maintaining favorable stability characteristics. As surgical techniques and rehabilitation protocols advance, the emphasis on individualized treatment planning has never been greater. The optimal graft choice must account for multiple factors, including the patient's activity level, anatomical considerations, and personal rehabilitation goals [7]. Future research directions likely will explore not only novel graft options but also biological augmentation strategies aimed at enhancing graft incorporation and potentially slowing the progression of post-traumatic osteoarthritis. This comprehensive understanding of graft-specific outcomes enables clinicians to make evidence-based decisions that balance immediate functional recovery with long-term joint preservation, ultimately improving the quality of care for patients with ACL injuries. This study aims to compare early functional outcomes (e.g., pain, quadriceps strength, and knee stability) between BPTB and HT autografts, providing evidence-based insights to guide surgical decision-making and postoperative rehabilitation strategies.

Methods

Study Design and Population

A prospective cohort study was conducted at Al-Massara and Al-Rasheed Clinics in 2024. Inclusion criteria were male patients undergoing primary ACL reconstruction. Exclusion criteria included revision surgery, bilateral ACL injury, and pre-existing joint disease.

Variables Collected

Collected variables included demographics (age, operated leg), graft type (hamstring or BPTB), functional outcomes such as walking without limp, ability to climb stairs normally, and kneeling pain. Clinical parameters included return to sport/work in months, Visual Analog Scale (VAS) pain scores at rest and during walking, range of motion (full extension and flexion), presence of stiffness, and postoperative complications such as infection or residual instability.

Statistical Analysis

Data were analyzed using SPSS software. Independent t-tests compared continuous variables (e.g., return to sport time, VAS scores), and Chi-square or Fisher's exact tests were applied for categorical variables (e.g., limp, kneeling pain, range of motion). A p-value < 0.05 was considered statistically significant.

Results

As shown in Table 1, both the hamstring and BPTB groups reported no pain at rest (VAS = 0). Pain on walking was low in both groups, with mean scores of 0.3 ± 0.6 for the hamstring group and 0.5 ± 1.0 for the BPTB group, showing no statistically significant difference ($p = 0.317$). This indicates effective early postoperative pain control irrespective of graft type. Return to sport or work was significantly faster in the hamstring group (mean 5.4 months) compared to the BPTB group (mean 7.2 months, $p = 0.048$). These findings suggest that hamstring graft patients may achieve earlier functional recovery, allowing a quicker return to activity. Full knee extension was achieved by 97% of hamstring patients and 90% of BPTB patients,

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with no significant difference (p = 0.361). Similarly, full flexion was restored in 97% and 95% respectively (p = 0.728). These findings demonstrate excellent early functional recovery in both groups. Both groups reported a mean VAS score of 0, indicating complete absence of pain at rest during the early postoperative phase. This suggests that pain control at rest is excellent, regardless of graft type.

Pain while walking was very mild in both groups. Although the BPTB group had slightly higher pain (mean 0.5) compared to the hamstring group (mean 0.3), the difference was not statistically significant (p = 0.317). Clinically, this implies both techniques provide comparable pain outcomes for early ambulation. Walking without a limp was reported in 90% of hamstring patients and 95% of BPTB patients (p = 0.553), showing comparable functional gait outcomes. Kneeling pain was reported slightly more in the hamstring group (33%) than in the BPTB group (30%), but this difference was not statistically significant (p = 0.815). This may reflect donor site discomfort associated with hamstring graft harvesting. Complications were low in both groups. One patient (3.3%) in the hamstring group and one patient (5%) in the BPTB group experienced superficial infection; this difference was not statistically significant (p = 0.755). Knee stiffness was rare, with no cases reported in either group. Residual instability occurred in 2 (6.7%) patients in the hamstring group and 1 (5%) patient in the BPTB group (p = 0.785). Overall, complication rates did not differ significantly between groups, indicating both grafts are safe with minimal early postoperative morbidity.

Table 1. Comparison of Outcomes Between Hamstring and BPTB Grafts

Outcome	Hamstring (n = 30)	BPTB (n = 20)	P-value
Mean Age (years)	30.6 ± 5.9	32.5 ± 6.8	0.287
Return to Work/Sport (months)	5.4 ± 2.2	7.2 ± 4.3	0.048
Walking Without Limp	27 (90%)	19 (95%)	0.553
Climb Stairs Normally	30 (100%)	20 (100%)	–
Kneeling Pain Present	10 (33%)	6 (30%)	0.815
VAS Pain at Rest (0–10)	0	0	–
VAS Pain on Walking (0–10)	0.3 ± 0.6	0.5 ± 1.0	0.317
Full Extension Achieved	29 (97%)	18 (90%)	0.361
Full Flexion Restored	29 (97%)	19 (95%)	0.728
Residual Instability	2 (6.7%)	1 (5%)	0.785

Discussion

This study demonstrates that both BPTB and hamstring autografts provide excellent early functional recovery. Although the hamstring group showed a statistically significant faster return to work/sport, differences in pain, kneeling discomfort, and range of motion were not statistically significant. Our findings align with Steiner et al., 2024 [7], who reported no major differences in rehabilitation milestones timing. Similarly, Tareen et al., 2024 [8] found comparable functional outcomes between graft types, while DeFazio et al., 2020 [9] observed a slightly quicker return to sport in patients with hamstring grafts. Our data support these findings and highlight the importance of individualized graft selection based on patient needs and surgeon preference.

Previous studies have mixed findings regarding anterior knee and kneeling pain, with some suggesting greater pain after BPTB due to donor site morbidity, while others report no significant difference [10-12]. Range of motion outcomes generally show equivalence between graft types[21]. Early postoperative pain control, critical for successful rehabilitation, was excellent in both groups, consistent with previous reports [13].

Our results generally align with those of other researchers investigating ACL reconstruction using hamstring tendon (HT) and bone-patellar tendon-bone (BPTB) grafts. Similar to Steiner et al., 2024 [7] and Tareen et al. 2024 [8], we observed that both graft types yielded comparable early recovery in terms of pain and function. We also found that patients with HT grafts returned to work and sports slightly faster, consistent with the findings of DeFazio et al., 2020 [9]. Complication rates and range of motion were similar between the two groups, as previously reported by previous studies [14,15]. One minor discrepancy involved kneeling pain: while prior studies have suggested greater kneeling pain with BPTB grafts, our study showed a slight (though non-significant) trend toward increased kneeling pain in the HT group. This difference could be attributed to variations in patient demographics or pain assessment methods [16]. Overall, our findings support the conclusion that both graft types are viable options, and the choice between them can be individualized based on patient needs and surgeon expertise [16].

Conclusion

Both bone–patellar tendon-bone (BPTB) and hamstring autografts provide favorable early functional and clinical outcomes following ACL reconstruction, with high rates of full knee extension and flexion, minimal pain at rest, and similar complication profiles. Although only the faster return to sport/work in the hamstring group reached statistical significance, there is a noticeable trend favoring hamstring grafts for earlier functional recovery and slightly lower incidence of kneeling pain, possibly related to differences in graft harvest sites. These findings align with previous studies. However, longer-term follow-up studies with

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larger patient cohorts are essential to better evaluate the durability of outcomes, potential late complications, and overall graft performance.

Conflict of interest. Nil

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