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Comparison of Hamstring and Bone–Patellar Tendon–Bone Grafts in Arthroscopic ACL Reconstruction

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Abstract

Background: Hamstring tendon (HT) and bone–patellar tendon–bone (BPTB) autografts are commonly used for anterior cruciate ligament (ACL) reconstruction. This study compared their clinical and functional outcomes. ***Methods***: Eighty patients undergoing arthroscopic ACL reconstruction were divided into HT (n=40) and BPTB (n=40) groups. Functional scores, knee stability, donor-site morbidity, graft failure, and return to activity were assessed over 12 months. ***Results***: At 12 months, Lysholm scores were 91.2 ± 5.7 and 92.6 ± 5.1 (p=0.251), while IKDC scores were 88.4 ± 6.3 and 89.7 ± 5.8 (p=0.341) in the HT and BPTB groups, respectively. Anterior knee pain (10.0% vs 27.5%, p=0.045) and kneeling pain (7.5% vs 30.0%, p=0.010) were higher with BPTB, whereas hamstring weakness was higher with HT (15.0% vs 2.5%, p=0.048). Graft failure and return to pre-injury activity were comparable. ***Conclusion***: Both grafts provided comparable functional outcomes and knee stability. Differences were mainly related to donor-site morbidity, supporting individualized graft selection.

Keywords: Anterior cruciate ligament; ACL reconstruction; hamstring tendon; bone–patellar tendon–bone; autograft; knee stability; functional outcome.

INTRODUCTION

Anterior cruciate ligament (ACL) rupture is one of the most clinically significant ligamentous injuries of the knee, particularly among young and physically active individuals[1]. The ACL serves as a primary restraint to anterior tibial translation and contributes to rotational stability of the knee. Its rupture may lead to recurrent instability, impaired functional performance, reduced participation in sports, and secondary meniscal and articular cartilage injury, with the potential for subsequent degenerative changes [2]. Arthroscopic ACL reconstruction is therefore widely performed in patients with symptomatic ACL deficiency to restore knee stability, improve function, and facilitate return to activity [3].
Several graft options are available for ACL reconstruction, of which bone–patellar tendon–bone (BPTB) and hamstring tendon (HT) autografts are among the most extensively studied. Despite advances in arthroscopic techniques, anatomical tunnel placement, graft fixation, and rehabilitation protocols, selection of the optimal autograft remains controversial [3–5]. Both grafts provide satisfactory clinical outcomes but differ in their biological incorporation, fixation characteristics, donor-site morbidity, muscle strength recovery, and potential risk of graft failure [4–6].BPTB autografts offer the advantage of bone-to-bone healing within the femoral and tibial tunnels, permitting secure fixation and predictable graft incorporation. Several comparative studies have demonstrated favourable postoperative stability with BPTB grafts [4,7,8]. However, harvesting the central portion of the patellar tendon is associated with donor-site morbidity, particularly anterior knee pain, kneeling pain, loss of extension, and extensor mechanism-related problems [3,5,7]. Conversely, hamstring tendon autografts, commonly prepared from the semitendinosus with or without the gracilis tendon, preserve the extensor mechanism and are associated with lower rates of anterior knee and kneeling pain. Nevertheless, concerns remain regarding tendon-to-bone incorporation, postoperative flexion weakness, graft diameter, residual laxity, and graft failure [5,6,9].The relative risk of graft failure is particularly important when choosing between these grafts. Large-scale evidence has suggested a modest advantage for BPTB in this respect. Samuelsen et al., in a meta-analysis involving 47,613 ACL reconstructions, reported a small but statistically significant difference in graft failure favouring BPTB, although

postoperative laxity was generally comparable between graft types [9]. Similarly, Scandinavian registry data involving 45,998 primary ACL reconstructions demonstrated a lower risk of revision with patellar tendon autografts than with hamstring autografts [10].However, differences between the grafts are less pronounced for many patient-reported and functional outcomes. Zhao et al., in a meta-analysis of 15 randomized controlled trials involving 1,298 patients with at least five years of follow-up, found no significant differences in objective IKDC score, Lysholm score, Tegner activity level, return to pre-injury activity, Lachman test, pivot-shift test, or osteoarthritic changes. Hamstring grafts were associated with less anterior knee and kneeling pain, whereas graft failure was less frequent with BPTB [11]. Long-term randomized studies have similarly demonstrated satisfactory clinical outcomes with both grafts [12,13]. Recent pooled evidence from randomized trials with long-term follow-up also suggests broadly comparable outcomes between BPTB and HT grafts for graft rupture, revision, functional scores, knee laxity, and osteoarthritis [14].

Thus, graft selection involves balancing graft stability and survival against donor-site morbidity and functional recovery. Patient age, activity level, sporting and occupational demands, kneeling requirements, surgical technique, rehabilitation protocol, and individual preference may influence graft choice. Despite extensive comparative research, no single graft has demonstrated advantages across all clinically relevant outcomes [3,5,11,14]. Therefore, the present study was designed to compare hamstring tendon and bone–patellar tendon–bone grafts in arthroscopic ACL reconstruction with respect to clinical and functional outcomes, postoperative knee stability, graft-related complications, and donor-site morbidity.

MATERIALS AND METHODS

This prospective comparative study was conducted in the Department of Orthopaedics at tertiary care centre. The study included patients with symptomatic anterior cruciate ligament (ACL) injury who underwent primary arthroscopic ACL reconstruction using either a hamstring tendon (HT) autograft or a bone–patellar tendon–bone (BPTB) autograft.

Study Population and Sample Size

A total of 80 patients fulfilling the eligibility criteria were enrolled. Patients were divided into two groups of 40 each:
Group HT (n=40): Arthroscopic ACL reconstruction using hamstring tendon autograft.
Group BPTB (n=40): Arthroscopic ACL reconstruction using bone–patellar tendon–bone autograft.

Inclusion Criteria

Patients aged 18–45 years with clinically and radiologically confirmed ACL tear, symptomatic knee instability, and who were planned for primary arthroscopic ACL reconstruction were included. Patients who were willing to participate in the study and comply with the prescribed postoperative rehabilitation and follow-up schedule were considered eligible.

Exclusion Criteria

Patients undergoing revision ACL reconstruction; those with multi-ligament knee injuries requiring additional ligament reconstruction, previous major surgery on the affected knee, advanced osteoarthritis, active local or systemic infection, significant associated fracture around the knee, or medical conditions interfering with postoperative rehabilitation were excluded.

Preoperative Assessment

A detailed history regarding the mechanism and duration of injury, instability episodes, pain, activity level, and previous treatment was obtained. All patients underwent clinical examination of both knees. ACL insufficiency was assessed using the Lachman test, anterior drawer test, and pivot-shift test.
Preoperative functional status was documented using validated knee outcome measures, including the International Knee Documentation Committee (IKDC) score, Lysholm Knee Score, and Tegner Activity Scale. Standard radiographs and magnetic resonance imaging (MRI) of the affected knee were evaluated to confirm ACL injury and identify associated meniscal or chondral lesions.

Surgical Technique

All procedures were performed arthroscopically under spinal or general anaesthesia using a standardized surgical technique. Diagnostic arthroscopy was initially performed to confirm ACL rupture and assess associated intra-articular pathology. Meniscal or chondral lesions, when present, were managed as clinically indicated.
In the HT group, the semitendinosus tendon, with or without the gracilis tendon depending on the required graft diameter, was harvested and prepared as a multi-strand graft. Appropriate femoral and tibial tunnels were created at the anatomical ACL footprints, followed by graft passage and fixation using the routinely employed fixation system.
In the BPTB group, the central third of the patellar tendon was harvested along with bone plugs from the patella and tibial tuberosity. After preparation of appropriately sized bone blocks, anatomical femoral and tibial tunnels were created, and the graft was passed and securely fixed. Graft tension and knee stability were assessed intraoperatively before wound closure.

Postoperative Rehabilitation

Both groups followed a standardized rehabilitation protocol. Early rehabilitation emphasized pain and swelling control, restoration of full knee extension, progressive improvement in flexion, quadriceps activation, and protected weight-bearing as appropriate. Progressive muscle strengthening, proprioceptive exercises, and functional training were subsequently introduced.

Return to running, sports-specific training, and sporting activities was permitted gradually according to clinical stability, muscle strength, functional recovery, and the rehabilitation protocol.

Follow-up and Outcome Assessment

Patients were evaluated preoperatively and postoperatively at 6 weeks, 3 months, 6 months, and 12 months. At each relevant follow-up, knee range of motion, anterior and rotational stability, pain, functional recovery, and complications were assessed.

The primary outcome measures included postoperative functional outcomes assessed using the IKDC and Lysholm scores and knee stability assessed using the Lachman and pivot-shift tests. Secondary outcomes included Tegner activity level, range of motion, anterior knee pain, kneeling pain, donor-site morbidity, graft failure/re-rupture, postoperative complications, and return to pre-injury activity or sports.

Particular attention was given to graft-specific morbidity. In the BPTB group, anterior knee pain, kneeling pain, patellar tendon-related symptoms, and extensor mechanism complications were recorded. In the HT group, hamstring-related symptoms and clinically evident flexion weakness were assessed.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using SPSS version 21. Continuous variables were expressed as mean ± standard deviation for normally distributed data or median with interquartile range for non-normally distributed data. Categorical variables were presented as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test. Continuous variables between the two groups were compared using the independent-samples t-test or Mann–Whitney U test, as appropriate. Within-group changes over time were analysed using the paired t-test, Wilcoxon signed-rank test, or repeated-measures analysis, as appropriate. Categorical variables were compared using the Chi-square test or Fisher's exact test. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

A total of 80 patients were included, with 40 each in the hamstring tendon (HT) and bone–patellar tendon–bone (BPTB) groups.

The groups were comparable at baseline with no significant differences in age, sex, BMI, side of involvement, duration of injury, sports-related injury, or preoperative functional scores (all p>0.05). Mean preoperative Lysholm scores were 55.8 ± 8.6 and 56.4 ± 8.2, while IKDC scores were 50.6 ± 7.8 and 51.2 ± 8.1 in the HT and BPTB groups, respectively (Table 1).

Both groups showed significant improvement in Lysholm and IKDC scores over 12 months (within-group p<0.001). At 12 months, Lysholm scores were 91.2 ± 5.7 versus 92.6 ± 5.1 (p=0.251), and IKDC scores were 88.4 ± 6.3 versus 89.7 ± 5.8 (p=0.341) in the HT and BPTB groups, respectively, with no significant between-group differences at any follow-up (Table 2).

At 12 months, negative Lachman (85.0% vs 92.5%), pivot-shift (90.0% vs 95.0%), and anterior drawer tests (87.5% vs 92.5%) were comparable between HT and BPTB groups (all p>0.05). Full range of motion was achieved in 95.0% and 92.5%, respectively (Table 3).

Anterior knee pain (10.0% vs 27.5%; p=0.045) and kneeling pain (7.5% vs 30.0%; p=0.010) were significantly more frequent in the BPTB group. Conversely, hamstring weakness was significantly more common in the HT group (15.0% vs 2.5%; p=0.048). Other donor-site complications were comparable (Table 4; Figure 1).

Graft failure occurred in 5.0% of HT and 2.5% of BPTB patients (p=0.556). Return to sports/activity (85.0% vs 87.5%; p=0.745), return to pre-injury activity level (77.5% vs 82.5%; p=0.576), and time to return to activity (8.3 ± 1.7 vs 8.1 ± 1.6 months; p=0.588) were comparable between groups (Table 5; Figure 2).

The 12-month IKDC score correlated negatively with age (r=−0.29; p=0.009), BMI (r=−0.23; p=0.041), injury-to-surgery duration (ρ=−0.27; p=0.016), and time to return to activity (r=−0.35; p=0.002). Positive correlations were observed with preoperative IKDC (r=0.44), preoperative Lysholm (r=0.38), 12-month Lysholm (r=0.72), and 12-month Tegner scores (ρ=0.48), with all $p<0.001$ (Table 6; Figure 3).

Table 1. Baseline demographic and clinical characteristics of the study groups

Parameter	Hamstring tendon (n=40)	BPTB (n=40)	p-value	Statistical test
Age (years), mean ± SD	27.6 ± 6.1	28.2 ± 6.4	0.669	Independent t-test
Male, n (%)	33 (82.5)	34 (85.0)	0.762	Chi-square test
Female, n (%)	7 (17.5)	6 (15.0)		
BMI (kg/m²), mean ± SD	24.3 ± 2.7	24.7 ± 2.9	0.526	Independent t-test
Right knee, n (%)	22 (55.0)	23 (57.5)	0.822	Chi-square test
Left knee, n (%)	18 (45.0)	17 (42.5)		
Duration of injury (months), mean ± SD	7.4 ± 3.2	7.1 ± 3.0	0.667	Independent t-test
Sports-related injury, n (%)	25 (62.5)	27 (67.5)	0.639	Chi-square test
Preoperative Lysholm score	55.8 ± 8.6	56.4 ± 8.2	0.750	Independent t-test
Preoperative IKDC score	50.6 ± 7.8	51.2 ± 8.1	0.737	Independent t-test

Table 2. Comparison of Lysholm and IKDC scores during follow-up

Follow-up	HT (n=40)	BPTB (n=40)	p-value	Statistical test
Lysholm score				
Preoperative	55.8 ± 8.6	56.4 ± 8.2	0.750	Independent t-test
3 months	73.5 ± 7.4	74.2 ± 7.1	0.668	
6 months	84.7 ± 6.3	86.1 ± 5.9	0.308	
12 months	91.2 ± 5.7	92.6 ± 5.1	0.251	
Within-group p-value	<0.001	<0.001	—	Repeated-measures ANOVA
IKDC score				
Preoperative	50.6 ± 7.8	51.2 ± 8.1	0.737	Independent t-test
3 months	69.8 ± 7.2	70.6 ± 6.9	0.614	
6 months	80.9 ± 6.7	82.3 ± 6.2	0.335	
12 months	88.4 ± 6.3	89.7 ± 5.8	0.341	
Within-group p-value	<0.001	<0.001	—	Repeated-measures ANOVA

Table 3. Comparison of postoperative knee stability at 12 months

Stability assessment	HT (n=40)	BPTB (n=40)	p-value	Statistical test
Lachman negative, n (%)	34 (85.0)	37 (92.5)	0.288	Fisher's exact test
Lachman Grade I, n (%)	5 (12.5)	3 (7.5)		
Lachman Grade II, n (%)	1 (2.5)	0		
Pivot-shift negative, n (%)	36 (90.0)	38 (95.0)	0.396	
Pivot-shift Grade I, n (%)	4 (10.0)	2 (5.0)		
Anterior drawer negative, n (%)	35 (87.5)	37 (92.5)	0.456	
Full ROM achieved, n (%)	38 (95.0)	37 (92.5)	0.644	

Table 4. Comparison of donor-site morbidity and graft-specific complications

Outcome	HT (n=40)	BPTB (n=40)	p-value	Statistical test
Anterior knee pain	4 (10.0%)	11 (27.5%)	0.045	Chi-square test
Kneeling pain	3 (7.5%)	12 (30.0%)	0.010	Chi-square test
Hamstring weakness	6 (15.0%)	1 (2.5%)	0.048	Fisher's exact test
Extension deficit	1 (2.5%)	3 (7.5%)	0.305	
Flexion deficit	2 (5.0%)	1 (2.5%)	0.556	
Donor-site numbness	2 (5.0%)	4 (10.0%)	0.396	

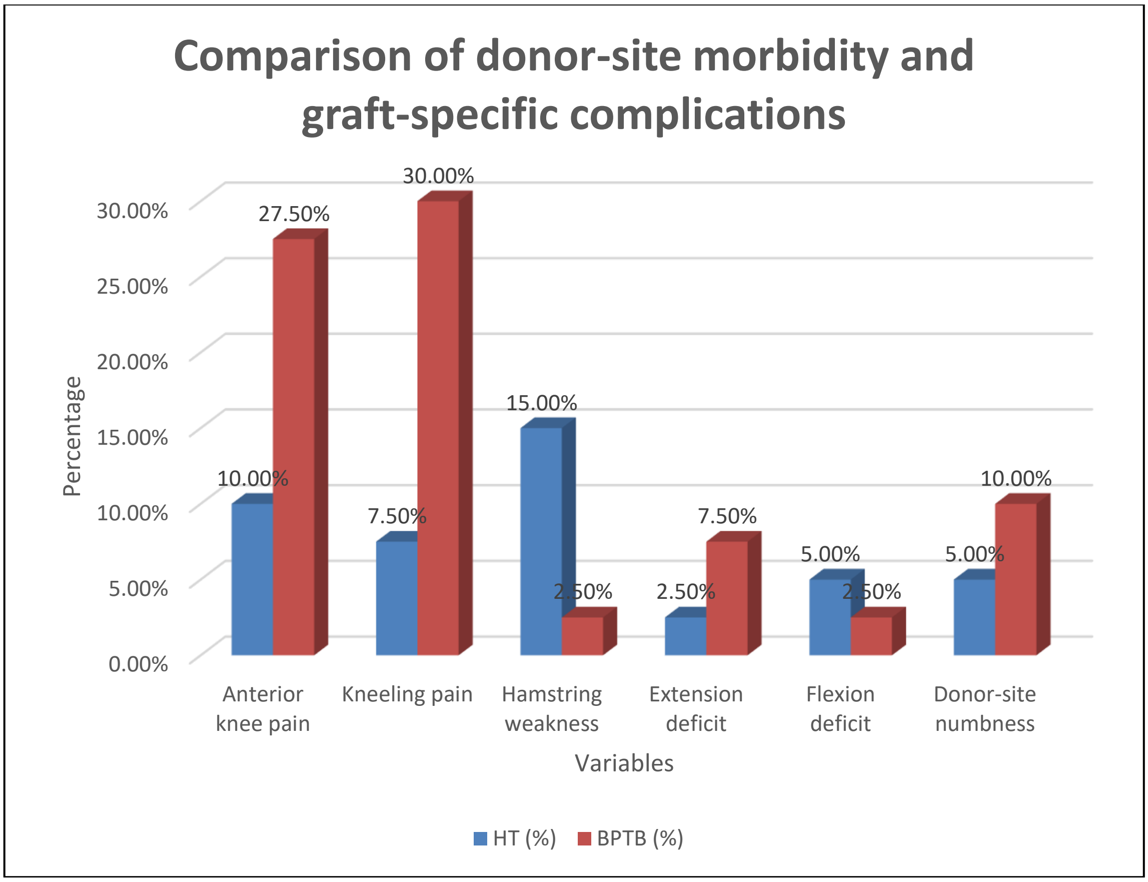

Figure 1. Comparison of donor-site morbidity and graft-specific complications

Table 5. Comparison of graft failure, complications and return to activity

Outcome	HT (n=40)	BPTB (n=40)	p-value	Statistical test
Graft failure/re-rupture	2 (5.0%)	1 (2.5%)	0.556	Fisher's exact test
Superficial infection	1 (2.5%)	1 (2.5%)	1.000	
Knee stiffness	2 (5.0%)	2 (5.0%)	1.000	
Reoperation	1 (2.5%)	1 (2.5%)	1.000	
Returned to sports/activity	34 (85.0%)	35 (87.5%)	0.745	Chi-square test
Returned to pre-injury activity level	31 (77.5%)	33 (82.5%)	0.576	Chi-square test
Time to return to activity (months)	8.3 ± 1.7	8.1 ± 1.6	0.588	Independent t-test

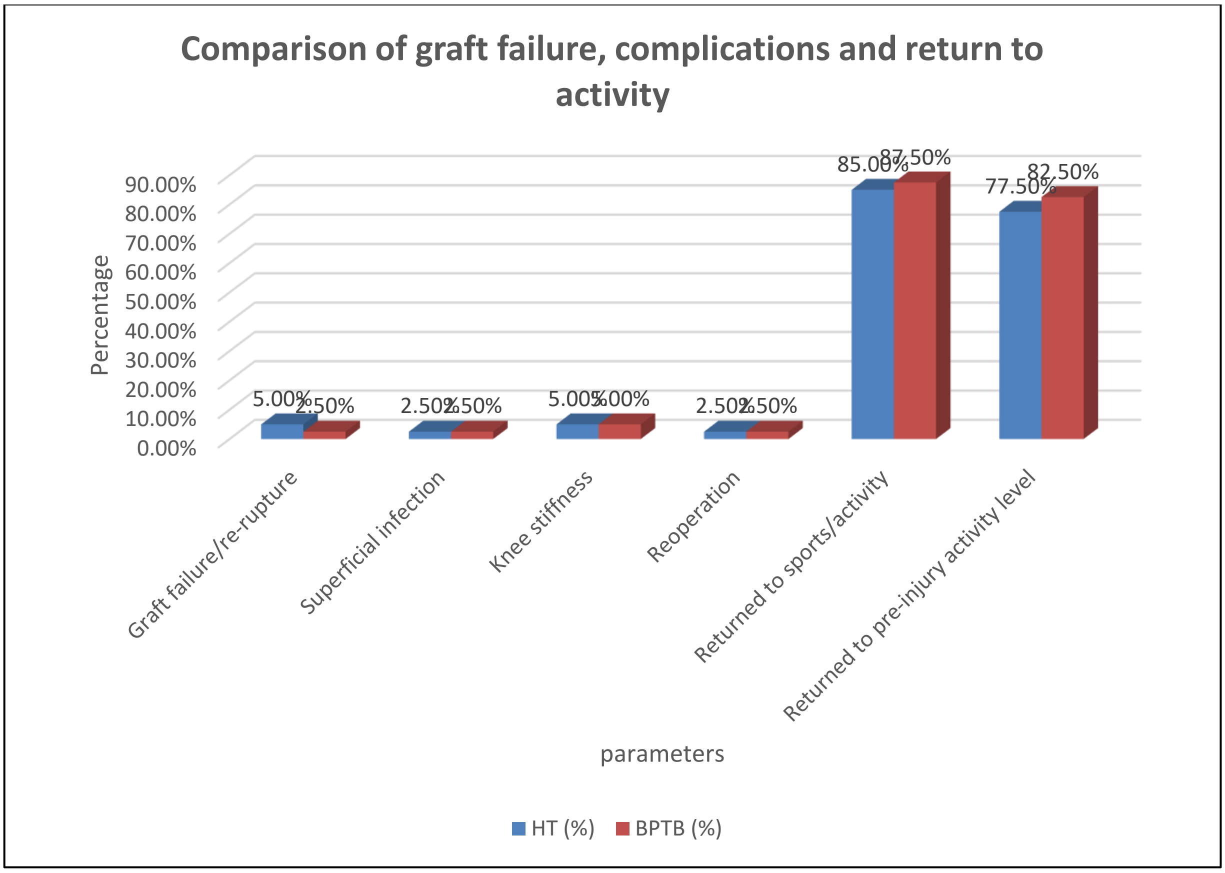

Figure 2. Comparison of graft failure, complications and return to activity

Table 6. Correlation of clinical variables with 12-month functional outcome

Variable	Correlation with 12-month IKDC (r/ρ)	p-value	Statistical test
Age	−0.29	0.009	Pearson correlation
BMI	−0.23	0.041	Pearson correlation
Duration from injury to surgery	−0.27	0.016	Spearman correlation
Preoperative IKDC score	0.44	<0.001	Pearson correlation
Preoperative Lysholm score	0.38	<0.001	Pearson correlation
12-month Lysholm score	0.72	<0.001	Pearson correlation
12-month Tegner score	0.48	<0.001	Spearman correlation
Time to return to activity	−0.35	0.002	Pearson correlation

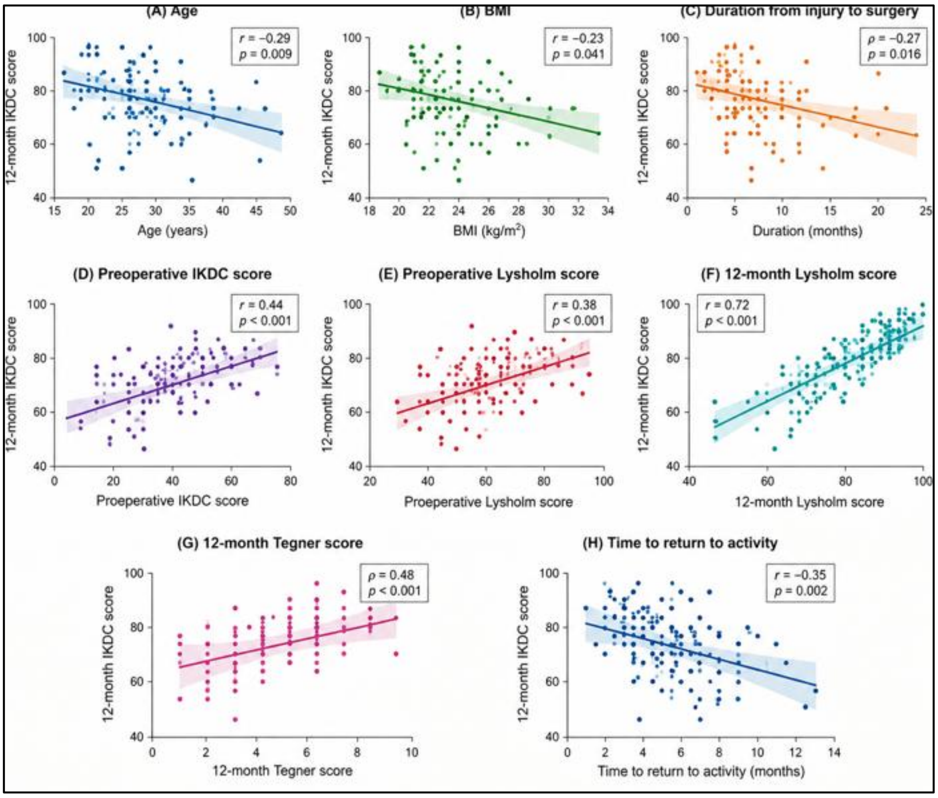

Figure 3. Correlation of clinical variables with 12-month functional outcome

DISCUSSION

Both grafts resulted in substantial functional improvement. At 12 months, the mean Lysholm score was 91.2 ± 5.7 in the HT group and 92.6 ± 5.1 in the BPTB group (p=0.251), while IKDC scores were 88.4 ± 6.3 and 89.7 ± 5.8, respectively (p=0.341). Harilainen et al. [15] similarly reported no significant differences between BPTB and HT grafts at 5 years in IKDC, Lysholm, Tegner, or Kujala scores. Heijne et al. [16], in 68 patients (34 BPTB and 34 HT), also observed no significant difference in knee function or quality of life at 5 years, with significant improvement in KOOS Sport/Recreation and quality-of-life domains in both groups (p<0.001).

In our study, a negative Lachman test at 12 months was observed in 85.0% of HT and 92.5% of BPTB patients (p=0.288), while the pivot-shift test was negative in 90.0% and 95.0%, respectively (p=0.396). Harilainen et al. [15] also found no significant differences in clinical or instrumented knee laxity between HT and BPTB at 5 years. Heijne et al. [16] similarly reported comparable anterior and rotational stability between graft groups. Harilainen and Sandelin [17] compared different hamstring graft fixation techniques in 120 patients and found no significant differences among fixation groups at 2 years, with almost all evaluated patients achieving IKDC grade A or B.

Anterior knee pain was significantly more frequent with BPTB than HT in our study (27.5% vs 10.0%, p=0.045), as was kneeling pain (30.0% vs 7.5%, p=0.010). Conversely, hamstring weakness was more frequent with HT (15.0% vs 2.5%, p=0.048). Heijne et al. [16] reported lower hamstring torque after HT reconstruction at 2 years (0.89 vs 1.05 with BPTB), although this difference was no longer evident at 5 years. These findings indicate different patterns of donor-site morbidity between the two grafts.

Graft failure/re-rupture occurred in 5.0% of HT and 2.5% of BPTB patients in our study (p=0.556). Return to pre-injury activity was achieved by 77.5% and 82.5%, respectively (p=0.576). Heijne et al. [16] reported new ACL injuries in 9/68 (13%) patients during 5 years, including seven graft re-ruptures and four contralateral ACL ruptures. Harilainen and Sandelin [17] also reported graft failures during follow-up, including two high-energy traumatic re-ruptures. These observations suggest that graft failure is influenced by several factors beyond graft selection alone.

In our study, the 12-month IKDC score correlated negatively with age (r=−0.29, p=0.009), BMI (r=−0.23, p=0.041), duration from injury to surgery (ρ=−0.27, p=0.016), and time to return to activity (r=−0.35, p=0.002). Positive correlations were observed with preoperative IKDC (r=0.44, p<0.001), preoperative Lysholm (r=0.38, p<0.001), 12-month Lysholm (r=0.72, p<0.001), and Tegner scores (ρ=0.48, p<0.001), indicating that final functional outcome was related to multiple patient and clinical factors.

Harris et al. [18] developed a 19-item methodological quality score for knee articular cartilage studies and demonstrated good interobserver (ICC=0.842) and strong intraobserver reliability. Although it did not directly compare ACL grafts, the study emphasizes standardized methodology and reliable outcome assessment in knee research. Higgins et al. [19] introduced the I^2 statistic for quantifying heterogeneity across studies in meta-analysis; therefore, its relevance to the present study is methodological rather than as a direct clinical comparator.

CONCLUSION

Both hamstring tendon and BPTB autografts provided significant functional improvement and satisfactory knee stability following arthroscopic ACL reconstruction. Functional scores, graft failure, and return to activity were comparable; however, BPTB was associated with greater anterior knee and kneeling pain, whereas HT was associated with greater hamstring weakness. Thus, graft selection should consider the expected donor-site morbidity and individual functional requirements.

Limitations

The study was limited by its relatively small sample size of 80 patients and a follow-up period of 12 months. The limited number of graft failures and complications also restricted definitive assessment of differences in long-term graft survival.

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