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Research Article

EFFICACY AND SAFETY OF PERONEUS LONGUS TENDON AUTOGRAFT IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A PROSPECTIVE COMPARATIVE STUDY WITH HAMSTRING TENDON AUTOGRAFT IN PATIENTS WITH CONCOMITANT GRADE III MEDIAL COLLATERAL LIGAMENT INJURY

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Abstract: ***Introduction:*** Anterior cruciate ligament (ACL) rupture associated with grade III medial collateral ligament (MCL) injury presents a surgical challenge, as medial hamstring harvest may increase the risk of wound complications, saphenous nerve injury, and further compromise of medial knee stability. The ipsilateral peroneus longus tendon (PLT) has emerged as a potential alternative autograft; however, prospective comparative evidence in this specific injury pattern remains limited. **Methods:** This prospective randomized comparative study conducted in the department of Orthopaedics at Sree Mookambika Institute of Medical Sciences between February 2024 and May 2025, included 38 skeletally mature patients with acute ACL rupture and concomitant grade III MCL injury. Patients underwent arthroscopic single-bundle ACL reconstruction using either doubled ipsilateral PLT autograft (Group A, n = 18) or quadrupled hamstring tendon (HT) autograft (Group B, n = 20), along with simultaneous MCL repair. In vitro biomechanical testing of PLT, HT, and native ACL specimens was performed using 16 amputated limb specimens. Postoperative knee stability was assessed using Lachman testing and KT-2000 arthrometry, while functional outcomes were evaluated using Tegner-Lysholm and IKDC scores at 3, 6, and 12 months. Donor ankle biomechanics were analysed using the Bose 3200 tensile machine and Biodex System 4 dynamometer. **Results:** The doubled PLT demonstrated ultimate tensile strength comparable to the quadrupled HT (4252 ± 291 N vs 4078 ± 272 N), and both exceeded that of the native ACL (2012 ± 258 N; $p < 0.05$). No significant between-group differences were observed in Lachman grade, KT-2000 measurements, Tegner score, Lysholm score, or IKDC score during follow-up. Donor ankle dorsiflexion, plantar flexion, and inversion-eversion torque did not show significant postoperative changes.**Conclusion:** Doubled ipsilateral PLT autograft provided knee stability and functional outcomes comparable to quadrupled HT autograft without clinically significant donor ankle morbidity. The PLT may therefore be considered a safe and reliable graft option in ACL reconstruction for patients with combined ACL-MCL injuries.

Keywords: Anterior cruciate ligament reconstruction; peroneus longus tendon autograft; hamstring tendon; medial collateral ligament; knee stability; donor ankle morbidity.

INTRODUCTION

Anterior cruciate ligament (ACL) rupture is one of the most common and compromising musculoskeletal injuries in both recreational and competitive sports populations. Systematic reviews have reported high incidence rates in ball sports, with non-contact mechanisms responsible for over half of all injuries, and female athletes consistently at greater risk than males [1]. The injury carries a considerable burden, including lengthy rehabilitation, high healthcare costs, and an increased risk of post-traumatic knee osteoarthritis. Arthroscopic ACL reconstruction is the accepted treatment for restoring knee stability and returning patients to activity. Autograft is generally preferred over allograft for primary procedures due to better biological incorporation and no risk of disease transmission [2].

Choosing the right autograft requires careful consideration of each patient's anatomy and circumstances. For isolated ACL injuries, both bone-patellar tendon-bone (BPTB) and quadrupled hamstring tendon (HT) grafts yield good results, though each has its own donor-site drawbacks. BPTB harvest is associated with anterior knee pain, kneeling discomfort, and occasional patellar fractures, though it may offer lower re-rupture rates in high-risk patients [3,4]. HT harvest risks saphenous nerve injury and may yield an undersized graft, particularly in women and smaller patients, which is an important determinant of surgical success [5]. Hamstring tendon dimensions vary widely between patients, and a graft diameter below 8 mm is a recognised risk factor for reconstruction failure [6].

The situation becomes considerably more complex when ACL rupture is accompanied by a grade III MCL injury, a combination seen in 20–38% of ACL tears and the most common pattern of multi-ligament knee injury [7,8]. These combined injuries result from higher-energy mechanisms, cause extensive medial soft tissue damage, and lead to greater functional impairment than isolated ACL tears. In this setting, harvesting the medial hamstrings is problematic because the pes anserine insertion lies within the zone of injury, raising the risk of wound breakdown, haematoma, and infection. There is also concern that removing dynamic medial stabilisers when the MCL is already completely disrupted may worsen instability, though this has not been conclusively demonstrated. The AAOS clinical practice guideline and systematic review by Rao et al. found no single graft or treatment strategy to be consistently superior in combined ACL-MCL injuries, emphasising the need for individualised surgical planning [7,9].

The peroneus longus tendon (PLT) has gained increasing attention as an alternative autograft for ACL reconstruction. Its lateral position at the ankle keeps it well away from the medial injury zone, making it particularly appealing in combined ACL-MCL cases. He et al. pooled data from 925 patients and found PLT and HT autografts produced similar Tegner, Lysholm, and IKDC scores, with a marginal advantage for PLT on functional measures [8,10,11]. Soleymanha et al. reviewed 1024 patients and reported postoperative AOFAS scores consistently above 96, confirming that PLT harvest has little impact on ankle function [9,12,13]. Studies of both anterior-half and full-thickness PLT harvest have shown sufficient graft diameter and length for single-bundle reconstruction, with negligible functional changes at the donor ankle [14,15]. The PLT has also shown good results in non-athletic patients [16,17] and has been used as a split-tendon graft for concurrent MCL augmentation alongside ACL reconstruction in combined injuries [18,19].

Despite this evidence, few prospective studies have directly compared doubled PLT with quadrupled HT specifically in patients with combined ACL and grade III MCL injury. Accordingly, the present study aimed to address this gap by:(1) establishing the in vitro biomechanical properties of the doubled PLT relative to the native ACL and quadrupled HT; and (2) comparing knee stability, functional outcomes, and donor ankle biomechanics between the two graft groups over 12 months.

MATERIALS AND METHODS

Study site and duration

This prospective randomized comparative study was conducted in the Department of Orthopaedics at Sree Mookambika Institute of Medical Sciences between February 2024 and May 2025. Institutional Ethics Committee approval was obtained prior to commencement of the study. All patients completed a minimum follow-up duration of 12 months.

In Vitro Specimen Preparation and Biomechanical Testing

Fresh PLT, HT, and native ACL specimens were harvested from the lower limbs of 16 patients (11 males, 5 females; age range 35–65 years) who underwent transfemoral amputation above the lower third of the thigh at our institution between February 2024 and May 2025. Indications for amputation were trauma or malignant pelvic or femoral neoplasm. Specimens with macroscopic evidence of tendon injury were excluded. Institutional Ethics Committee approval was secured, and written informed consent was obtained from all participants before specimen collection. The doubled PLT was prepared by bisecting the harvested tendon at its midpoint and folding it to create a two-strand construct. The quadrupled HT was prepared by harvesting gracilis and semitendinosus tendons via a standard medial approach with a tendon stripper, combining them, and folding to achieve a four-strand construct. Both constructs were preloaded at 10 pounds for 10 minutes and mounted in a Bose 3200 tensile testing machine. Ultimate tensile strength (N) and maximum deformation length (mm) were recorded.

Patient Population and Randomization

A consecutive series of 38 patients presenting between February 2024 and May 2025 with acute ACL rupture and concomitant grade III MCL injury were enrolled. Diagnosis was based on clinical examination, MRI, and arthroscopic confirmation. All patients were skeletally mature. Random number allocation divided patients into Group A (doubled PLT autograft, n = 18; mean age 42 years, range 19–58 years) and Group B (quadrupled HT autograft, n = 20; mean age 40 years, range 21–54 years). Male-to-female ratios, preoperative Tegner scores, activity levels, and comorbidities were comparable between groups.

Surgical Technique

All procedures were performed by a single surgeon. Arthroscopic single-bundle ACL reconstruction using Endobutton fixation was performed in both groups. An anteromedial portal technique was used for femoral tunnel drilling in all cases. Meniscal and chondral pathology was addressed at the time of index reconstruction. MCL repair using TWINFIX suture anchors was performed from the distal insertion in all patients; the posterior oblique ligament and proximal MCL were uninvolved in all cases.

For PLT harvest, meticulous distinction from the peroneus brevis tendon was ensured intraoperatively. The PLT was fully transected 1.0–1.5 cm proximal to its distal insertion and harvested proximally with a tendon stripper. The remaining PLT stump and the peroneus brevis were sutured together to partially preserve eversion function. The graft was doubled and prepared for routine ACL tunnel passage and fixation.

Postoperatively, patients were placed in articulating knee braces. Active knee extension and quadriceps contraction exercises with ankle plantar- and dorsiflexion exercises commenced on day 2. Knee flexion was progressed to 30° at day 8, 90° at 4 weeks, and 120° at 6 weeks. Crutches were weaned at 6 weeks; full physical activity was targeted at 12 months.

Outcome Measures

Knee stability was assessed at 3, 6, and 12 months using the Lachman test (grade 0: <3 mm, grade I: 3–5 mm, grade II-III: >5 mm) and the KT-2000 arthrometer at a standardized 134 N anterior force at 12 months. MCL integrity was confirmed at each visit via valgus stress testing at 0° and 30°. Subjective functional outcomes were measured using the Tegner-Lysholm Knee Scoring Scale and the IKDC Subjective Knee Form. Donor ankle dorsiflexion and plantar flexion force (N) were recorded using the Bose 3200 at preoperative, 6-month, and 12-month assessments. Eccentric and concentric inversion and eversion torque (Nm) were measured by the Biodex System 4 robotic dynamometer at 30 and 180 deg/s, preoperatively and at 12 months, with comparison against the contralateral non-donor limb.

Statistical Analysis

Statistical analysis was performed using SPSS version 27.0. Continuous group comparisons employed one-way ANOVA. The chi-square test was applied to Lachman test distributions and categorical functional index data. A p-value < 0.05 was set as the threshold for statistical significance.

RESULTS

In Vitro Biomechanical Properties

Tensile testing results are summarized in Table 1. The ultimate tensile strength of the doubled PLT (4252 ± 291 N) was statistically equivalent to that of the quadrupled HT (4078 ± 272 N). Both constructs significantly exceeded the load-to-failure of the native ACL (2012 ± 258 N; p < 0.05 for each comparison). Maximum deformation values were also comparable across groups. The present findings support previous biomechanical studies showing adequate tensile strength of PLT grafts.

Table 1. Mechanical Test Results of Tendons and Ligaments

Structure	Ultimate Tensile Strength (N)	Max Deformation (mm)
Anterior cruciate ligament	2012 ± 258	15.06 ± 4.12
Posterior cruciate ligament	2175 ± 446	15.24 ± 3.38
Hamstring tendon (quadrupled)	4078 ± 272	12.18 ± 2.64
Peroneus longus tendon (doubled)	4252 ± 291	13.42 ± 2.28

Values expressed as mean ± SD. *p < 0.05 versus native ACL. PLT: peroneus longus tendon; HT: hamstring tendon.

Knee Stability Outcomes

Lachman test findings across the three postoperative time points are shown in Table 2. No statistically significant between-group differences were detected at 3 months (p = 0.821), 6 months (p = 0.869), or 12 months (p = 0.878). No patient in Group A reached a grade II-III Lachman result at any follow-up. In contrast, Group B contained two patients with grade II-III findings at both 6 and 12 months, including one individual who demonstrated gross anterior laxity at 3 months; MRI confirmed graft resorption in the absence of a reported re-injury or premature strenuous activity. This finding aligns with the evidence that smaller or less consistent graft diameters may increase biological failure risk in HT reconstructions. No comparable complication was observed in Group A.

Table 2. Knee Lachman Tests at 3, 6, and 12 Months After Surgery

Indicators	**3 Months After Surgery**			**6 Months After Surgery**			**12 Months After Surgery**		
	0	**I**	**II–III**	**0**	**I**	**II–III**	**0**	**I**	**II–III**
Group A (cases)	15	3	0	14	4	0	13	5	0
Group B (cases)	16	4	0	16	2	2	15	3	2
p-Values	0.821			0.869			0.878		

Grade 0: <3 mm; Grade I: 3–5 mm; Grade II–III: >5 mm anterior tibial translation. $p < 0.05$ is considered statistically significant.

KT-2000 arthrometer measurements at 12 months (Table 3) corroborated clinical Lachman findings. Anterior translation within the 0–2 mm range was recorded in 77.78% of Group A patients versus 75.00% in Group B, with no significant intergroup difference ($p = 0.804$). MCL repair integrity was confirmed at all follow-up visits in both groups, with no pathological valgus laxity observed on stress testing, consistent with published outcomes of simultaneous ACL reconstruction and MCL repair.

Table 3. KT-2000 Arthrometer Measurements 12 Months Postoperatively

Anterior Translation	**Group A**	**Group B**	**p-Value**
0–2 mm	14 (77.78%)	15 (75.00%)	0.804
3–5 mm	4 (22.22%)	4 (20.00%)	
> 6 mm	0 (0%)	1 (5.00%)	

$p < 0.05$ considered statistically significant.

Subjective Functional Outcomes

Tegner activity scores, Lysholm knee scores, and IKDC subjective scores at 3, 6, and 12 months are detailed in Table 4. No statistically significant differences were found between Group A and Group B at any assessment point (all $p > 0.05$). Functional outcomes remained satisfactory and comparable between both groups throughout the follow-up period. Similar findings have been reported in previous studies. He et al., in a meta-analysis, observed no significant differences in Tegner activity scores or Lachman grades between PLT and HT autografts, while Rhatomy et al. demonstrated excellent IKDC, Modified Cincinnati, and Tegner-Lysholm outcomes at 2-year follow-up following ACL reconstruction using PLT autograft.

Table 4. Subjective Index Appraisal at 3, 6, and 12 Months After Surgery

Indicators	**3 Months After Surgery**			**6 Months After Surgery**			**12 Months After Surgery**		
	Tegner	**Lysholm**	**IKDC**	**Tegner**	**Lysholm**	**IKDC**	**Tegner**	**Lysholm**	**IKDC**
Group A	6±0.52	93±5.88	89.12±3.02	5±0.91	94±6.24	90.22±2.48	5±0.82	93±6.42	89.88±3.14
Group B	6±0.61	95±2.48	90.36±4.41	6±0.08	95±3.48	90.05±4.18	6±0.16	92±5.36	89.46±3.72
p-Values	0.4268	0.3372	0.2415	0.4324	0.3318	0.2742	0.4217	0.4335	0.4381

IKDC: International Knee Documentation Committee. $p < 0.05$ considered statistically significant.

Donor Ankle Biomechanical Outcomes

Table 5 presents ankle dorsiflexion and plantar flexion force values for Group A patients preoperatively and at 6 and 12 months postoperatively. No statistically significant differences were detected between preoperative and postoperative measurements for either motion at either time point (ADF $p = 0.832$ and 0.836; APF $p = 0.861$ and 0.858). Similar results were reported by Hsu et al., who observed no clinically significant changes in ankle range of motion or patient-reported functional outcomes at 1-year follow-up after PLT harvest.

Table 5. Ankle Biomechanical Testing of Group A (Doubled PLT) at Preoperative, 6- and 12-Month Follow-up (N)

	Preoperative	6 Months After Surgery	p-Value	Preoperative	12 Months After Surgery	p-Value
ADF	81.04±0.24	80.16±0.52	0.832	81.04±0.24	81.58±0.44	0.836
APF	148.12±0.34	147.84±0.28	0.861	148.12±0.34	150.36±0.31	0.858

ADF: ankle dorsiflexion; APF: ankle plantar flexion. Values expressed as mean ± SD.

Dynamometric torque assessments are summarized in Tables 6 through 9. Concentric inversion and eversion torque at both 30 and 180 deg/s showed no statistically significant differences between donor and contralateral ankles at 12 months (Table 6) or between preoperative and postoperative donor ankle values (Table 7). Eccentric torque comparisons were similarly non-significant for all conditions (Tables 8 and 9). Percentage torque losses ranged from 6.18% to 9.62% across all assessments, consistent with the minimal functional deficits reported by Angthong et al. following isokinetic testing after PLT harvest, and with the long-term follow-up study by Soleymanha et al. demonstrating structural foot integrity at 12-to-23-year intervals.

Table 6. Concentric Torque: Donor Ankle vs. Contralateral Ankle at 12 Months (Biodex System 4)

	Healthy Side (Nm)	Donor Side (Nm)	% Loss	p-Value
30 deg/s (CON)				
Inversion	36.42±21.88	34.05±13.26	6.18±4.58	0.431
Eversion	17.16±12.54	16.04±14.62	7.42±10.18	0.372
180 deg/s (CON)				
Inversion	22.18±16.08	21.12±15.54	6.74±7.12	0.494
Eversion	11.46±8.96	10.14±8.36	7.94±7.92	0.401

CON: concentric contraction; Nm: Newton-metres.

Table 7. Concentric Torque: Donor Ankle Preoperative vs. 12 Months Postoperative (Biodex System 4)

	Before Harvesting (Nm)	After Harvesting (Nm)	% Loss	p-Value
30 deg/s (CON)				
Inversion	37.26±18.84	34.18±16.08	8.76±9.42	0.482
Eversion	18.12±11.08	16.04±14.62	6.24±11.18	0.342
180 deg/s (CON)				
Inversion	22.88±15.42	21.12±15.54	8.12±7.06	0.421
Eversion	12.18±10.08	10.14±9.04	9.62±8.42	0.327

CON: concentric contraction; Nm: Newton-metres.

Table 8. Eccentric Torque: Donor Ankle vs. Contralateral Ankle at 12 Months (Biodex System 4)

	Healthy Side (Nm)	Donor Side (Nm)	% Loss	p-Value
30 deg/s (ECC)				
Inversion	44.52±20.04	41.32±21.16	9.28±8.74	0.498
Eversion	28.44±21.12	26.52±22.88	8.56±10.94	0.389
180 deg/s (ECC)				
Inversion	30.08±22.86	27.88±19.02	9.18±12.04	0.412
Eversion	31.46±18.42	27.84±11.08	8.34±14.42	0.401

ECC: eccentric contraction; Nm: Newton-metres.

Table 9. Eccentric Torque: Donor Ankle Preoperative vs. 12 Months Postoperative (Biodex System 4)

	Before Harvesting (Nm)	After Harvesting (Nm)	% Loss	p-Value
30 deg/s (ECC)				
Inversion	43.34±21.28	41.32±21.16	9.18±8.02	0.408
Eversion	27.68±16.12	26.52±22.88	7.28±6.92	0.404
180 deg/s (ECC)				
Inversion	29.28±17.04	27.88±19.02	8.52±4.22	0.418
Eversion	28.96±16.08	27.84±11.08	8.92±8.42	0.396

ECC: eccentric contraction; Nm: Newton-metres.

DISCUSSION

This prospective study demonstrates that a doubled ipsilateral PLT autograft is an effective option for arthroscopic single-bundle ACL reconstruction in patients with concomitant grade III MCL injury. Over the 12-month follow-up period, the PLT graft provided knee stability and functional outcomes comparable to those achieved with the conventional quadrupled HT autograft, without significant donor ankle morbidity.

Biomechanical evaluation showed that the doubled PLT possessed ultimate tensile strength exceeding that of the native ACL and comparable to the quadrupled HT construct. These observations further support the suitability of PLT as a mechanically reliable graft source for ACL reconstruction and are in accordance with previously published comparative studies [8,10,14]. Shi et al. reported comparable load-to-failure values between doubled PLT and quadrupled HT grafts (4,268 N and 4,090 N, respectively), with both grafts demonstrating strength substantially greater than the native ACL [14]. In the present study, the doubled PLT consistently yielded a graft diameter between 8 and 9 mm with an average usable length of approximately 30 cm. In contrast, hamstring tendon grafts are known to exhibit considerable interindividual variability in diameter, and undersized grafts have been associated with increased rates of graft failure [5]. The single case of graft resorption observed in the HT group, despite the absence of documented reinjury, may possibly be related to these factors; however, larger studies are required before any definitive conclusion can be drawn.

The rationale for avoiding hamstring tendon harvest becomes particularly relevant in combined ACL-MCL injuries. Rao et al., in a systematic review of 52 studies, reported that concomitant MCL injury occurs in approximately 20–38% of ACL tears, making it the most frequently encountered multi-ligament knee injury pattern [6]. In grade III MCL injuries, the medial soft tissues are often extensively disrupted, and surgical dissection around the pes anserinus may increase the risk of wound complications, haematoma formation, and additional compromise of medial stabilising structures. Harvesting the PLT through a lateral ankle approach avoids operating within the zone of medial injury while still providing adequate graft strength for reconstruction. Similar observations were reported by Hinz et al., who utilised a split PLT graft for MCL augmentation in conjunction with ACL reconstruction and achieved satisfactory restoration of valgus stability without clinically significant ankle dysfunction [19].

The present findings suggest that graft selection in combined ACL-MCL injuries should consider not only graft strength and postoperative stability, but also preservation of medial soft tissue integrity. Avoidance of hamstring harvest may theoretically reduce additional insult to already compromised medial stabilisers during the early healing phase. In this context, the PLT offers a biomechanically adequate graft while avoiding surgical dissection within the zone of medial injury. Recent systematic reviews and meta-analyses have similarly demonstrated comparable functional outcomes between PLT and HT autografts, with lower donor-site morbidity associated with PLT harvest [6, 19, 20].

Functional recovery improved progressively in both study groups throughout the follow-up period. Tegner, Lysholm, and IKDC scores remained comparable between the PLT and HT groups at all postoperative assessments, with no statistically significant intergroup differences identified. He et al., in a meta-analysis involving 925 patients, similarly reported comparable functional outcomes and graft failure rates between PLT and HT autografts.[8]. Comparable mid-term outcomes have also been reported by Gunadham et al. at a minimum follow-up of three years [10].

No clinically important impairment of donor ankle function was identified during follow-up in the PLT group. Measurements of dorsiflexion and plantar flexion strength remained stable at both 6 and 12 months after surgery. Similarly, isokinetic assessment demonstrated no statistically significant reduction in inversion or eversion torque during either concentric or eccentric testing, despite minor torque reductions ranging from 6% to 9%. Preservation of ankle function may be explained by the compensatory contribution of the peroneus brevis and other surrounding musculotendinous structures, which partially maintain eversion and plantar flexion function following PLT harvest. Previous studies have also reported minimal donor-site morbidity following PLT harvest [9,14,15]. Soleymanha et al. observed no significant structural alteration of the foot arch even at long-term follow-up intervals extending up to 23 years [9], while Manit et al. similarly concluded that PLT harvest does not produce clinically significant biomechanical impairment at the ankle [15]. In addition, Shi et al. reported preservation of ankle dorsiflexion, plantar flexion, and inversion-eversion strength following PLT harvest [14]. In the present series, routine suturing of the residual PLT stump to the peroneus brevis tendon may also have contributed to preservation of postoperative ankle function, as suggested in previous reports [16].

Several limitations of the present study should be acknowledged. First, the relatively small sample size limits the statistical power to detect subtle differences between groups and reflects the comparatively uncommon nature of this injury combination. Second, no formal pre-study power analysis was performed. Finally, the duration of follow-up may be insufficient to fully evaluate long-term graft durability and late complications. Future investigations with larger patient populations, longer follow-up durations, validated ankle-specific functional scoring systems, and gait analysis may provide a more comprehensive assessment of donor-site morbidity and long-term reconstructive outcomes.

CONCLUSION

In conclusion, doubled ipsilateral PLT autograft demonstrated biomechanical strength comparable to quadrupled HT autograft for ACL reconstruction, while providing similar postoperative knee stability and functional outcomes at 12 months. Donor ankle function remained well preserved, with no clinically significant biomechanical impairment observed during follow-up. In patients with combined ACL and grade III MCL injuries, where medial hamstring harvest may increase the risk of additional soft tissue morbidity, the PLT represents a safe and effective alternative graft option. The technique may be particularly valuable in complex multi-ligament injuries, revision procedures, and cases involving substantial medial-sided soft tissue compromise.

Conflict of interest

None declared.

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