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ORIGINAL ARTICLE

# Peroneus Longus Tendon Autografts have Better Graft Diameter, Less Morbidity, and Enhanced Muscle Recuperation than Hamstring Tendon in ACL Reconstruction

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**Abstract**

**Background** Recently the peroneus longus tendon (PLT) gained popularity in anterior cruciate ligament (ACL) reconstruction and has been utilized with satisfactory outcomes. However, there are concerns regarding donor site morbidity. This study aims to compare the functional outcome of ACL reconstruction using hamstring (HT) and PLT autografts and evaluate the donor site morbidity.

**Methods** Patients who underwent ACL reconstruction were allocated to two groups (HT and PLT). Graft diameter was measured intraoperatively. Knee functional outcome was evaluated with IKDC and Tegner-Lysholm scores preoperatively, and postoperatively after 3 months, 6 months, and 1 year. Donor site morbidities were assessed with thigh circumference measurements, subjective evaluation of sensory disturbances, and ankle scoring with AOFAS and FADI scores.

**Results** At 1-year follow-up, the PLT group showed comparable IKDC ($p=0.925$) and Tegner-Lysholm ($p=0.600$) scores with those of the HT group. The mean graft diameter in the PLT group (7.93 ± 0.52 mm) was larger compared with the HT group (7.43 ± 0.50 mm) ($p<0.001$). The incidence of thigh atrophy (HT-16.7%, PLT-10%) and sensory disturbances (HT-73.3%, PLT-10%) was greater in the HT group. There was no significant ankle donor site morbidity in the PLT group (AOFAS-98.67 ± 3.45, FADI-99.23 ± 1.69).

**Conclusion** ACL reconstruction with PLT had comparable functional outcome with that of HT at 1 year. However, PLT demonstrated larger graft diameter, less donor site morbidity, and enhanced muscle recovery without significantly affecting the ankle function. PLT can be safely used as an acceptable alternative graft choice harvested from outside the knee for ACL reconstruction.

**Keywords** ACL reconstruction · ACL tear · Autograft · Peroneus longus tendon · Hamstring tendon

## Introduction

ACL is one of the most frequently injured knee joint structures in sports traumatology. If ACL injuries are left untreated, it can lead to knee instability, meniscal injuries, and early osteoarthritic changes [1].

The current gold standard treatment for ACL injury in young active patients is arthroscopic anatomic ACL reconstruction (ACLR) [2]. Graft choice for ACLR is crucial, but the optimal graft source remains controversial. The ideal graft choice for ACLR should reproduce the complex anatomy of the ACL, provide the same biomechanical properties as the native ACL, permit strong and secure fixation, promote rapid biologic incorporation, and minimize the donor site morbidity [3]. Autografts are the first choice in ACL surgery, with bone patellar tendon-bone grafts and HT grafts

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being the most popular [4]. Currently, a perfect graft for ACLR does not exist with all grafts having advantages and disadvantages.

HT autograft is one of the most popular graft choices for ACLR worldwide [5]. Its strength has been found comparable to the native ACL with good functional outcomes. The limitations of HT include its unpredictable graft size, numbness around the distribution of saphenous nerve, potential post-operative thigh atrophy, and residual hamstring strength deficits [6].

Given the drawbacks of HT graft, another alternative with minimal donor site morbidity is warranted. Also, the need for additional grafts has risen with the advent of multi-ligament reconstructions. The use of PLT autograft is a recent development in the field of ACLR. The advantages include a larger graft diameter, greater ultimate tensile load, and relatively easy graft harvesting technique [7]. However, there are only a few studies regarding the clinical outcome and donor site morbidity. PLT is one of the main ankle evertors. So, one of the main concerns of using PLT autograft is a potential ankle instability [8].

The purpose of this study is to compare the functional outcome of PLT as a graft for primary ACLR with respect to HT and study its possible effects on foot and ankle function.

## Materials and Methods

This is a prospective observational study of ACLR in patients conducted at our tertiary care center. The study period is of 1-year duration from November 2020 to November 2021. The study required a sample size of 25 for each group (a total sample size of 50, assuming equal group sizes), to achieve a power of 80% and a level of significance of 5% (two-sided), for detecting a true difference in means between the peroneus longus graft diameter and the hamstring diameter of 0.6 (i.e. 8.8–8.2) units and a pooled standard deviation of 0.75 units, based on the study done by Rhatomy et al. [9]. A total of 60 patients were selected with 30 patients each in the HT and PLT group. Patient selection was randomized following the odd–even rule. The patients provided informed written consent to participate in the study, and ethical committee clearance was granted. The indications for reconstruction were functional instability during daily or sports activities with a high-grade tear of the ACL.

The inclusion criteria were patients with ACL injury, aged 16–50 years. Patients with a concurrent injury to the meniscus were also included in our study. In each group, half of the patients had isolated ACL injuries and the other half had associated meniscal injuries also. The exclusion criteria were multi-ligament injuries, chondral damage, pre-existing deformity of ipsilateral knee or ankle joint, previous knee or ankle surgery, previous ankle instability, and fractures around the knee.

### Surgical Technique

For PLT harvest, a skin incision was made 2–3 cm above and 1 cm behind the lateral malleolus. The PLT and peroneus brevis tendons (PBT) were identified after dissecting the superficial fascia. The PLT tendon was divided 2–3 cm above the level of the lateral malleolus. The distal stump of PLT was sutured to the PBT with end-to-side heavy absorbable poly filament sutures (Fig. 1). The PLT was stripped proximally with a tendon stripper to about 4–5 cm from the fibular head to prevent peroneal nerve injury.

For HT harvest, a 2–3 cm incision was made at the medial aspect of the proximal tibia. The semitendinosus and gracilis tendons were identified after the sartorial fascia was incised. The semitendinosus was preferred, but harvesting of both tendons was considered in case of small graft size. After releasing from their proximal muscle attachment, the tendons were stripped with a tendon stripper.

The harvested grafts were evaluated, and the measurements including the length and diameter of the grafts were made. The graft configuration was aimed to obtain a minimum of 6.5–7 cm length and > 7 mm diameter for the grafts. The peroneus tendon was double bundled and the hamstring tendon was quadrupled.

All the patients underwent arthroscopic ACLR by making use of the standard portals. Meniscal repairs were done in those with meniscal injuries. All the patients underwent similar rehabilitation protocols. Post-operatively, the patient's knee was immobilized in a ROM knee brace. Toe-touch weight bearing was initiated in the first week in patients with isolated ACL injury. In patients with concomitant meniscal injury, non-weight bearing was started with bilateral axillary crutches. Static quadriceps, patellar gliding, straight leg raise, and ankle pump exercises were begun immediately and gradually increased in intensity. Gradual knee flexion was allowed from 0° to 90° with subsequent full flexion at 4 weeks post-surgery. By 6 weeks, complete weight bearing was allowed with a full knee range of motion. The patients were allowed jogging after 3 months with a return to sports after 9 months depending on the patient's performance.

### Post-Operative Assessment

The clinical evaluation was done pre-operatively and post-operatively after 3 months, 6 months, and 1 year. Pain was assessed using a Visual-Analog-Scale (VAS). The diameter of the harvested graft was documented intraoperatively. Knee functional outcome was assessed using the International-Knee-Documentation-Committee (IKDC) score and Tegner-Lysholm (TL) knee score. All patients were assessed

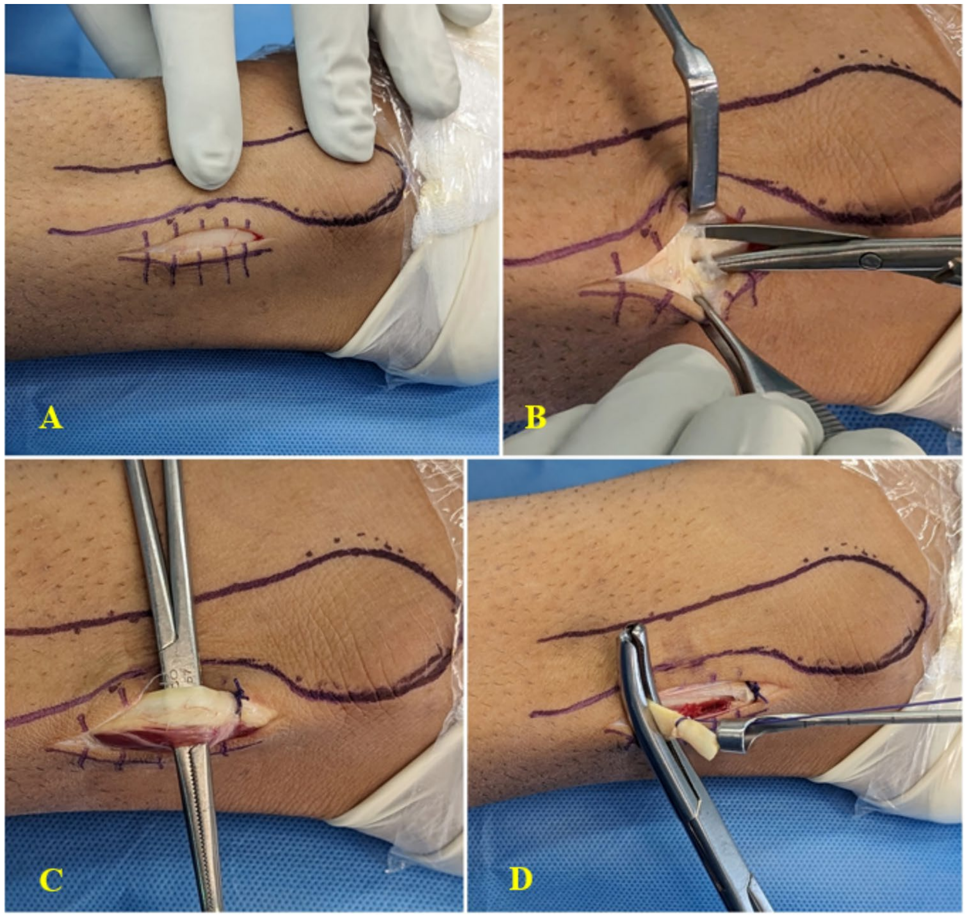



**Fig. 1** Peroneus Longus tendon harvest. **A** Skin incision 2–3 cm above and 1 cm behind the lateral malleolus. **B** Identifying the peroneal tendons by dissecting the superficial fascia. **C** Isolating the PLT with its distal stump sutured to PBT. **D** The PLT is cut and stripped proximally with a tendon stripper

for thigh atrophy by measuring the distal thigh circumference 15 cm proximal to the superior pole of the patella. Thigh atrophy of > 10 mm was considered to be significant. Ankle functional outcome was measured using the American-Orthopaedic-Foot-and-Ankle-Society (AOFAS) score and the Foot-and-Ankle-Disability-Index (FADI) score. Muscle power around the ankle was assessed using Medical-Research-Council (MRC) power grading. The patients were also asked for any other morbidity around the donor graft site including pain, scar tenderness, sensory deficits around the area of the harvest site, infection, hematoma, and bumpy harvest site. These were documented at each follow-up visit (Fig. 2).

The statistical analysis was done using SPSS software version.22. The independent sample *t*-test was used to test the statistical significance of difference between the means

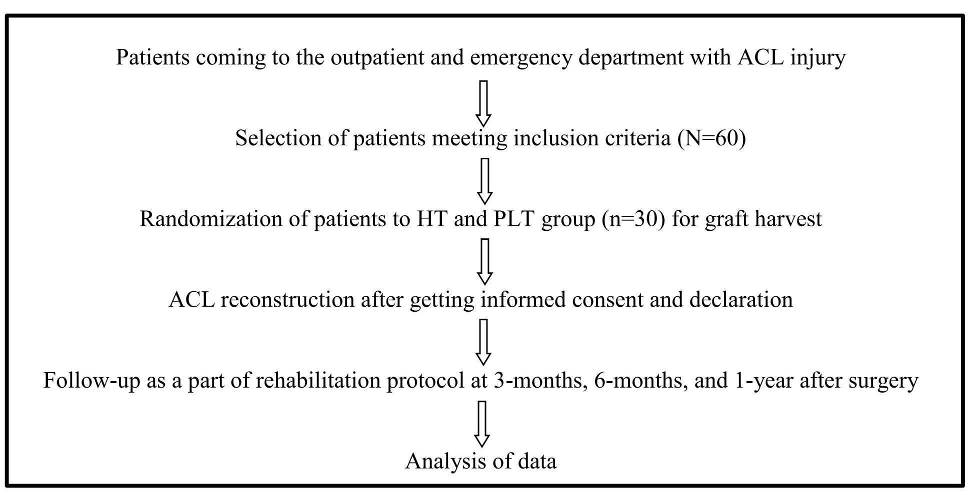



**Fig. 2** Recruitment of patients for the study

**Table 1** Demographic data analysis

| Variable | Hamstring group (n = 30) | Peroneus Longus group (n = 30) | p value |
|---|---|---|---|
| Age | 29.53 ± 8.22 | 28.07 ± 6.20 | 0.439 |
| Sex | | | |
| Male | 27 | 25 | 0.706 |
| Female | 3 | 5 | |
| Mode of injury | | | |
| RTA | 4 | 8 | 0.393 |
| Sports | 17 | 13 | |
| Others | 9 | 9 | |
| Side of injury | | | |
| Right | 17 | 14 | 0.438 |
| Left | 13 | 16 | |
| Interval between injury and surgery (weeks) | 12.23 ± 18.51 | 10.67 ± 20.65 | 0.758 |

of variables among the different independent groups. The Pearson Chi-square test and Fisher's Exact test were used for comparing categorical variables between groups. A *p*-value of < 0.05 was considered statistically significant.

## Results

The assessment was done pre-operatively and post-operatively at 3 months, 6-months, and 1 year. No patients were lost to follow-up. The mean age of the patients who suffered ACL injury in our study was 28.80 ± 7.25 years. There were 52 males (86.7%) and 8 females (13.3%). Most patients (50%) in our study sustained ACL injury during sports activities. Road traffic accidents accounted for 20% of injuries, while the remaining were due to domestic accidents including twisting injuries, slips, and falls. 31 patients (51.7%) sustained right-sided injuries and 29 patients (48.3%) had injuries involving the left knee. The mean interval between the injury and the surgery was (12.23 ± 18.51) weeks in the HT group and (10.67 ± 20.65) weeks in the PLT group. The demographic data analysis between the two groups was not statistically significant (Table 1).

**Graft diameter**—The mean graft diameter of HT was 7.43 ± 0.50 mm and PLT was 7.93 ± 0.52 mm. A statistical significance was found favoring the PLT (*p* value < 0.001).

**Table 2** VAS score

| | HT | PLT | p value |
|---|---|---|---|
| Pre-op | 4.10 ± 1.26 | 4.40 ± 1.47 | 0.402 |
| 3-months | 2.57 ± 0.62 | 2.57 ± 0.67 | 1.000 |
| 6-months | 1.53 ± 0.73 | 1.50 ± 0.73 | 0.860 |
| 1-year | 0.83 ± 0.74 | 0.77 ± 0.85 | 0.749 |

**Table 3** IKDC score

| | HT | PLT | p value |
|---|---|---|---|
| Pre-op | 44.03 ± 11.82 | 43.38 ± 10.67 | 0.823 |
| 3-months | 63.78 ± 4.03 | 63.71 ± 4.20 | 0.948 |
| 6-months | 77.96 ± 2.85 | 78.03 ± 3.00 | 0.927 |
| 1-year | 89.59 ± 2.93 | 89.67 ± 3.29 | 0.925 |

**Table 4** Tegner-Lysholm score

| | HT | PLT | p value |
|---|---|---|---|
| Pre-op | 34.80 ± 8.74 | 36.47 ± 8.51 | 0.458 |
| 3-months | 84.17 ± 5.62 | 85.53 ± 4.86 | 0.318 |
| 6-months | 95.23 ± 3.03 | 94.47 ± 2.97 | 0.388 |
| 1-year | 98.22 ± 2.37 | 98.40 ± 2.97 | 0.600 |

### Functional Outcome of Knee

*Pain VAS score*—There was a comparable improvement in the mean VAS score in both groups (Table 2). At 1-year, no statistically significant difference was seen between the two groups (*p*-value 0.749).

*IKDC and Tegner-Lysholm scores*—There was a significant improvement in both the scores in the two groups at 1 year. However, no statistical significance could be established between the two groups at any point in time (Tables 3, 4).

### Donor Site Morbidity in HT Group

*Thigh atrophy*—At 3-months after the surgery, 12 patients (40%) in the HT group had thigh atrophy > 10 mm compared to 9 patients (30%) in the PLT group. At 6-months, atrophy persisted in 8 patients (26.7%) in the HT group and 5 patients (16.7%) in the PLT group. 1-year after the surgery, 5 patients (16.7%) in the HT group and 3 patients (10%) in the PLT group continued to have the problem (Fig. 3). The hamstring group had a higher incidence of thigh atrophy, albeit not to a statistically significant degree ($p$-value 0.706).

*Sensory disturbances*—At 3 months after the surgery, 22 patients (73.3%) had sensory disturbances below the knee in the region of distribution of infrapatellar and sartorial branches of the saphenous nerve. The patients complained of either hypoesthesia or numbness. 15 patients (50%) continued to have the problem at 6-months. One year after the surgery, the problem persisted in 9 patients (30%). The subjective assessment of the patients indicated that the sensory abnormalities subsided over time and did not have a significant effect on their physical or mental health.

*Miscellaneous*—One year after the surgery, 5 patients (16.6%) complained of stretch pain at the hamstring harvest site particularly after climbing the stairs and running for some distance. No patients had significant hamstring muscle power weakness compared to the healthy side. There was no incidence of surgical site infection, hematoma, or scar tenderness.

## Donor Site Morbidity in PLT Group

*Ankle functional outcome*—The mean AOFAS score was 97.07 ± 6.20 at 3 months, 98 ± 4.06 at 6 months and 98.67 ± 3.45 at 1 year. The mean FADI score was 97.43 ± 4.96 at 3 months, 98.57 ± 2.99 at 6 months, and 99.23 ± 1.69 at 1 year. Ankle functions were grossly preserved in all the patients with MRC grading of flexion/extension, inversion/eversion, and rotation of the ankle and subtalar joints comparable to the healthy side.

*Bumpy harvest site*—11 patients (36.7%) had swelling over the PLT harvest site at 3 months. At 6 months and 1 year post-surgery, 7 patients (23.3%) and 4 patients (13.3%) continued to have the swelling (Fig. 4). But the swelling decreased in size in all the patients. None of the patients complained of pain, discomfort, or dissatisfaction due to the swelling with no hindrance to normal ankle functions.

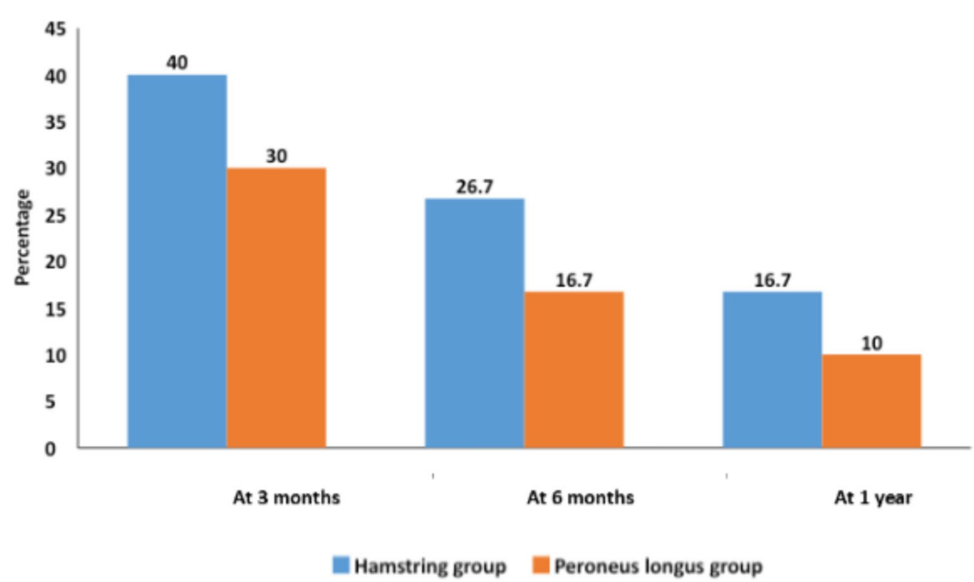
*Sensory disturbances*—3 patients (10%) complained of numbness over the outer aspect of the leg from mid-calf to the foot in the region of distribution of superficial peroneal nerve and sural nerve. In two patients, the numbness improved over time, but the other patient was dissatisfied with the result because of this newly developed complication.

2 patients (6.66%) had numbness over the medial aspect of the leg below the knee. It extended till mid-calf in one patient while the other patient complained till ankle. It gradually decreased in intensity over time and did not cause any concern for the patients.

On comparing the incidence of sensory disturbances due to the graft harvest in both groups, a statistically significant difference was found with a higher number of patients in the HT group ($p$ value < 0.001, odds ratio 24.75) (Fig. 5).

*Miscellaneous*—1 patient (3.33%) developed hematoma at the harvest site 3 weeks after the surgery which required aspiration. The patient did not have any preceding traumatic injury. There was no report of further recurrence. 3 patients (10%) complained of stretch pain at the harvest site on inversion but did not cause any functional impairment. There was no incidence of surgical site infection or scar tenderness at the harvest site.

**Fig. 3** Thigh atrophy > 10 mm



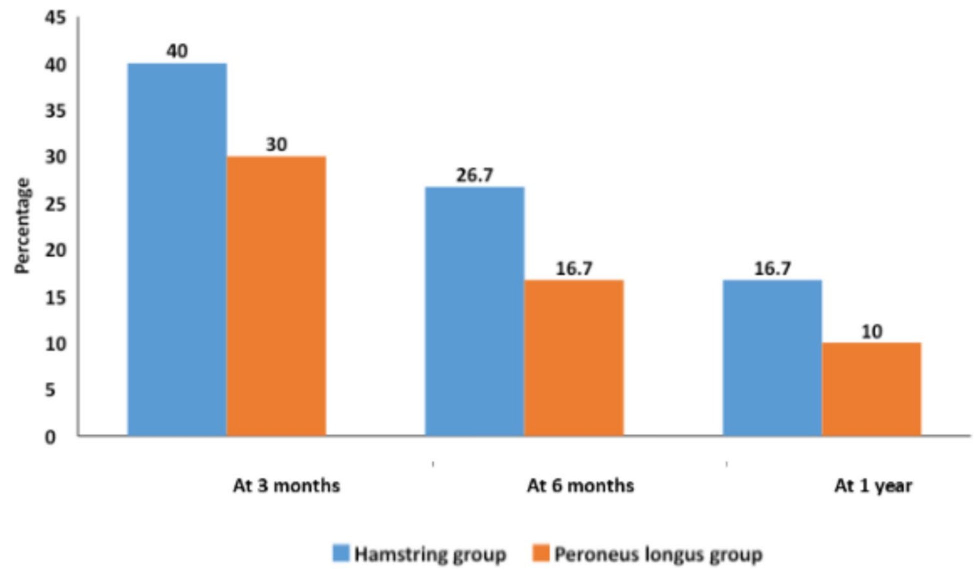



**Fig. 4** Incidence of bumpy harvest site in PLT group

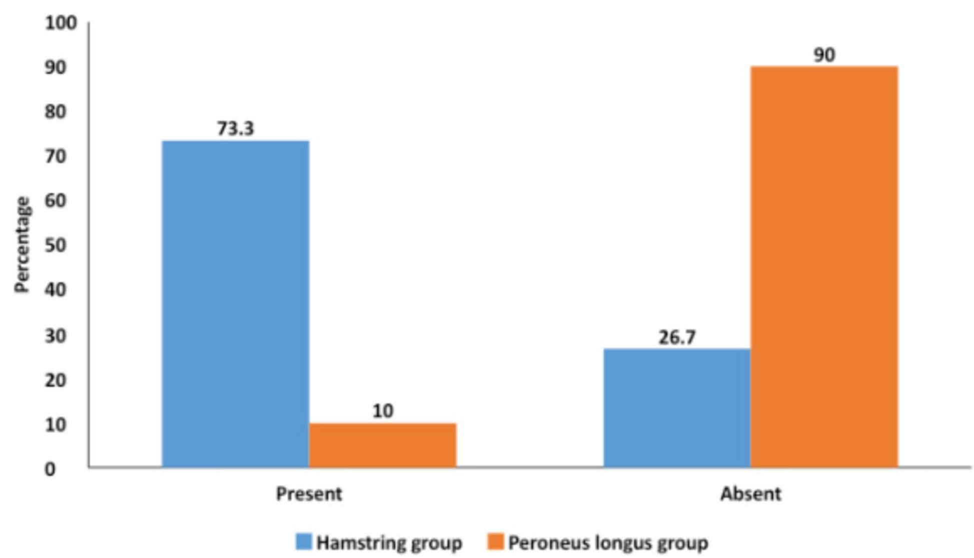



**Fig. 5** Incidence of sensory disturbances

## Discussion

Graft selection is one of the most important considerations in ACLR. The characteristics of an ideal graft for ACLR would be one with an acceptable amount of strength, adequate size, easily and safely harvested [3]. With every 0.5 mm incremental increase in graft diameter, the risk of revision rate is 0.82 times lower [10]. As previously reported, the PLT graft in our study also exhibited a significantly larger diameter with a mean difference of 0.50 mm between the two [9]. Previous studies on ACLR with PLT have reported good results in terms of both functional outcome and knee stability [7, 11, 12]. The findings from our study are consistent with their results, supporting the use of PLT in ACLR with satisfactory functional outcomes for the patients at 1-year follow-up.

Donor site morbidity is an important aspect of the graft harvest. Thigh atrophy due to HT harvesting results in reduced hamstring strength, especially at deep flexion angles. It also results in quadriceps–hamstring imbalance and dynamic knee instability [9]. The number of patients who had thigh atrophy in our study was lower compared to the previous studies [9]. Though not statistically significant, the incidence of thigh atrophy was higher in the hamstring group. When asked about compliance with rehabilitation protocols, all the patients who developed thigh atrophy did not actively follow the exercise regimen. All the patients who strictly adhered to the rehabilitation protocols restored their thigh muscle bulk.

Sensory disturbances following HT harvest is a relatively common complication. This is due to the injury to sartorial and infrapatellar branches of the saphenous nerve. Patients typically complain of numbness or hypoesthesia in the cutaneous distribution of these nerves. Its incidence has been reported to be 39.7–88% [13]. The findings in our study also showed a persisting high incidence of this complication following HT harvest. Most patients found this minimally bothersome, and none had any serious impact on their activities of daily life.

Only one study by Kerimoglu et al. has reported the occurrence of neurological complications around the donor ankle [11]. They reported a 6.9% (2/29) incidence of sensory disturbances in the form of dysesthesia and paraesthesia in the region of the extracted PLT. This can be attributed to the proximity of the course of the sural and superficial peroneal nerves. Solomon et al. reported a high risk of laceration of malleolar branches of these nerves during the approach to lateral malleolus [14]. In our study, three patients (10%) complained of numbness over the outer aspect of the leg from mid-calf to the ankle. It is recommended that the tendon stripper used for harvest should be kept parallel and superficial to the fibula, and the harvest must stop at a level of 5 cm below the fibular head to avoid injury to the superficial peroneal nerve. Surprisingly, 2 patients in the PLT group developed this complication around the knee like in the HT group. We believe this is due to the procedures around the knee and not related to PLT harvest [15]. When comparing the incidence between the two groups, a statistically significant difference was found with a lower incidence of sensory complications in the PLT group.

Donor ankle morbidity is one of the major concerns of PLT graft harvest. The primary concern of the donor ankle following PLT harvest is the deterioration of first-ray plantar flexion, eversion strength, and ankle instability [8]. Otis et al. reported that PBT is a more effective evertor of the ankle, which will maintain the eversion even after harvesting the PLT [16]. Only the proximal portion of PLT above the level of lateral malleolus is harvested. The distal PLT stump was sutured to PBT which may preserve some PLT functions. Recent studies show that PLT harvest does not affect foot and ankle function to any clinically significant degree [7, 11, 12, 17, 18]. The findings in our study also showed similar outcomes with a mean AOFAS score of $98.67 \pm 3.45$ and an FADI score of $99.23 \pm 1.69$ at 1-year. Ankle functions were grossly preserved in all the patients even after PLT harvest.

Bumpy harvest site is another minor complication of PLT harvest. It occurs as a soft to firm swelling of 1–2 cm size over the harvest site. There is very little information regarding this complication in the available literature. 36.7% of patients in our study developed this complication and it persisted in 13.3% of patients at 1 year. None of the patients reported it to cause any discomfort. From our experience, this can be prevented by closing the fascia over the peroneal tendons. Spontaneous hematoma at the PLT harvest site has not been reported elsewhere. Sterling et al. reported that shear stress-induced bleeding between the subcutaneous skin and the fascia can cause spontaneous hematoma [19]. The exact reason why this happened is not known. It was managed by surgical evacuation and there was no recurrence.

This study has the following limitations. First, the study had only a limited number of patients. Differences in the patient population characteristics like age, sex, time of surgery, associated meniscal injuries, and compliance to the rehabilitation protocols could affect the subsequent functional outcomes as well as complication rates. In this study, we used general functional scores like IKDC, TL, AOFAS, and FADI to assess the functional outcome. Although the overall outcome was favorable, the results should be interpreted with caution due to the inherent weaknesses of these scores. We did not do any power analysis to objectively evaluate the stability, range of motion, and strength at the donor site. The arthrometer like KT-2000 was not used due to unavailability. The 1-year follow-up in this study is also a shortcoming. Even though most patients performed well in their daily activities of life, very few patients resumed pre-injury sports activities at 1-year. Hence, studies evaluating the long-term outcome of ACL reconstruction using PLT autograft are warranted to identify any late-onset complications.

## Conclusion

PLT can be safely used as an acceptable alternative graft choice harvested from outside the knee for ACLR. PLT had a significantly larger graft diameter compared to HT. Both the HT and PLT autografts had comparable satisfactory knee functional outcomes. The incidence of thigh atrophy and sensory disturbances was less in PLT patients. With the advantage of less donor site morbidity, PLT can be used as a safe and effective autograft choice for ACLR.

**Author contributions** All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by Jacob Varughese, Bipin Theruvil and Deepu Jacob Punnoose. The first draft of the manuscript was written by Deepu Jacob Punnoose and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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**Data availability** The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

## Declarations

**Conflict of interest** The authors have no competing interests to declare that are relevant to the content of this article.

**Ethical approval** This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Lakeshore Hospital and Research Centre, Kochi, India. (Date – 05/11/2020, Approval Number – LHRC/EC-2020-1/04).

**Consent to Participate and Publish** Informed written consent was obtained from all individual participants included in the study.

**Informed Consent in Studies with Human Subjects** All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). Informed consent was obtained from all patients.

**Animal Studies** This article does not contain any studies with animal subjects.

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