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ORIGINAL ARTICLE

Donor-site morbidity following arthroscopic anterior cruciate ligament reconstruction using peroneus longus tendon autograft

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Abstract

Introduction Peroneus longus has proved to be a promising graft for ACL reconstruction due to its high tensile strength, and ease of harvesting. While multiple studies have assessed the functional outcomes of the knee after ACL reconstruction using peroneus longus autograft, we aimed to evaluated donor site morbidity among the Indian population.

Matreials and methods This was a prospective, longitudinal, descriptive study conducted at a tertiary care hospital. Preoperative AOFAS and Karlsson-Peterson scores were obtained, and patients were followed up after surgery for a period of 6-months using the same scoring systems and strength testing with a hand-held Chatillon MSE-100-M dynamometer. Pedobarographs were done using Diers Pedoscan Plantar Pressure Measurement System on a subset of seven patients.

Results 20 patients participated in the study. Mean AOFAS and Karlsson-Peterson scores pre-operatively were 99.7 ± 1.34 and 98.5 ± 4.62 respectively. On completing 6- months of follow-up these scores were found to be 95.6 ± 9.43 and 88.75 ± 18.42 respectively. Deterioration of mean evertor strength was noted at all follow-ups compared to the opposite side. Static pedobarographs showed significant decreased in total surface area of contact and pressure over the posterior aspect of the operated side by 3-months which improved later at 6-months. Dynamic pedobarographs showed decreased mean average plantar pressure while walking on the operated side and significant increase in mean surface area of contact of the operated side (191.886±22.678 cm^2) at 6-months of follow-up compared to the opposite side (184.471 ± 22.218 cm^2). Five patients showed deviation of the point of maximum pressure while walking on the operated foot making it lateral to the COP with increased lateral plantar/ medial plantar pressure ratio.

Conclusion While the use of peroneus longus tendon autografts in arthroscopic ACL reconstruction does not seem problematic on short-term subjective assessment, there is objective evidence in keeping with evertor weakness, weakness of first ray plantar flexion and possible ankle instability.

Level of Evidence Level lll.

Keywords Peroneus longus · ACL reconstruction · Donor site morbidity · Pedobarography · Planar pressure measurement

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Introduction

The anterior cruciate ligament (ACL) is the most frequently injured structure in the knee, accounting for 86.5% of knee injuries [1]. Multiple studies have established the crucial role that the ACL plays in knee alignment, stability and kinematics. If not appropriately restored, its deficiency can lead to early degenerative changes in the knee joint [2].

Arthroscopic ACL reconstruction is the mainstay of treatment of ACL tears, for which a wide array of autografts and allografts has been employed. Though the ongoing debate of hamstring-tendon graft versus bone-patellar-bone-tendon graft persists to be the most popular, recent studies adopting the use of the peroneus longus tendon autograft in ACL reconstruction have surfaced showing promising functional outcomes in the knee. Its thickness, high tensile strength and ease of harvesting make it an ideal graft [3, 4]..

While prior studies have primarily focused on surgical outcomes for the knee, few have considered the possibility of donor-site morbidity at the ankle, and even fewer have evaluated the same in the Indian community [5–15].. The purpose of this study was to assess whether harvesting the ipsilateral peroneus longus tendon for ACL reconstruction causes donor-site morbidity at the ankle.

Materials and Methods

This was a prospective longitudinal study conducted from July 2019 to September 2021 at a tertiary care hospital in South India after approval from the Institutional ethics committee. Adults above the age of 18 years diagnosed to have an ACL injury based on clinical assessment and confirmed on magnetic resonance imaging undergoing arthroscopic ACL reconstruction with peroneus longus tendon autograft at our institution were included after providing their written informed consent. Patients with ligament laxity, inflammatory ankle pathologies, osteoarticular disease of the ankle, prior ankle injuries or surgery around either ankle were excluded.

Surgical technique

All patients were operated upon at a single centre by two surgeons from the same department after standardising the protocol for harvesting the graft. Surgeries were performed under spinal anaesthesia in supine position with a high pneumatic tourniquet applied to the ACL-deficient limb. The lower portion of the table was dismantled and the affected limb left to dangle with the knee flexed to 90° with a well-padded lateral post for support. A well-leg support was used for the opposite side, and the ACL-deficient limb was painted and draped. After exsanguinating the limb with an Esmarch bandage, tourniquet pressures were maintained at 300 mmHg for a time no longer than 100 min. A conventional diagnostic arthroscopy confirmed the presence of a torn ACL and any other associated injuries.

The patient's ankle was exposed and peroneus longus tendon palpated subcutaneously. A 3cm longitudinal skin incision was made behind the lateral malleolus with a No. 22 blade to expose the peroneus longus and brevis within their tendon sheath (Fig. 1a). The sheath was then incised longitudinally with a No. 10 blade and the peroneus longus tendon identified and isolated with a right-angled forceps (Fig. 1b). Using Ethibond 1–0, the tendon was tagged and cut distally leaving a 1cm stump (Fig. 1c). A tendon stripper was used to separate the peroneus longus tendon at its musculotendinous junction which was then retrieved through the incision (Fig. 1d). The distal stump of the peroneus longus was sutured to the peroneus brevis using Ethibond 1–0 in interrupted sutures and the peroneal sheath was closed using Vicryl 2–0 interrupted sutures (Fig. 1e). A compression dressing was applied to the ankle which was then changed to a water-resistant adhesive dressing on the second post-operative day. Suture removal was done on the eleventh post-operative day.

Rehabilitation

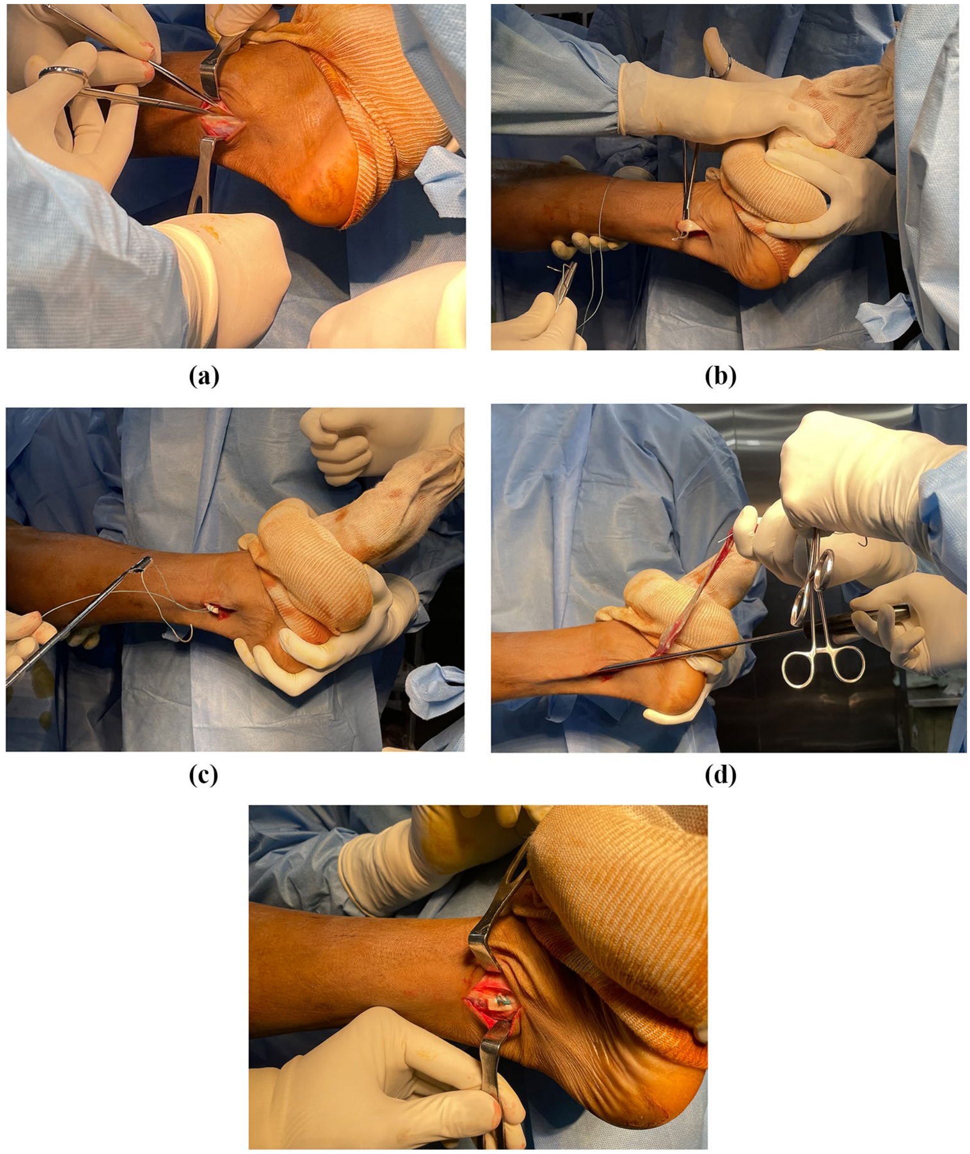
All patients had a post-operative physiotherapy assessment and were provided with a printed pictographic protocol for home-based ankle rehabilitation aimed at evertor strengthening and obtaining good range of motion at the ankle and subtalar joints (Annexure 1). The protocol with exercises was explained to patients during follow-up visits and implemented in a timely fashion with increasing difficulty.

Functional outcomes of the ankle joint

Patients were followed up at one, three and six months from their date of surgery. Foot and Ankle Score (AOFAS) and Karlsson–Peterson scoring systems were used for subjective functional assessment of the ankle preoperatively and during all follow-up visits. Invertor and evertor strength were assessed using Chatillon MSE-100-M hand-held dynamometer (Fig. 2) by a single investigator at 1, 3 and 6 months following surgery and compared to the normal side. Static and dynamic plantar pressure measurements were done on those patients willing for the same at 3- and 6-month of follow-up, comparing findings of the operated limb to that of the normal side using a Diers Pedoscan Plantar Pressure Measurement System.

The data were analysed using descriptive statistics with the aid of SPSS version 28 and Microsoft Excel 2022. The

Fig. 1 **a**–**e** Operative technique for harvesting peroneus longus from the ipsilateral ankle



(a) (b) (c) (d) (e)

quantitative data were reported in terms of mean and standard deviation, and significance was determined using the student's t test and analysis of variance (ANOVA). To investigate group differences, subsets of data were subjected to post hoc analyses. A p-value < 0.05 was considered statistically significant.

Results

Our study consisted of 20 patients with a mean age of 32.75 ± 10.53 (19–56) years operated upon at a mean of 6.85 ± 9.76 (0.5–36) months following injury. We noticed a male predominance of 70% among participants and that the left knee (60%) was more frequently affected than the right. Most patients sustained injuries from sport (45%) followed by falls (40%) and road traffic accidents (15%).

Ankle scores

Table 1 shows the mean AOFAS and Karlsson–Peterson ankle scores prior to surgery till 6 months of follow-up with Fig. 3 showing trend in the two scores between pre-op and follow-up. Post hoc analysis of the same is shown in Table 2 with gradual improvement in ankle function and no significant difference between pre-operative scores and scores at 6 months of follow-up.

Fig. 2 Chatillon MSE-100-M hand-held dynamometer

Ankle strength

While invertor strength was not significantly impaired, dynamometric findings showed significant impairment of eversion in the operated ankle compared to the normal side (Table 3). Post hoc analysis showed significant short-term improvement in strength of both eversion and inversion (Table 4), and the same trend can be observed in Figs. 4, 5, respectively.

Pedobarography

Among the 20 participants, 7 agreed to undergo static and dynamic plantar pressure analysis as detailed in Tables 5 and 6, respectively.

At 3 months of follow-up, the mean average plantar pressure, foot axis angle, maximum plantar pressure, plantar surface area, weight distribution and hindfoot weight distribution during static pedobarography were found to be higher on the normal side compared to that of the operated limb. Among these, the differences in plantar surface area and hindfoot weight distribution were found to be statistically significant. By 6 months of follow-up, there was no significant difference in any parameter between the normal and operated sides.

During dynamic pedobarography, the average plantar pressure, maximum plantar pressure, step duration, surface area and weight distribution at 3 months of follow-up were found to be higher on the normal side. The difference in

Table 1 Mean AOFAS and Karlsson–Peterson scores (n = 2)

Parameter		N	Mean	Std. Deviation	Repeated measures ANOVA p value
AOFAS	Pre-op	20	99.70	1.34	0.000
	1 month	20	72.90	16.39	
	3 months	20	85.40	9.29	
	6 months	20	95.60	9.43	
Karlsson–Peterson	Pre-op	20	98.50	4.62	0.000
	1 month	20	59.35	14.86	
	3 months	20	79.25	10.89	
	6 months	20	88.75	18.42	

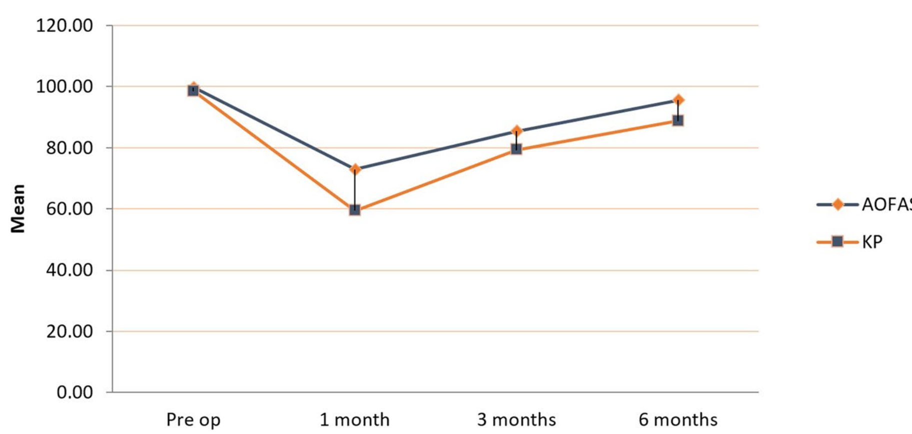


Fig. 3 Trend in mean AOFAS and Karlsson–Peterson (KP) score from pre-op to 6 months follow up

Table 2 Post hoc analysis of mean AOFAS and Karlsson–Peterson scores

Scoring system		Mean difference	Std. Deviation of difference	change (%)	Bonferroni p value
AOFAS	Pre-op–1 month	26.80	16.43	26.88	0.000
	Pre-op–3 months	14.30	9.27	14.34	0.000
	Pre-op–6 months	4.10	9.60	4.11	0.214
	1 month–3 months	− 12.50	12.91	− 17.15	0.001
	1 month–6 months	− 22.70	19.22	− 31.14	0.000
	3 months–6 months	− 10.20	10.84	− 11.94	0.001
Karlsson–Peterson	Pre-op–1 month	39.15	16.92	39.75	0.000
	Pre-op–3 months	19.25	11.93	19.54	0.000
	Pre-op–6 months	9.75	17.36	9.90	0.064
	1 month–3 months	− 19.90	14.70	− 33.53	0.000
	1 month–6 months	− 29.40	25.61	− 49.54	0.000
	3 months–6 months	− 9.50	19.97	− 11.99	0.140

Table 3 Mean strength of eversion and inversion of the peroneus-deficient and normal sides (n = 20)

Parameter		N	Mean	S D	Mean difference	SD of difference	t test p value
Eversion (Lbf)	1-month Operated side	20	6.760	0.810	− 0.734	0.699	0.000
	1-month Normal side	20	7.494	0.364			
	3 months Operated side	20	7.364	0.640	− 0.562	0.571	0.000
	3 months Normal side	20	7.926	0.636			
	6 months Operated side	20	7.665	0.528	− 0.255	0.461	0.023
	6 months normal side	20	7.920	0.531			
Inversion (Lbf)	1-month Operated side	20	7.199	0.749	− 0.226	0.571	0.094
	1-month Normal side	20	7.424	0.597			
	3 months Operated side	20	7.769	0.491	0.015	0.441	0.881
	3 months Normal side	20	7.754	0.603			
	6 months Operated side	20	7.872	0.489	− 0.076	0.552	0.545
	6 months Normal side	20	7.948	0.497			

Table 4 Post hoc analysis of mean strength of eversion and inversion of the peroneus-deficient foot

Parameter		Mean difference	Std. Deviation of difference	Change (%)	Bonferroni p value
Eversion (Lbf)	Operated side 1-month – 3 months	−0.60400	0.55171	−8.93491	0.000
	Operated side 1-month – 6 months	−0.90500	0.85448	−13.38757	0.000
	Operated side 3 months – 6 months	−0.30100	0.65084	−4.08745	0.053
Inversion (Lbf)	Operated side 1-month – 3 months	−0.57050	0.79044	−7.92526	0.004
	Operated side 1-month – 6 months	−0.67350	0.95603	−9.35612	0.005
	Operated side 3 months – 6 months	−0.10300	0.50908	−1.32578	0.377

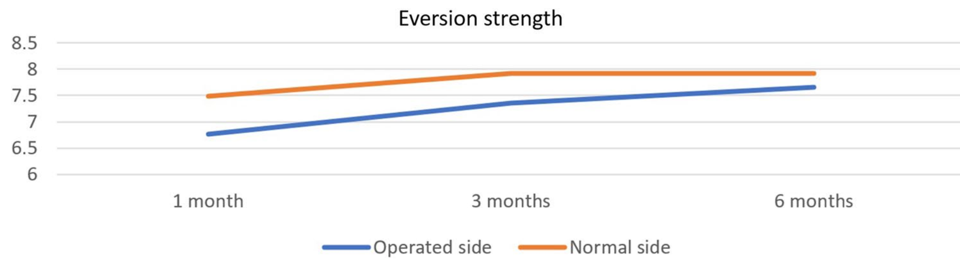


Fig. 4 Trend in mean strength of eversion of operated and normal sides during follow-up ($n = 20$)

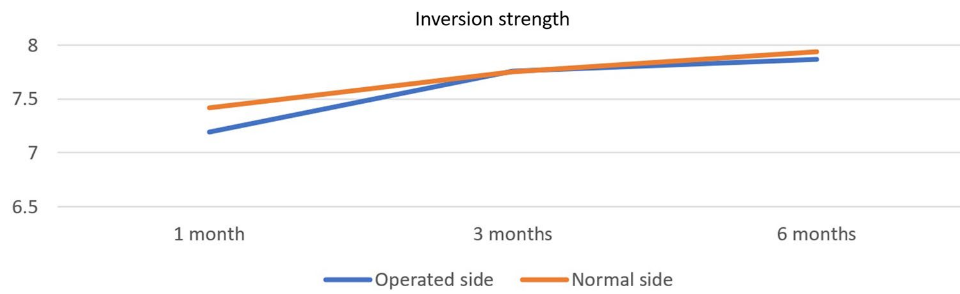


Fig. 5 Trend in mean strength of inversion of operated and normal sides during follow-up ($n = 20$)

Table 5 Static plantar pressure parameter measurements of operated & normal foot at 3- and 6-month follow-up (n = 7)

Parameter			N	Mean	Std. Deviation	Mean difference	S.d of difference	t test p value
Average pressure static (N/cm^2)	3	Operated side	7	2.600	0.465	−0.471	0.903	0.217
		Normal side	7	3.071	0.757			
	6	Operated side	7	2.700	0.392	−0.014	0.339	0.915
		Normal side	7	2.714	0.478			
Foot axis angle (°)	3	Operated side	7	5.071	4.920	−0.557	5.524	0.799
		Normal side	7	5.629	4.407			
	6	Operated side	7	3.086	2.564	−10.457	19.738	0.211
		Normal side	7	13.543	20.475			
Max pressure static (N/cm^2)	3	Operated side	7	12.957	3.993	−2.557	2.810	0.053
		Normal side	7	15.514	2.402			
	6	Operated side	7	13.414	3.678	−0.714	4.185	0.667
		Normal side	7	14.129	2.782			
Surface area static (cm^2)	3	Operated side	7	162.929	20.192	−5.543	5.718	0.043
		Normal side	7	168.471	20.519			
	6	Operated side	7	147.271	61.175	−17.857	45.530	0.339
		Normal side	7	165.129	24.362			
Weight distribution (%)	3	Operated side	7	45.000	6.432	−10.000	12.864	0.085
		Normal side	7	55.000	6.432			
	6	Operated side	7	50.214	3.154	0.429	6.307	0.863
		Normal side	7	49.786	3.154			
Weight distribution back (%)	3	Operated side	7	23.971	7.000	−8.100	8.438	0.044
		Normal side	7	32.071	2.457			
	6	Operated side	7	29.671	4.489	0.743	5.812	0.747
		Normal side	7	28.929	3.856			
Weight distribution front (%)	3	Operated side	7	21.043	2.817	−1.886	5.384	0.390
		Normal side	7	22.929	5.123			
	6	Operated side	7	20.514	4.639	−0.343	4.976	0.861
		Normal side	7	20.857	2.988			

Table 6 Dynamic plantar pressure parameter measurements of operated & normal foot at 3- and 6-month follow-up (n = 7)

Parameter			N	Mean	Std. Deviation	Mean difference	S.d of difference	t test p value
Average pressure dynamic (N/cm^2)	3	Operated side	7	1.129	0.095	– 0.257	0.257	0.038
		Normal side	7	1.386	0.279			
	6	Operated side	7	1.243	0.172	– 0.043	0.098	0.289
		Normal side	7	1.286	0.186			
Maximum pressure dynamic (N/cm^2)	3	Operated side	7	32.643	13.823	– 6.286	15.131	0.314
		Normal side	7	38.929	12.711			
	6	Operated side	7	31.329	5.983	1.314	5.663	0.562
		Normal side	7	30.014	5.677			
Step duration (ms)	3	Operated side	7	1268.143	476.542	– 72.857	381.509	0.631
		Normal side	7	1341.000	598.636			
	6	Operated side	7	1011.143	182.401	– 21.857	148.196	0.710
		Normal side	7	1033.000	196.746			
Surface area dynamic (cm^2)	3	Operated side	7	179.814	37.012	– 10.357	29.994	0.396
		Normal side	7	190.171	20.820			
	6	Operated side	7	191.886	22.678	7.414	7.366	0.037
		Normal side	7	184.471	22.218			
Weight distribution back dynamic (%)	3	Operated side	7	46.100	9.142	1.200	8.489	0.721
		Normal side	7	44.900	7.389			
	6	Operated side	7	44.671	5.769	– 2.443	6.166	0.335
		Normal side	7	47.114	4.860			
Weight distribution front dynamic (%)	3	Operated side	7	53.900	9.142	– 1.200	8.489	0.721
		Normal side	7	55.100	7.389			
	6	Operated side	7	55.329	5.769	2.443	6.166	0.335
		Normal side	7	52.886	4.860			

average pressure was the only one that was statistically significant, which then normalised by 6 months of follow-up. The plantar surface area on the operated side significantly increased on the operated side at 6 months of follow-up ($p = 0.037$).

Among these seven patients, five (71.4%) produced an abnormal pattern in their dynamic pedobarographic on the peroneus-deficient side (Fig. 6). We noticed a deviation of the point of maximum pressure away from the medial aspect of the forefoot to a point much lateral to the centre of pressure trace. Two patients showed these features at 3 months, two at 6 months and one at both 3 and 6 months of follow-up.

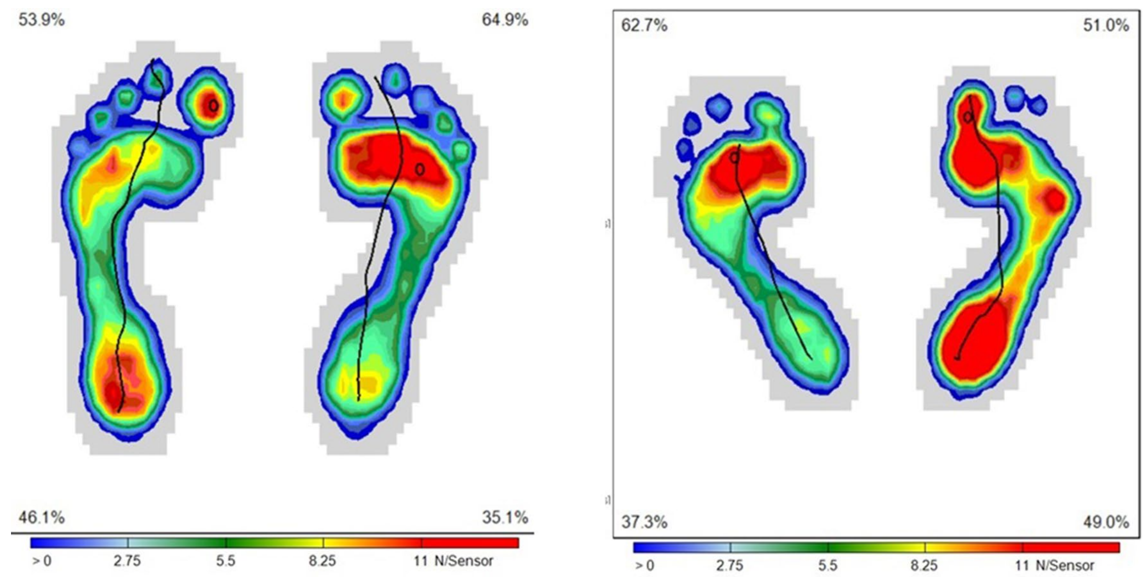
Discussion

The peroneus longus tendon is an attractive autograft option for ACL reconstruction with its ease of harvesting, predictable size, tensile strength and good functional outcomes as evidenced by pre-existing literature [3, 4, 10, 11, 14, 16–21]. Our findings suggest that while this procedure results in good subjective outcomes as perceived by patients, there is objective evidence suggestive of donor-site morbidity. The combination of evertor weakness alongside with the dynamic pedobarographic findings of redistributed plantar pressure to a point more lateral can be explained by the deficiency of peroneus longus in these subjects.

The peroneus longus not only plays a role in first-ray plantar flexion and eversion, but also maintains the transverse arch and medial longitudinal arch. It contributes to the stability of the ankle whilst acting in equilibrium with other muscles [22]. Manik et al. highlighted the possible compensatory role of other leg muscles in case of removal of the peroneus longus. They also mentioned that while ankle instability is associated with decreased evertor strength, a modest decrease may not have as drastic an impact [22].

Kerimoglu et al. found good knee function after using the peroneus longus and deemed it a suitable autograft in ACL reconstruction to circumvent morbidity from harvesting hamstrings. Their assessment of the donor site however, was subjective and based on symptoms reported by patients [23]. Various studies have relied on subjective scoring systems that have shown good results during short-term follow-up much like our study [3, 10, 11, 13, 14, 19–21, 24].

Fermin et al. concluded that while the peroneus longus autograft is adequate in its dimensions and outcomes, that non-validated tools and questionnaires provide favourable



(a) **(b)**

Fig. 6 Dynamic pedobarographic findings at 3-months after harvesting the right peroneus longus tendon autograft (**a**) and left peroneus longus tendon autograft (**b**). The black circle denotes the point of maximum pressure and has shifted lateral to the centre of pressure (COP) trace

outcomes of donor-site morbidity. Stronger evidence using validated tools is required to justify its routine use [25].

Rhatomy et al. have studied the use of peroneus longus and have demonstrated the potential of the tendon to regenerate on MRI [9, 13, 18, 24]. They used subjective questionnaires and a hydraulic dynamometer for strength testing, but unlike our study, did not find a significant difference between the two sides [26].

While Angthong et al. saw good knee function with minimal deterioration in AOFAS and VAS-FA scores post operatively, they found laxity in 8.4% of patients. They noticed deterioration of eversion, inversion, and first-ray plantar flexion on isokinetic testing with one patient developing ankle instability and therefore could not recommend peroneus longus as an autograft for ACL reconstruction [27]. Studies by Shi et al. and Nazem et al. used a robotic dynamometer and Kistler force plate respectively and reported no short-term evidence of donor-site morbidity [4, 28].

Our literature review failed to uncover any previous study that used pedobarographic data in analysing peroneus longus-deficient ankles. Mineta et al. conducted a study on 22 athletes with ankle instability following lateral ankle sprains and noticed increased lateral loading during a single-leg balance test. They correlated this with decreased peroneus longus activity and recommended that rehabilitation should include specific muscle activation training [29]. Though our patients were not made to perform single-leg balance tests, the findings described by the author were comparable to the dynamic changes seen in our study while making patients walk.

Despite how common and frequently used peroneus longus has become as an autograft in ACL reconstruction, there are very few tools to objectively assess the effects on the ankle. Our study is unique as it provides insight into the merit of pedobarographs as a tool for assessing the donor ankle. According to our literature review, no previous study has employed pedobarographic data as an objective tool for assessing donor ankles following the harvest of peroneus longus. The limitations of this study were the small sample size, short duration of follow-up and while strength testing was done by a single examiner, the use of a hand-held dynamometer is prone to poor intra-examiner reliability. We did not have access to an isokinetic dynamometer and were unable to perform gait analysis on these patients which would have.

Conclusion

While the use of peroneus longus tendon autografts in arthroscopic ACL reconstruction does not seem problematic on short-term subjective assessment, there is objective evidence in keeping with evertor weakness, weakness of first-ray plantar flexion and possible ankle instability.

Peroneus longus tendon is a viable option in selected patients who acknowledge the need for compliance with physiotherapy and are committed to rehabilitative efforts. Plantar pressure studies at regular intervals of follow-up can determine compliance to physiotherapy, need for aggressive rehabilitation and the presence of ankle instability. Further research with pedobarography is necessary to evaluate long-term donor-site morbidity and the possible effects on ankle stability independent of subjective questionnaires.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00590-024-04046-x.

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Declarations

Conflict of interest The author declare no conflict of interest in the work submitted.

Ethical approval Ethical approval Institutional ethical clearance was obtained. Written informed consent was obtained from all participants enrolled in the study.

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