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Original article

Evaluation of Ankle and Foot Function Following Peroneus Longus Tendon Graft Harvest

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Abstract

Background: Nowadays, orthopedic surgeons perform anterior cruciate ligament (ACL) reconstruction using the peroneus longus tendon as an autograft along with the common usage of hamstring tendon or bone-patellar tendon-bone grafts. **Methods:** This prospective study was conducted on thirty patients aged 18 - 45 years undergoing reconstruction of ACL or Posterior Cruciate Ligament Injury (PCL) primary who are admitted at Orthopedic Surgery Department, at Benha University Hospital, from January 2020 to December 2022. All patients were subjected to the following personal history, history of present complaint of patient, timing of the trauma, and history. **Results:** There was an insignificant difference between preoperative and 1-year postoperative AOFAS and FADI scores, but there was slight deference at 6 months postoperative ($P<0.001$, 0.007). Peak torque, peak torque/ kg body weight, maximum work, total work was significantly lower one year postoperatively compared to preoperatively ($P<0.001$). Regarding complications, a total of 7 (23.33%) minor complications were observed, 4 (13.33%) patients had hypoesthesia over the dorsolateral aspect of the foot distal to the incision scar. Three of them reported complete recovery of the hypoesthesia within the first month. Only one of the patients reported hypoesthesia mildly affecting their daily lives. Two (6.67%) patients had hyperalgesia over the incision scar without hypoesthesia. One (3.33%) patient had superficial wound infection at the harvesting site. **Conclusions:** Harvesting PLT with meticulous dissection and good tenodesis to peroneus brevis (PB) eliminate occurrence of minor complications and does not impair the overall functions of the ankle.

Keywords: Ankle, Foot, Peroneus Longus, Tendon Graft.

Introduction

Peroneus longus is also known as fibularis longus is a long muscle located superficially in the lateral compartment of the leg, together with the peroneus (fibularis) brevis muscle. Peroneus longus spreads from the proximal aspect of the fibula to the medial cuneiform and the first metatarsal bones [1]. Its main role is to strengthen first ray plantarflexion and to evert the foot [2].

Nowadays, orthopedic surgeons perform anterior cruciate ligament (ACL) reconstruction using the peroneus longus tendon as an autograft along with the common usage of hamstring tendon or bone-patellar tendon-bone grafts [3]. Orthopedic surgeons try to use the peroneus longus tendon in deltoid ligament reconstruction and medial patellofemoral ligament reconstruction because there is a synergistic function between the peroneus longus and peroneus brevis muscles which can offer some advantage if both undergo tenodesis [4-6].

The added advantage of peroneus longus tendon graft is the regenerative potential of the peroneus longus tendon, as observed in a few magnetic resonance imaging (MRI) studies at 1 year follow-up after its removal [7]. A study confirmed that the peroneus longus graft can be recommended as a superior graft over hamstring in a single bundle ACL reconstruction because the peroneus longus has a graft with a larger diameter and less hypotrophy [8]. There is some concern about the deterioration of ankle eversion and first ray plantarflexion strength after peroneus longus tendon harvest [3].

In the present study we will evaluate ankle and foot function and biomechanics after peroneus longus tendon graft harvest by isokinetic muscle testing and foot and ankle scoring scales.

The aim of this work is to evaluate functional and clinical effect of ankle and foot after peroneus longus tendon graft harvest by isokinetic muscle testing and foot and ankle scoring scales.

Patients and Methods

This prospective study was conducted on thirty patients aged 18 - 45 years undergoing reconstruction of ACL or PCL primary who are admitted at Orthopedic Surgery Department, at Benha University Hospital, from January 2020 to December 2022. The study was presented to the research Ethics Committee of faculty of medicine Benha University with **Approval code (MD 1-5-2022).** Informed consent was obtained from the patients before participating in this study.

Exclusion criteria where patient unfits for surgery or poor general condition, patient with advanced ankle or knee osteoarthritis, patient with significant limb malalignment, patient with pre-

existing flatfoot, ankle deformity, previous significant injuries to ankle, and local condition including [infection, local malignancy].

All patients were subjected to the following personal history, history of present complaint of patient, timing of the trauma, and past history including previous injury and methods of management either medical or surgical. All patients were assessed by the neurovascular and muscle power of ankle included [Foot & ankle disability index (FADI) score and B. American Orthopedic Foot and Ankle Society scale (AOFAS)] The FADI specific questionnaire for foot and ankle consists in a total of 26 items, grouped into three different categories of questions: 16 items (1-16) related to walking, 6 items (17-22) to daily activity and 4 (23-26) to pain. Each item can be scored on a 5-points Likert scale (from zero to four), with a maximum total score of 104 points; the score can be transformed into percentage if a comparison with other questionnaires is needed [9]. American Orthopedic Foot and Ankle Society scale (AOFAS)

This clinical rating system [10], the scale includes nine items that can be divided into three subscales (pain, function and alignment). Pain consists of one item with a maximal score of 40 points, indicating no pain. Function consists of seven items with a maximal score of 50 points, indicating full function. Alignment consists of one item with a maximal score of 10 points, indicating good alignment. The maximal score is 100 points, indicating no symptoms or impairments.

All patients were assessed by the isokinetic strength of the ankle muscles was measured using the isokinetic dynamometer - Isoforce - isokinetic system device (TUR Germany).

The exercises were selected as follows: internal and external rotation in the hip, knee and ankle joint, ballistic movement in the anterior–posterior direction in the hip joint with relaxed lower limb, hand walk, lunge stretches, lateral lunges, squats, standing plantar/dorsal flexions and inversion/eversion movements at the ankle joint, calf raises and vertical jump exercises (rope jumps, jumping jacks). There were 6–8 repetitions per stretching exercise and 30 repetitions per jump exercise. The participants were seated on the dynamometer seat with the hip joint at about 80° and knee at 110° (180° = full knee and hip extension), so the shin was positioned horizontally to the ground. The foot was placed on the foot adapter with an ankle angle in 10° of plantar flexion (0° = neutral position of the talocrural joint) and fixed with two Velcro straps. A handheld goniometer was used to set the angles. The hip and knee joint angles were adjusted by changing the distances between the chair and the foot adapter and the height of the support adapter over the thigh. The waist and thigh of the tested leg were fixed by straps.

Data recording and reduction, the manufacturer’s computer software Isoforce Analyze V.1.0.5 (TUR

Germany) was utilized. Four isokinetic variables were extracted for each movement (INV/EV), muscle action (concentric, eccentric), and angular velocity (30°/s and 120°/s, depending on the movement): Peak Torque (PT), Peak Torque/KG Body Weight, Maximum Work (MW) and Total work (TW).

Peroneus longus tendon graft is harvested with a longitudinal skin incision at 2 to 3 cm (2 fingerbreadths) above and 1 cm (1 finger - breadth) behind the lateral malleolus, followed by superficial fascia incision in line with skin incision. The peroneus longus and peroneus brevis tendons were then identified. The tendon division location was marked at 2 to 3 cm above the level of the lateral malleolus. After that, an end-to-side suture was performed between the distal part of the peroneus longus tendon and peroneus brevis tendon. The peroneus longus tendon was stripped proximally with a tendon stripper to at least 5 cm from the fibular head to prevent peroneal nerve injury.

All patients were assessed postoperatively by rehabilitation programs specific for foot and ankle, partial to full weight-bearing was allowed as early as possible. No splint or immobilization device was applied. Ankle exercises were encouraged from the second postsurgical day. Once the ankle ranges of movement had been regained, ankle strengthening exercises with an elasticated resistance band, as well as balance and proprioceptive exercises were performed and gradually increased.

All patients were followed up by 6 - 12 months include clinical evaluation by scoring systems (AOFAS – FADI) and 1-year post-operative isokinetic muscle testing by isokinetic system device (TUR Germany) as preoperative with the same Testing Procedures.

Statistical analysis

Statistical analysis was done by SPSS v26 (IBM Inc., Armonk, NY, USA). Quantitative variables were presented as mean and standard deviation (SD). Qualitative variables were presented as frequency and percentage (%). Pre and postoperative readings were compared using paired Student's t- test. A two tailed P value ≤ 0.05 was considered statistically significant.

Results

Regarding demographic data of the studied patients, age with a mean of 32.3 ± 7.25 years. There were 22 (73.33%) males and 8 (26.67%) females. BMI with a mean of 27.6 ± 4.44 kg/m2. Regarding smoking, 10 (33.33%) patients were smokers, and 20 (66.67%) patients were non-smokers. Regarding history of comorbidities in the studied patients, 7 (23.33%) patients had hypertension, and 4 (13.33%) patients had diabetes mellitus. Regarding clinical investigation in the studied patients, 25 (83.33%) patients were dominant on their right side and 5 (16.67%) patients were dominant on their left side, 17 (56.67%) patients were injured on their right side and 13 (43.33%) patients were injured on their left side; 14 (46.67%) patients were injured from road traffic accidents, 10 (33.33%) patients were injured from sports, and

6 (20%) patients were injured from self-fall. Regarding the duration of injury prior to surgery, 6 (20%) patients had the surgery within 1 months from the injury, 12 (40%) patients had the surgery from 1 to 3 months' post injury, 8 (23.33%) patients had the surgery from 3 to 6 months' post injury, and 4 (13.33%) patients had the surgery more than 6 months' post injury. Regarding injury of the studied patients, 18 (60.00%) patients had 1ry ACL, 4 (13.33%) patients ACL revision, 4 (13.33%) patients had 1ry PCL, and 1 (3.33%) patient PCL revision and 3 (10%) patients had both ACL and PCL. The length of harvested PLT for the ranged from 22 to 31 cm with a mean of 26.1 ± 2.51 cm. The graft diameter with a mean of 9 ± 0.85 mm. **Table 1**

Table 2 shows that the length of harvested PLT for the ranged from 22 to 31 cm with a mean of 26.1 ± 2.51 cm. The graft diameter ranged from 8 to 10 mm with a mean of 9 ± 0.85 mm. The follow-up duration ranged from 6 to 12 months with a mean of 7.5 ± 1.14 months. There was an insignificant difference between preoperative and 1-year postoperative AOFAS and FADI scores, but there was slight deference at 6 months postoperative (P<0.001, 0.007). **Table3**

Table 4 shows that peak torque, peak torque/ kg body weight, maximum work, total work was significantly lower one year postoperatively compared to preoperatively (P<0.001).

Table 1: baseline characteristics of the studied patients

		N=30
Age (year)		32.3 ± 7.25
Sex	**Male**	28 (93.33%)
	Female	2 (6.67%)
BMI (Kg/m^2)		27.6 ± 4.44
Smoking		10 (33.33%)
History of comorbidities		
Hypertension		7 (23.33%)
Diabetes mellitus		4 (13.33%)
Clinical investigation		
Dominant side	**Right**	25 (83.33%)
	Left	5 (16.67%)
Side of injury	**Right**	17 (56.67%)
	Left	13 (43.33%)
Mode of injury	**Road Traffic Accidents**	14 (46.67%)
	Sports	10 (33.33%)
	Self-fall	6 (20%)
Duration of injury prior to surgery		
Duration of injury prior to surgery	**Within 1 m**	6 (20%)
	1 to 3 m	12 (40%)
	3 to 6 m	8 (23.33%)
	>6 m	4 (13.33%)
ACL	**1ry**	18 (60.00%)
	Revision	4 (13.33%)
PCL	**1ry**	4 (13.33%)
	Revision	1 (3.33%)
Multi-ligaments	**ACL + PCL**	3 (10%)

Data presented as mean ± SD or number (%) *: statistically significant as P value <0.05, BMI: body mass index, HTN: hypertension, DM: diabetes mellitus.

Table 2: Graft properties and follow-up duration

	N=30
Graft properties	
Length of PLT (cm)	26.1 ± 2.51
Graft diameter (mm)	9 ± 0.85
Follow-up duration	
Follow-up (Months)	7.5 ± 1.14

Data presented as mean ± SD, ACL: Anterior cruciate ligament, PCL: Posterior cruciate ligament.

Table 3: Comparison of pre and postoperative AOFAS and FADI Scores in the studied patients

	Preoperative	6 Months Postoperative	1 year Postoperative	P-value
AOFAS	98.3 ± 1.91	96.5 ± 2.21	98.1 ± 1.4	**<0.001***
FADI score	98.7 ± 1.06	97.6 ± 1.71	98.2 ± 1.1	**0.007***

Data presented as mean ± SD or number (%) *: statistically significant as P value <0.05 AOFAS: American Orthopedic Foot and Ankle Score, FADI: Foot and Ankle Disability Index

Table 4: Comparison of pre and postoperative Isokinetic Muscle Testing in the studied patients and Complications in the studied patients

	Preoperative	Postoperative	P-value
PT(Nm)	31.6 ± 2.89	24.33 ± 3.28	**<0.001***
Peak Torque/Kg Body weight (Nm/Kg)	0.44 ±0.05	0.35 ± 0.059	**<0.001***
Maximum Work (Joules)	17.06 ± 1.48	12.87 ± 1.07	**<0.001***
Total Work (Joules)	129.24 ± 5.59	85.63± 3.21	**<0.001***
			N=30
Complications	**Minor**		7 (23.33%)
	Hypoesthesia		4 (13.33%)
	Hyperalgesia		2 (6.67%)
	Superficial Infection		1 (3.33%)
	Mild instability		0 (0%)
	Major		0 (0%)
	Peroneal nerve injury		0 (0%)
	Compartment syndrome		0 (0%)

Data presented as mean ± SD *: statistically significant as P value <0.05, PT: Peak Torque

Regarding complications, a total of 7 (23.33%) minor complications were observed, 4 (13.33%) patients had hypoesthesia over the dorsolateral aspect of the foot distal to the incision scar. Three of them reported complete recovery of the hypoesthesia within the first month. Only one of the patients reported hypoesthesia mildly affecting their daily lives.

Two (6.67%) patients had hyperalgesia over the incision scar without hypoesthesia. One (3.33%) patient had superficial wound infection at the harvesting site. Some patients had slightly lateral ankle bulging after surgery most of them reported complete recovery within the first 3 weeks. No patient's mild instability, compartment syndrome or major complications. **Table 4**

Cases

A 28-year-old worker complained of twisting injury to his left knee during playing football, 2 months before seeking medical advice. On presentation he complained of giving away, on and off pain as well as effusion to his left knee. Symptoms increased with squatting and relieved with rest. Preoperative scores included AOFAS score: 99 /100 and FADI score: 102 /104

Isokinetic Muscle Testing as (Peak Torque (Tmax): 34.4 Nm, Peak Torque/Kg Body weight: 0.51 Nm/Kg, maximum Work: 17 Joules and total Work: 140.2 Joules).

ACL reconstruction by peroneus longus tendon graft and fixed by end button on femur and biodegradable screw in tibia. **Figure 1.**

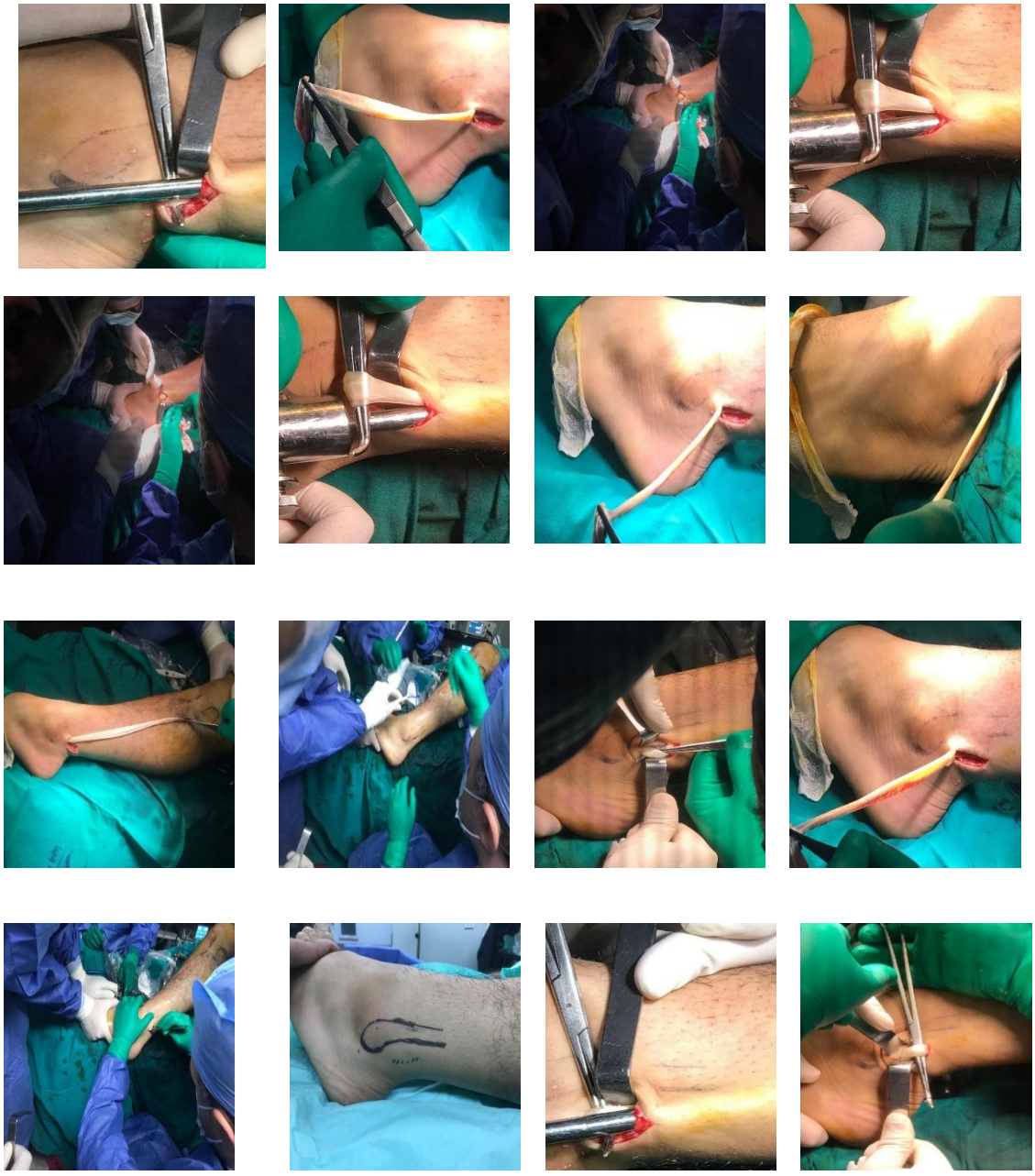

Figure 1: Intraoperative procedures

Postoperative scores included after 1 year (AOFAS score: 99/100, FADI score: 101/104), After 6 months (AOFAS score: 97/100, FADI score: 100/104). Investigations included Isokinetic Muscle Testing Peak Torque (Tmax): 21.6 Nm, Peak Torque/Kg Body weight: 0.39 Nm/Kg, Maximum Work: 11.2 Joules, and Total Work: 87.2 Joules. **Figure 2**

Figure 3: Postoperative follow up

Discussion

Peroneus longus is a powerful evertor of the foot and flexor of the great toe. Loss of this function is an important concern in the use of this graft, but this donor site morbidity has not been adequately evaluated in most of the studies [11].

Several options for tendon grafts exist in ACL reconstruction surgeries. The most popular autografts used are quadrupled hamstring graft and bone patellar tendon-bone (BPTB) graft. The choice of an appropriate autologous graft becomes difficult in cases of revision ACL surgeries or multi-ligament reconstructions, where more than one tendon may be needed. Allografts can be used in such situations but they are not easily available, and carry a small but definite risk of transmission of blood-borne infections and a higher rate of graft rupture [12]. Adequate diameter and length of PL have their upper hand over hamstrings autograft. It was found that even the anterior half of the PL tendon has enough length and strength to be effective in ACL reconstruction. Harvesting the entire PL has no effect on the stability of the ankle or gait [2].

Regarding clinical investigation in the studied patients, 25 (83.33%) patients were dominant on their right side and 5 (16.67%) patients were dominant on their left side, 17 (56.67%) patients were injured on their right side and 13 (43.33%) patients were injured on their left side; 14 (46.67%) patients were injured from road traffic accidents, 10 (33.33%) patients were injured from sports, and 6 (20%) patients were injured from self-fall.

Similar to ours, results of the study done in 2022, showed that right side was more commonly injured in 23 (51%) patients than the left side in 22 (49%) patients [14].

In our results, 14 (46.67%) patients were injured from road traffic accidents, 10 (33.33%) patients were injured from sports, and 6 (20%) patients were injured from self-fall.

Mode of injury in a study by Vijay et al., [15] study in Peroneus Longus group was comparable to ours, they illustrated that 8 patients had road traffic accident, 9 had Self-fall, and 6 had injury during playing sports. There were 30 days after injury presenting to OPD.

In our results, 6 (20%) patients had the surgery within 1 months from the injury, 12 (40%) patients had the surgery from 1 to 3 months' post injury, 7 (23.33%) patients had the surgery from 3 to 6 months' post injury, and 4 (13.33%) patients had the surgery more than 6 months' post injury.

Similarly, time duration from the injury to surgery (months) in Joshi et al., [16] study were evaluated, they found that 6 patients were within 1 month, 24 patients were within 1-3 months, 12 patients were within 3-6 months, and 6 patients were > 6 months. In agreement with the previous findings, Varma et al., [14] found that there was associated meniscal injury in 30 (67%) patients. The most injured was medial meniscus in 28(62%) patients, followed by injury to both medial and lateral meniscus in 6 (13%) patients. Isolated ACL tear was present in 15 patients (33%).

The length of harvested Peroneus longus tendon (PLT) for the ranged from 22 to 31 cm with a mean of 26.1 ± 2.51 cm. The thickness of graft ranged from 8.1 to 9.5 mm with a mean of 8.7 ± 0.44 mm. The graft diameter ranged from 8 to 10 mm with a mean of 9 ± 0.85 mm.

In line with us, a retrospective study aimed to examine the complications and donor site morbidity following PLT harvesting, they had mean graft thickness of 8.16 ± 0.7 (range, 7–10) [17]. However, 61 (74.4%) patients underwent primary ACLR. Varma et al., [14] was in coincidence with us, since he found that, maximum thickness of graft harvested was 9.5mm whereas minimum thickness obtained was 8mm. Mean thickness of graft harvested was 8.5mm ± 0.452. In maximum number of patients (18%) thickness of graft obtained was 8.5mm whereas 9.5 mm thickness was obtained in 3 patients only. Maximum length of graft harvested was 290 mm whereas minimum length was 270mm. Mean length obtained was 278mm ± 6.34.

Goyal et al., **[11]** showed comparable results, mean AOFAS score was 98.9 ± 1.6 in the affected side and 99.3 ±0.7 on the normal side in our study. None of the patients complained of ankle pain or stiffness in the follow-up period. So, they decided that peroneus longus graft can be considered as a potential autograft option for ACL reconstruction in multi-ligament knee injuries and revision ACL reconstruction with favourable functional outcomes. In contrary, a previous case series included 4 patients [18] where evaluation of the functional outcome of the donor site after harvesting PL tendon for revision of knee ligament reconstruction in all the patients before surgery was done, and two weeks and three months after surgery by using AOFAS and FADI. They noted the score was slightly decreased for all patient without significant foot and ankle problems in two weeks after surgery. Furthermore, the function of the foot and ankle returned to normal in three months after surgery which is shown by all score criteria.

Regarding the comparison of pre and postoperative isokinetic muscle testing in the studied patients, Peak torque, peak torque/ kg body weight, maximum work, total work was significantly lower postoperatively compared to preoperatively (P<0.001).

Similarly, a previous study done in 2020, the donor site morbidity and tendon morphology were evaluated after harvesting whole length, full-thickness peroneus longus tendon and reported that the harvested limb had significantly less eversion peak force compared to the contralateral limb ($p < 0.001$) [7].

After comparing of pre and postoperative ankle assessment, ankle inversion and eversion (30°) were significantly reduced postoperatively compared to preoperatively (P=0.008 and 0.018 respectively), while ankle dorsiflexion, ankle plantar flexion, inversion and eversion (180°) were insignificantly different pre and postoperatively.

In line with the previous findings of our study, Goyal et al., [11] confirmed that PLT may be a very useful tendon graft for ligament reconstruction. However, its use is not very popular. One of the main reasons behind its underutilization in knee ligament reconstruction is apprehension about the ankle stability and function and altered foot mechanics after harvesting this graft. They found no functional deficits in any of the 37 patients included in this study. Ankle range of motion and stability were unaffected. Functional outcome scores for the ankle joint were unaffected after harvest of this graft.

Regarding complications, A total of 7 (23.33%) minor complications were observed, 4 (13.33%) patients had hypoesthesia over the dorsolateral aspect of the foot distal to the incision scar. Three of them reported complete recovery of the hypoesthesia within the first month. Only one of the patients reported hypoesthesia mildly affecting their daily lives.

In a recent study 2023 similar results as ours were obtained, since the researchers in this study found that one patient (1.2%) had a transient peroneal nerve injury and foot drop. However, he differs with our remaining complications, since he found that 18.3% of patients had hypoesthesia over the dorsolateral aspect of the foot distal to the incision scar, 2.4% of patients had hyperalgesia over the distal incision scar, and one patient (1.2%) had mild ankle instability. There were two cases (2.4%) of compartment syndrome[7].

Our study results suggest the use of peroneus longus tendon graft harvest technique over other traditional techniques, these results may explain and confirmed by the fact that the peroneus longus tendon graft has many advantages over conventionally used auto-graft. It is easy to identify with a simpler harvesting process, diameter of the graft obtained is larger and less graft associated donor site complications. Peroneus longus tendon graft has equivalent mechanical

strength to that of the hamstring and BPTB grafts.

It was, illustrated that The PLT is the most powerful evertor muscle of the ankle, working as an antagonist of the anterior tibialis muscle. It also acts as the dynamic stabilizer of the ankle. The development of ankle instability in peroneal tendon ruptures has been reported in previous studies. Theoretically, it can be assumed that PLT tendon removal will give rise to the loss of these functions and cause loss of ankle eversion strength or lateral instability. However, the side-by-side tenodesis of the peroneus longus and brevis tendons ensures that the PB tendon compensates for these functions. No loss of muscle strength was observed in any patient in our series [17].

Conclusions

It can be concluded that harvesting PLT with meticulous dissection and good tenodesis to PB eliminate occurrence of minor complications and does not impair the overall functions of the ankle. Peroneus longus graft can be considered as a potential autograft option for ACL reconstruction in multi-ligament knee injuries and revision ACL reconstruction with favorable functional outcomes. longer follow-up periods, larger sample sizes and high-level athletes should be further investigated may be needed to fully evaluate the long-term effects of PLT graft harvest.

This study has some limitations including relatively small sample size, few high-level athletes were included, short follow-up duration, and it was a single center study.

Isokinetic muscle testing for ankle and foot is recommended to improve evaluation of the functional and clinical effect of PLT graft harvest, using more functional score for assessment will be advisable, the effects of PLT autograft for high level athletes should be further investigated and specific Rehabilitation programs for foot and ankle should be started as early as possible after PLT graft harvest.

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