Primary anterior cruciate ligament reconstruction using full-thickness peroneus longus tendon autograft

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Introduction
Many grafts have been described for ACL reconstruction; however, disagreements regarding globally accepted gold standard graft choice persist. Recently, the peroneus longus tendon (PLT) Autograft has been used in the field of ACL reconstruction as an alternative autograft. This study aimed to evaluate the efficacy of the peroneus longus tendon as a graft for primary ACL reconstruction and to study its possible effects on foot and ankle function.

Patients and methods
This was a prospective study that included patients who underwent ACL reconstruction using Peroneus longus tendon autograft. Results were assessed via physical examination. Donor site morbidity of the foot and ankle was assessed using Medical American Orthopedic Foot & Ankle Society (AOFAS) score and Foot and Ankle Disability Index (FADI). Postoperative knee function was evaluated by the International Knee Documentation Committee (IKDC) and Tegner-Lysholm score.

Results
Thirty patients were included in the study with a mean age of 28 years old. Peroneus longus graft diameter was 8.5 ± 0.7 mm. There was a significant difference between pre and postoperative functional scores in IKDC and Tegner-Lysholm score. Ankle scores were excellent. The mean of AOFAS was 97.7 ± 3.1 and FADI was 98.5 ± 0.5.

Conclusion
The peroneus longus tendon is an appropriate autograft source for ACL reconstruction. Its use in primary ACL reconstruction is very encouraging with minimal donor site morbidity.

Keywords:
anterior cruciate ligament reconstruction, tendon autograft, thickness peroneus longus

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Introduction

Anterior cruciate ligament (ACL) injury is considered the most common knee injury, with an incidence of 1: 3000 in the general population [1]. ACL reconstruction is the current gold standard to restore the stability of the knee and to reduce the risk of subsequent meniscal injuries and osteoarthritis [2].

There was a lot of graft selection an autograft, allograft, or artificial grafts. Hamstring tendon (HT) autograft is the most widely used graft for ACL reconstruction all over the world [3]. While The bone-patellar tendon-bone (BPTB) graft is considered by others to be the gold standard graft in reconstruction [4,5]. Disagreements regarding globally accepted gold standard graft choice persist because of some disadvantages and donor site morbidities [6].

Recently, the peroneus longus tendon (PLT) Autograft has been used in the field of ACL reconstruction as an alternative autograft [7,8]. Its use in ACL reconstruction was first described by the Turkish group, Kerimoglu *et al.* [7]

Biomechanical properties of the PLT have been studied in vitro by Mustamsir *et al.* [9] and reported no significant difference in tensile strength between the PLT and a four-strand HT with the same cross-sectional area. Other biomechanical studies reported that the ultimate tensile strength of the peroneus longus tendon ranged from 2122 to 2483 N [10–12], which is similar or even higher than that of the native ACL 2160 N [13]. These findings support the use of PLT autograft in ACL reconstruction.

Subsequently, multiple clinical studies reported good clinical outcomes with minimal donor site complications and supported the use of PLT as an autograft for ACL reconstruction.[7,8,14–25]. However, there is wide variability in techniques and outcome measures between studies.

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The advantages of using PLT graft are its strength and mean thickness is nearly the same as that of the native ACL and its harvest is not difficult. But there are few studies regarding donor site morbidity [7]. This study aimed to evaluate the efficacy of the Peroneus Longus tendon as a graft for primary ACL reconstruction and to study its possible effects on foot and ankle function.

Patients and methods

This is a prospective study of a series of 30 patients with a primary ACL tear and indicated for surgical reconstruction. The study was conducted in the Department of Orthopedics, Beni-Suef university hospital from March 2018 to January 2020. The mean age at surgery was 28 years (range 19–43 years), there were 26 males and 4 females.

ACL rupture was diagnosed by appropriate history, physical examination (anterior drawer, Lachman's, and pivot shift tests), and MRI examination of the injured knee. The inclusion criteria were cases of isolated ACL rupture or combined with medial collateral ligament injuries that were treated conservatively at ages from 18 to 45 years old. Exclusion criteria were as follows: 1- associated multi-ligamentous injury. 2- Patients with pre-existing ankle deformity, neurological impairment conditions, poliomyelitis, or previous significant injuries to the ankle. 3- Patients with overlying skin infections or previous plastic reconstructions over the knee or the ankle. 4- Patients with chondral damage of the knee. 5- Patients with meniscal tears. Preoperative functional scores (International Knee Documentation Committee (IKDC) and Tegner-Lysholm score) were recorded.

Surgical Technique

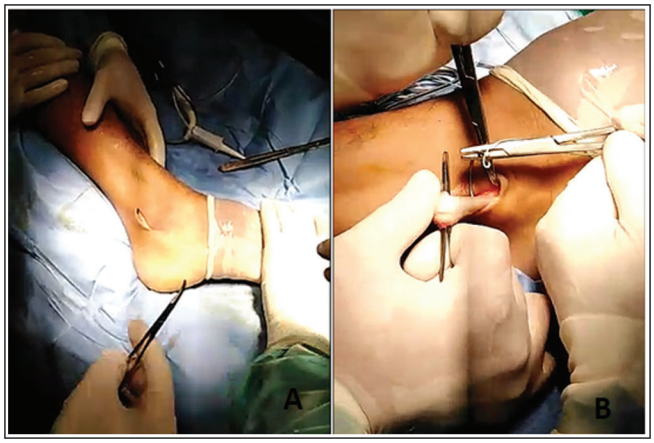
Surgery was performed under spinal anesthesia in a supine position with a bump under the ipsilateral buttock to reduce external rotation of the leg. Prophylaxis IV antibiotic was given and the tourniquet was used in all cases. Standard Diagnostic arthroscopy of the knee through anterolateral and anteromedial portals was performed and preparation of femoral footprint for ACL was done.

The peroneus longus tendon of the ipsilateral leg was harvested through a 2–3 cm longitudinal incision along the posterior border of the lateral malleolus, just above the superior peroneal retinaculum. Skin, subcutaneous tissue, and superficial fascia were incised. The peroneus longus and peroneus brevis tendons were identified and differentiated by the presence of fleshy muscle attached to peroneus brevis at this level and also by the superficial position of peroneus longus relative to peroneus brevis. Both Peroneus longus tendon (PLT) and peroneus brevis tendon were sutured together at the most distal part of the wound with nonabsorbable sutures (Fig. 1).

The open stripper was then used to harvest the Peroneus longus tendon until about 4 to 5 cm below the fibular head to avoid peroneal nerve injury [21] (Fig. 2). The tendon was cut with a scalpel just above the sutures and prepared with number 5 nonabsorbable sutures (Fig. 3).

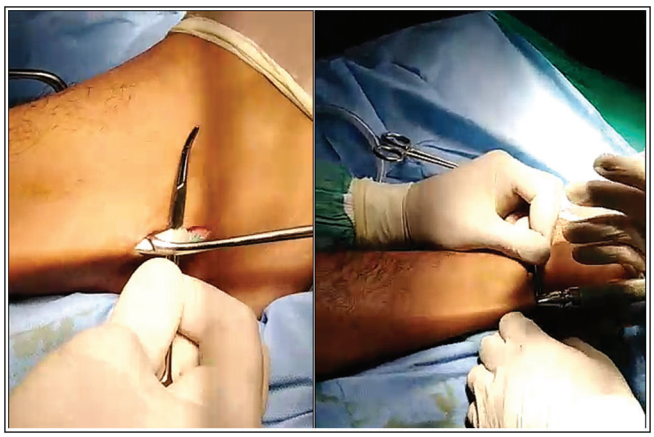
The graft was prepared and folded into triple bundles for single-bundle ACL reconstruction. One end of the graft was attached to the femoral fixation device (Fig. 4). Graft thickness was measured by passing it through cylindrical sizers to determine the exact size of the graft to decide the size of the femoral and tibial tunnel. The femoral tunnel was drilled through a far anteromedial portal independent from the tibial tunnel. The graft was passed from the tibial to femoral tunnel and tensioned through the cycling of the knee joint

Figure 1



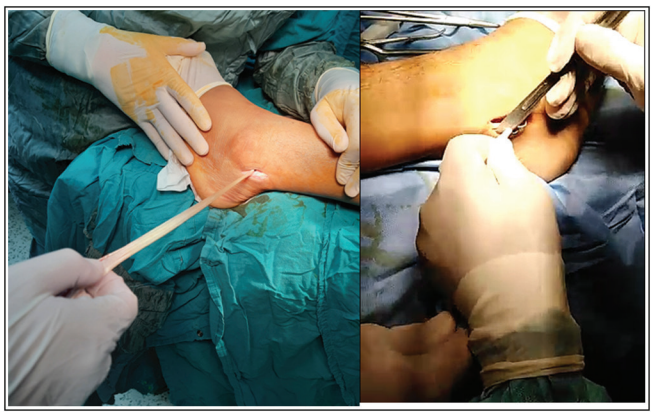
(a): Skin incision behind the lateral malleolus. (b): Suturing both peronii with nonabsorbable sutures.

Figure 2



Open stripper was used for harvesting PLT.

Figure 3



Scalpel was used to cut the harvested tendon above the suture site.

Figure 4

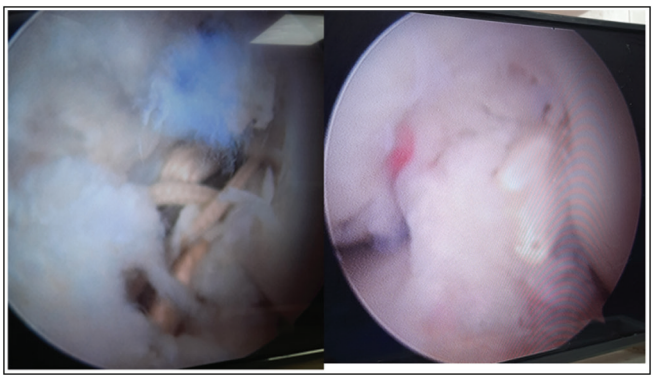
The graft was prepared and folded into a triple. One end of the graft was attached to the femoral fixation device.

up to 25 times to remove any slackness in the graft (Fig. 5). The graft tendon was fixed on the femoral side with the undo button and on the tibial side with the bioabsorbable screw.

The patient was given postoperative antibiotics, analgesics, DVT prophylaxis in risky patients, and a knee immobilizer. Postoperative x-ray was done to ensure proper placement of the tunnels and the position of the fixation devices.

The ACL rehabilitation program was applied to all patients. Patients were educated to exercise the

Figure 5



Arthroscopic view from the anterolateral portal showing the passage of the graft from tibial to femoral tunnel.

operative side leg with partial weight-bearing until 3-weeks post-surgery. Knee extension was maintained immediately after postsurgery and Knee flexion was increased gradually from 0 to 90° in the 1st 3-weeks post-surgery. Each patient was encouraged to exercise the affected ankle actively from the first day postoperatively.

Patients have reviewed 2 weeks post-surgery for removal of stitches and wound assessment. At 3rd week patients were allowed full weight-bearing. The knee immobilizer was continued till one month postoperatively. Patients were then followed up regularly at 3 months, 6 months, 1 year, and annually thereafter.

Postoperative evaluation

Postoperative functional outcome and donor site morbidity were recorded sequentially for at least 1 year after surgery with recording the results of instability tests (Lachman and pivot shift test), functional scores (IKDC and Tegner-Lysholm score), ankle functional scores (The American Orthopedic Foot & Ankle Society (AOFAS) score [26] and Foot and Ankle Disability Index (FADI) score) [27]. Bilateral thigh circumference at 10 cm and 20 cm from the upper pole of the patella were measured and recorded

Statistical analysis

The outcomes of final postoperative measurements were compared to the preoperative scores using the Mann–Whitney *U* test. Statistical significance was accepted at $P<0.05$.

Results

The study sample of 30 patients consists of 26 males and 4 females. The right knee was involved in 13cases and the left in 17. The mean age of the patients was 28 years (range 19–43 years). The injury mechanism of the patients was road traffic accidents (RTA) in

Table 1 Demographic data

Variable	Result
Age/Years	28 ± 8.3 (19–43)
Sex M/F	26 (86.6%) M/ 4(13.3%) F
Side R/L	13(43.3%) R/ 17(56.6%)L
Mechanism of injury	RTA: 16, Sports: 9 And Others: 5
Follow-up period in months.	20 (12-36)

Table 2 Stability tests outcomes

Test	Negative	Grade 1	Grade 2	Grade 3
Lachman	25 (88%)	4 (13%)	0	0
Pivot Shift	29 (96.6%)	1 (3.3)	0	0

53.4%, sports-related injury in 30%, and other injuries in 16.6% Table 1.

Graft diameter

Intra-operative measurement of PLT diameter was recorded. The mean diameter was 8.5 ± 0.7 mm. The maximum diameter of the graft was 9. 5 mm and the minimum diameter was 7.5 mm. In 93% (28 cases) the graft diameter was ≥8 mm.

Stability examination

Postoperatively, knee joint stability was assessed using the Lachman test which showed normal findings in 25 cases (88%), while 4 patients (13%) had 1+ laxity and gross laxity in one patient who was experienced repeated trauma and re-tearing of the ACL graft. Pivot shift test was reported negative in 29(96.6%) cases and positive in one patient Table 2.

Functional outcome

The mean IKDC score preoperative was 55.6 ± 12 and postoperative at final follow-up was 91.5 ± 6.2. Mean Tegner-Lysholm score preoperative was 66.8 ± 10.2 and postoperative was 91.5 ± 8.3. There were significant differences between preoperative and postoperative Scores in IKDC and Tegner-Lysholm score (P<0.05) (Fig. 6).

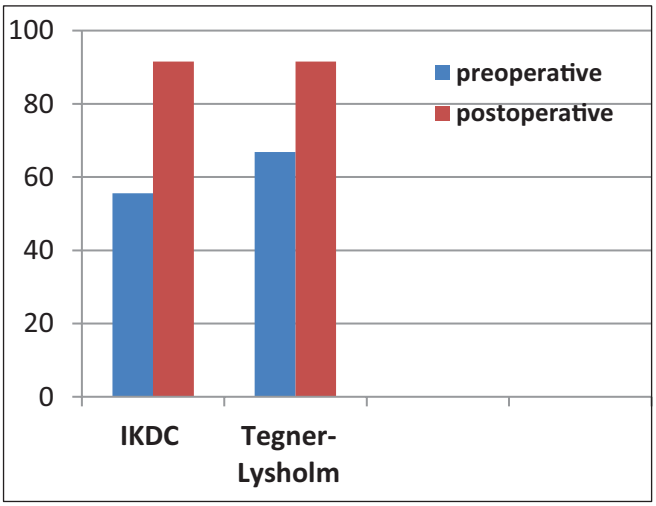
Donor site morbidity

The effect of harvesting PLT autograft on the ankle joint was evaluated using AOFAS and FADI score. The mean AOFAS score of the donor's ankle was 97.7 ± 3.1 and the FADI score was 98.5 ± 0.5. See Table 3.

Thigh circumference

The mean of thigh circumference measurement at 10 cm and 20 cm from the upper pole of the patella in the operative site and the contralateral side were recorded and illustrated in Table 4. There was no significant difference both at 10 cm and 20 cm of thigh circumference between both sides (P>0.05).

Figure 6



Functional outcome scores.

Table 3 Donor site morbidity scores

Score	Mean	Range	Rating
AOFAS	97.7 ± 3.1	88–100	Excellent
FADI	98.5 ± 0.5	90–100	Excellent

Table 4 The mean thigh circumference measurements

Side	At 10 cm	At 20 cm
Operative Side	42.8 ± 3.65	51.3 ± 3.26
Contralateral Side	44.10 ± 3.80	52.7 ± 3.31
P Value	0.473	0.279

Discussion

There are multiple graft options available for ACL reconstruction. bone-patellar tendon-bone (BPTB), hamstring tendon autograft, and allograft are popular options but the argument still exists about the most suitable graft for ACL reconstruction [28]. Although BPTB graft is considered the gold standard for ACL reconstruction, it has many complications such as rupture of the patellar tendon, patellar fracture, quadriceps weakness, anterior knee pain, difficulty in kneeling, and injury to the infra-patellar branch of the saphenous nerve which may cause numbness [12].

The hamstring tendon grafts are less likely to produce anterior knee pain compared with BPTB graft but they can produce weakness in hamstring muscle strength which may impair the protective effect of the hamstring muscles on the reconstructed ACL [29]. Allograft also has many drawbacks like less availability in some countries, high costs, and the possibility of disease transmission and immunological reaction [30].

Peroneus longus tendon was used for ACL reconstruction and showed good functional outcomes [7]. the tensile

strength of the peroneus longus was biomechanically tested and showed no significant difference when compared to the four-strand hamstring tendon [9]. Graft diameter is considered one of the most important factors affecting the outcomes of ACL reconstruction. Autograft with a diameter equal to or larger than 8 mm showed decreased failure rates and also provided a protective effect in young patients less than 20 years [31]. Another study found a higher revision rate with a graft diameter of less than 8 mm and also a significantly higher KOOS score and IKDC score with a 1 mm increase in graft diameter [32].

In this study, we found that the mean diameter of triple strands peroneus longus tendon graft was 8.5 ± 0.7 mm. This result indicates that peroneus longus autograft is a potential choice for ACL reconstruction with a lower risk of later re-rupture incidence in the future. Rhatomy *et al.* studied the results of ACL reconstruction with peroneus longus tendon autografts and compared it with hamstring tendon autografts. They found that there was a significant difference in graft diameter between both tendons in favor of the PLT graft with a mean difference of 0.6 mm.

Our study showed good results in terms of both functional outcome and knee stability. Postoperative IKDC score and Tegner-Lysholm score results were excellent. This result is similar to the results of the previous studies in the literature. Kerimoglu *et al.* showed a good result of ACL reconstruction using the peroneus longus tendon as a graft in 29 patients. The mean Lysholm score was 83.7 [7]. Rhatomy *et al.* retrospectively reviewed the 2-years follow-up outcomes of Single bundle ACL reconstruction with peroneus longus tendon graft in 75 patients. IKDC, Modified Cincinnati and Tegner-Lysholm scores were 95.69 ± 3.35, 93.29 ± 7.04, and 89.70 ± 8.34, respectively [8,33,34]. See Table 5, showing a demonstration of the results of the previous studies in the literature.

The primary action of Peroneus longus is plantar flexion the first ray of the foot, while other actions include plantar flexion and eversion of the ankle. So, the main concerns after harvesting the Peroneus longus tendon are ankle instability and the deficit of first ray plantarflexion especially in the stance phase of gait. [18] Angthong *et al.* reported that the peak torques of eversion and inversion were significantly lower on the harvested ankle compared with the contralateral ankle. However, they reported that there was a non-significant deterioration of ankle functions via the evaluations of ankle scores.[14] The results of our study were matched with many other authors who founded that the function of the donor's ankle was excellent according to the ankle functional test [18,24,33].

The limitations of this study were the limited number of patients involved in the study. The relatively short period of follow-up and further studies could focus on a longer evaluation. The preoperative donor ankle scores were not reported. Objective measurements of ankle evertor strength and its relationship with the functional ankle score could be evaluated. Instrumented measurement of knee and ankle

Table 5 Showing the comparison of our study with the previous similar studies

Study, year	Cases (male/female)	Age, year	Follow-up, months	PLT graft	Fixation methods	Knee scores	Ankle outcomes and scores
Kerimoglu, 2008 [34]	12 (12/0)	31 ± 8	52 ± 32	Full-thickness	Interference nail	Lysholm: 83.3% good or very good IKDC: (66.6%) normal or nearly normal,	Two patients (6.9%) complained of mild to moderate pressure pain, paresthesia, No ankle joint dysfunction
Zhao, 2012 [8]	12 (4/8)	29 (20–46)	24	Anterior-half	Endobutton + Bioscrew	IKDC 95.6 ± 3.9 Lysholm 97.7 ± 4.1	AOFAS: 97.2 ± 1.6 FADI: 96.9 ± 2.5
Angthong, 2015 [14]	24 (15/9)	NR	12.8	Full-thickness	Endobutton + Bioscrew	NR	AOFAS: 96.0 ± 9.6 Peak torques of eversion and inversion were significantly lowered
Rhatomy, 2019 [33]	75 (59/16)	26.7 ± 8.6	24	Full-thickness	XO-button + Bioscrew	IKDC: 95.69 ± 3.35. Modified Cincinnati: 93.29 ± 7.04. Tegner-Lysholm: 89.70 ± 8.34.	AOFAS: 98.93 ± 3.10 FADI: 99.79 ± 0.59
Rhatomy, 2019 [21] (PLT vs. HT study)	24 (20/4)	26.4 ± 8.6	12	Full-thickness	XO-button + Bioscrew	IKDC: 92.5 ± 6.2 Modified Cincinnati: 92.7 ± 5.9 Lysholm: 94.9 ± 5.6	AOFAS: 97.3 ± 4.2 FADI: 98 ± 3.4
Shao, 2020 [24]	7 (3/4)	34.0 ± 11.2	31.8 ± 7.7	Full-thickness	NR	NR	AOFAS: 98.5 ± 2.4 Karlsson-Peterson: 97.9 ± 2.5
Narayanan, 2020 [18]	25 (19/6)	NR	3	Full-thickness	Tightrope + Bioscrew	IKDC: 98.53	MRC grading of the ankle was grade 5 in all patients.
Our study	30 (26/4)	28 (19–43)	20 (12–36)	Full-thickness	Endo-button + Bioscrew	IKDC: 91.5 ± 6.2. Tegner-Lysholm: 91.5 ± 8.3.	AOFAS: 97.7 ± 3.1 FADI: 98.5 ± 0.5

stability by newer devices such as arthrometers was not available. The results of our study are very encouraging, but long-term follow-up and a large number of patients are needed further. Also, a comparison of the results of PLT graft with other graft options is required to conclude these results and observations.

Conclusion

The peroneus longus tendon is an appropriate autograft source for ACL reconstruction. Its use in primary ACL reconstruction is very encouraging and has many advantages such as easy harvesting, obtaining adequate graft diameter, excellent postoperative knee and ankle functional scores, and minimal donor site morbidity.

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Conflicts of interest

The authors have no relevant financial or non-financial interests to disclose.

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