Flexor hallucis longus reroute for chronic achilles tendon rupture with no root

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Received: 12-Jun-2024
Revised: 04-Aug-2024
Accepted: 10-Aug-2024
Published: 08-Mar-2025

The Egyptian Orthopaedic Journal 2024, 59:612–621

Background
Chronic Achilles tendon (AT) tendinopathy and ruptures are coupled with remarkable functional impairment and incapacitating pain. Flexor hallucis longus (FHL) transfer is a promising surgical procedure to regain function and improve Achilles disease pain. This study aimed to explore the clinical results of FHL transfer to the AT.
Methods
From March 2020 to October 2022, 24 cases with neglected AT rupture with a considerable gap were admitted to our department. All patients were managed with open tendon debridement and transosseous FHL tendon transfers. Patients were assessed by the American Orthopedic Foot and Ankle Society hind foot score, the short form 12 question (SF-12) questionnaire.
Results
The mean age of the cohort at surgery was 47.6±5.9 years. All cases were followed-up for at least 1 year after surgery. The dimension of the defect in the tendon calculated was 5.4±0.8 cm. Regarding patient reported outcome measures, their values are conveyed in Table 2. The mean hindfoot American Orthopedic Foot and Ankle Society score improved from 56.8±5.4 presurgery to 87.8±6.4 postsurgery. The mean physical SF-12 score improved significantly form preoperative value of 36.8±5.0 to 53.5±2.8 postoperatively.
Conclusion
In conclusion, the FHL transfer for chronic Achilles tears is a harmless, reproducible, and easy technique with little risk of complications. Most patients recuperated to their previous daily doings with a high level of gratification.

Keywords:
chronic Achilles tendon rupture, flexor hallucis longus transfer, non reconstructable Achilles rupture

Egypt Orthop J 2024, 59:612–621

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Introduction

Chronic tears of the tendon Achilles can be coupled with remarkable functional loss and pain. Frequently, those cases are treated first with nonoperative trials such as analgesics, eccentric calf reinforcement exercises, functional ankle rehabilitation exercsies, extracorporeal shock wave therapy, or a combined approach [1].

However, if these measures failed after three months without advance, then surgical management was attempted. Usually, those patients have large gaps, therefore an augmentation procedures should be done [2]. Examples for the augmentation procedures described are V-Y myotendinous flap or a Bosworth turndown flap, free tendon grafts (eg, gracilis), and transfers of musculotendinous units (peroneus brevis (PB), flexor digitorum longus (FDL), and flexor hallucis longus (FHL)). Other methods include the usage of synthetic grafts [3].

Since its introduction in 20 years by Hansen *et al.* [4], the transfer of the FHL has found a pervasive acceptance in managing neglected and irreparable Achilles tendon (AT) ruptures. It offers good to excellent clinical results while improving pain and plantar flexion strength. Along with the mechanical backing postulated by the tendon transfer, it delivers extra blood source to the unhealthy AT [5,6].

Different operative procedures for FHL transfer are pronounced in the literature. In the classical paper by Wapner *et al.* [7], a trans osseous tunnel was anticipated to anchor the tendon within the calcaneus and reroute it to the AT. Hansen and Hahn *et al.* [8] reported a modification of that technique without the calcaneal tunnel, redirecting the FHL tendon directly through the tendinous soft tissue insertion site of the AT to escape the shift of the lever arm of the Gastrosoleal muscle complex. Nevertheless, a transtendinous

transfer keeps a lever arm analogous to the AT but has the menace of weak fixation, creep, and stretching over time, consequently leading to an elongation and decreased plantar flexion power [9].

The primary outcome of this study was to explore the clinical and functional results after a trans-osseous FHL transfer. A secondary goal was to study the influence of impaired great toe function after transfer on the subjective outcome and the effect of the muscle quality on the overall functional results.

Patients and methods

From March 2020 to October 2022, 24 cases with old, neglected rupture of the AT with a considerable distance were admitted to our department. All patients were treated with open tendon debridement and trans-osseous FHL tendon transfers.

Patients were diagnosed with careful medical history and through clinical examination. Clinically, all patients had a gap in the course of the AT, swelling of the torn edges, difficult tip-toe walking. Thompson test [10] was positive in all patients in prone position. Magnetic resonance imaging was done for all cases to assess quality of the tendon edges, and the presence of a distal stump and to measure the tendon gap in millimeters.

Surgical technique

All cases were done under general anesthesia in a prone position, a high thigh tourniquet was applied in supine position after the limb being exsanguinated, and then the patient was positioned prone with the protection of all bony prominences. The leg was hung from the edge of the table to facilitate the plantar flexion of the ankle.

A posterior vertical incision was done to the gastrosoleus complex proximally to the upper part of the calcaneus distally. Scrupulous removal of degenerated and frayed tendon edges was done with a possible preservation of the tendon sheath. Both edges of the torn tendon were cleaned of any fibrotic, unhealthy, and necrotic materials.

The dimensions of the resultant gap were calculated with the ankle in thirty degrees of plantar flexion. Gastrocnemius recession [11] was attempted when needed. The proximal stump was left in place with no repair in this technique. (Fig. 1).

The FHL was dissected via a separate medial incision from the base of the big toe to the navicular bone at the level of the master knot of Henry [12]. The FHL

Figure 1

Posterior ankle incision in prone position showing degenerated proximal stump with little potential for healing.

was then debrided from the adjoining soft-tissue and the neighbouring FDL tendons, to which it is linked, then it was split distally leaving a part of the tendon available for tenodesis with FDL of the second toe in neutral position. (Figs. 2–4).

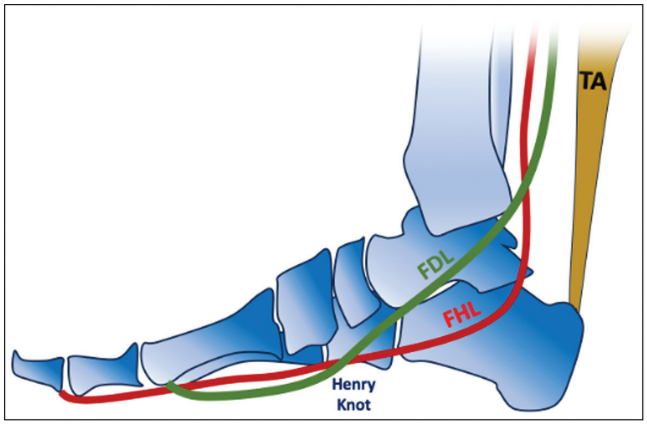
The FHL is identified proximally behind the torn stump of AT. The FHL is then retrieved via the posterior incision and the free end is whipstitched for later rerouting. (Figs. 5,6).

In all cases a horizontal tunnel of an adequate diameter enough to allow the FHL tendon was created in the calcaneus near the insertion of the AT in a medial to a lateral path.

The rerouting was done on 4 steps: the first step is medial retrieval of the graft, the second step is transosseous passage, the third step is lateral retrieval of the graft and the final step is suturing the graft back to itself. The FHL tendon after going through the burrow was interlaced through the proximal part and then sutured to itself and the torn ends of the tendon were stitched back to the FHL. (Figs. 7–11).

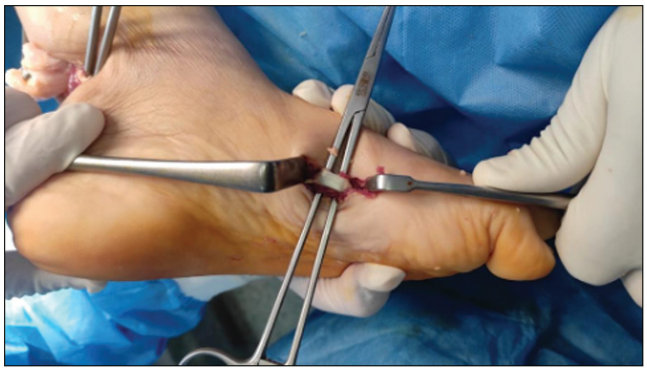
The tension of the repair was determined based on the tension of the contralateral side. The paratenon was closed as possible to avoid postoperative adhesions with the scar. The repair was immobilized in a below knee plaster with the ankle in 45° of plantar flexion for 3 weeks, sutures were detached after 3 weeks and a new plaster in a zero degrees of flexion position was applied for another 3

Figure 2



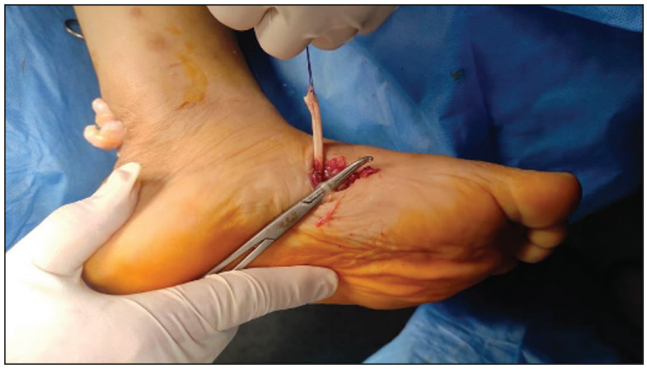
The decussation of the flexor digitorum longus and flexor hallucis longus at level of the master knot of Henry.

Figure 3



Exposing the flexor hallucis longus at Master knot of Henry.

Figure 4



Distal harvesting of flexor hallucis longus at Henry knot.

Figure 5

Exposing the flexor hasllucis longu behind the torn Achilles tendon.

Figure 6

Retrieving the flexor hallucis longus proximally.

weeks. Partial weight bearing was permitted after 6 weeks. Physical therapy commenced afterward. Cases were followed-up at 3 weeks, 6 weeks then monthly for 6 months, every 3 months till last follow-up.

In the follow-up appointments, all cases were evaluated for neutral foot walking, hind foot and fore foot alignment, wound status, pain intensity if present, ankle range of motion, great toe plantar flexion, heel rise, Thompson test, gastrosoleal muscle atrophy.

An informed consent was taken from every case before involvement in the analysis. The research was accepted by the local ethical team of the university.

Patients' assessment

Patients were assessed during follow-up visits using multiple functional, objective and quality of life scores. The American Orthopedic Foot and Ankle Society (AOFAS) hindfoot score was used for the evaluation of the outcomes, this 100 points score comprises 40 points for pain, 50 for function, and 10 points for alignment, it was evaluated preoperative, and at the final follow-up (minimum 12 months postoperatively) [13].

Foot function index (FFI) was also used to assess how the foot pain has affected the ability to manage in everyday life. It has pain scale (50 points), disability scale (90 points) and Activity limitation scale (30 points). The overall score is divided by 170 points and the percentile is calculated to assess functional index [14].

Figure 7

Rerouting step 1: medial retrieving the tendon from distal to proximal.

Figure 8

Rerouting step 2: Passing tendon through the trans-osseous tunnel.

Figure 9

Rerouting step 3: Lateral retrieval of flexor hallucis longus from distal to proximal.

The short form 12 question (SF-12) questionnaire was used to assess quality of life before and after the surgery. Only physical score was used [15].

The hallux plantar flexion was also assessed after surgery to investigate loss of power after FHL transfer. The power was assessed using paper grip test. A simple grading was used; 0 only passive hallux planter flexion, 1: active hallux planter flexion, 2: acive againsit resistance of examiner thumb, 3: firm paper grip test [16].

The postoperative pain was assessed using a numerical visual analog score where 0 equals no pain while 10 equals worst pain faced [17].

The calf muscle power and ankle planter flexion power were judged using the MRC (Medical Research Council) scale which has six ratings from 0 to 5, where 0 means no motion in the muscle, 1 means twinkles, 2 means motion only if gravity was abolished, 3 means motion versus gravity, 4 means motion versus gravity with some resistance, and 5 meets for standard power [18].

Achilles Tendon Total Rupture Score was also used as an injury specific patient reported outcome measure. It includes 10 questions related to limitations and difficulties specific to injured AT. It has a total score of 100 points [19]. The Victorian Institute of Sport Assessment-Achilles scale is another patient reported

outcome measure that is used to evaluate the clinical severity for patients with chronic Achilles rupture. It has eight questions covering all symptoms related to Achilles injury with a total socre of 100 points [20].

Statistical methods

The data of the cohort were statistically evaluated using the statistical package for social sciences (SPSS) version 25 for Windows (IBM Corp., Armonk, NY, USA). Paired sample test was used to describe the relations between functional outcomes preoperative, and at the final follow-up. The Qui square test was performed to analyze the qualitative data. *P* values of less than 0.05 were pondered as significant.

Figure 10

Rerouting step 4: suturing tendon back to itself using nonabsorbable sutures.

Results

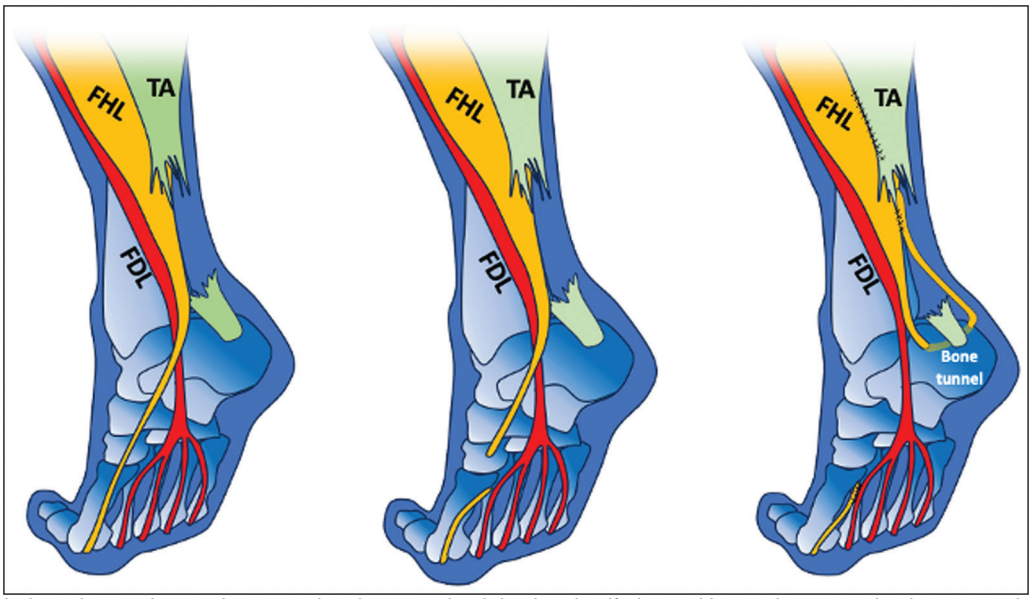
The study cohort included 24 patients with full-thickness rupture of AT. The mean age of the cohort was 47.6±5.9 years. There were 20 (83.3%) male patients and four (16.7%) females. The right side was affected more than the left side. (15 right and 9 left). Four cases were diabetic type II (16.7%). (Table 1).

Three (12.5%) cases had sport related injury, 8 (33.3%) cases reported just simple falling, 10 (41.7%) patients had history of chronic Achilles tendinopathy while the last 3 (112.5%) cases reported history of steroid injection with spontaneous tendon rupture a couple of weeks after injection (Table 1).

All cases were followed-up for at least 12 months after surgery. The mean follow-up period was 16.4±3.1 months. The mean interval from injury to surgery was 6±2.3 months. The average span of the defect in the tendon calculated intraoperatively after debridement while the foot in a 30 of plantar flexion was 5.4±0.8 cm ranging from 4 to 6.5 cm. (Table 1).

Regarding patient reported outcome measures, their values are conveyed in Table 2. The mean hindfoot AOFAS score upgraded from 56.8±5.4 preoperatively to 87.8±6.4 postoperatively. The mean

Figure 11



Summary of technique: harvesting tendon, rerouting then suturing it back to itself along with suturing to proximal stump and tenodesis of the remaining flexor hallucis longus to flexor digitorum longus.

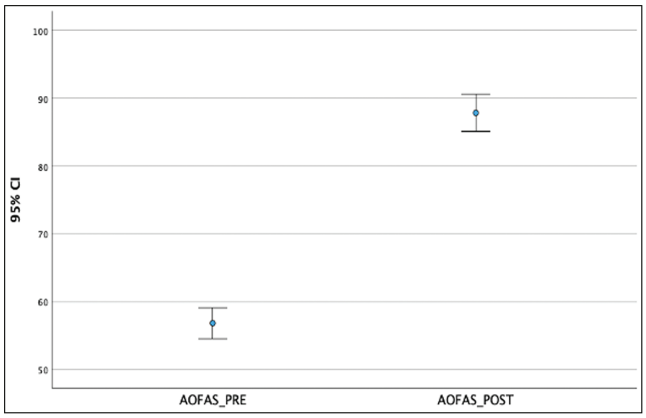
foot function index score improved significantly from 37.1±3.8 preoperative to 84±14.9 postoperative. The mean physical SF-12 score improved significantly from preoperative value of 36.8±5.0 to 53.5±2.8 postoperatively. The mean ARTS score increased from 48.4±5.2 preoperatively to 87±4 postoperatively. The mean Victorian Institute of Sport Assessment-Achilles improved from 40.9±4.6 preoperatively to 78.9±2.4 postoperatively. The mean visual analog scale score at the final follow-up was 1.87±1.39 points. (Table 2, Figs 12–16)

Regarding objective ankle examination, the mean active postoperative ankle dorsiflexion was 9.4 degrees and the mean active ankle plantar flexion was 43.5 degrees. The ankle planter flexion power upgraded significantly from 0.4±0.6 preoperatively to 4.2±0.6 postoperatively. The hallux plantar flexion power was assessed postoperatively. One case had only passive and lost active plantar flexion. Two cases had active hallux plantar flexion but not against resistance. Nine cases had good power against resistance and the rest 12 cases had very firm paper grip test and very stable tip toe walking. (Fig. 17)

Table 1 Demographic data of the patients (*n*=24 patients)

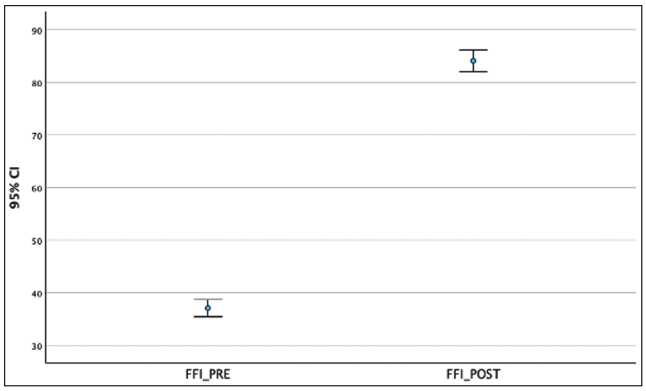
Age		
Mean±SD	47.6±5.9	
Median	45.5	
Range	39–58	
Sex, *n* (%)		
Male	20	83.3
Female	4	16.7
Medical comorbidities, *n* (%)		
DM	4	16.7
Side, *n* (%)		
Right	15	62.5
Left	9	37.5
Mode of injury, *n* (%)		
Sport related	3	12.5
Falling	8	33.3
Chronic tendinopathy	10	41.7
Steroid injection	3	12.5
Follow-up		
Mean	16.4 months±3.1	
Median	15.5	
Range	12–24	
Interval between rupture and surgery		
Mean	6 months±2.3	
Median	6	
Range	2–10 months	
Gap size		
Mean	5.4 cm±0.8	
Median	5.5 cm	
Range	4–6.5 cm	

Figure 12



An error bar showing a significant improvement between the preoperative and postoperative hindfoot American Orthopedic foot and ankle society score.

Figure 13



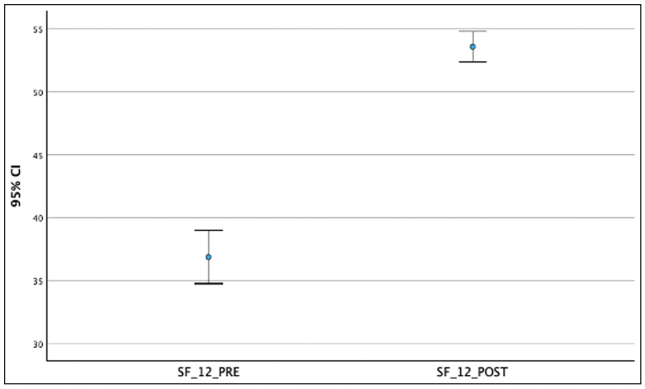
An error bar showing a significant improvement between the preoperative and postoperative foot function index scores.

Table 2 Patient reported clinical outcome scores

	Preoperative	Postoperative	Test	Significance
AOFAS hindfoot	56.8±5.4	87.8±6.4	Z= 4.29	*P*<0.001
FFI	37.1±3.8	84±14.9	Z= 4.28	*P*<0.001
SF-12	36.8±5.0	53.5±2.8	Z= 4.26	*P*<0.001
ATRS	48.4±5.2	87±4	Z= 4.29	*P*<0.001
VISA-A	40.9±4.6	78.9±2.4	Z= 4.21	*P*<0.001
Postoperative VAS at 12 m follow-up	1.87±1.39			

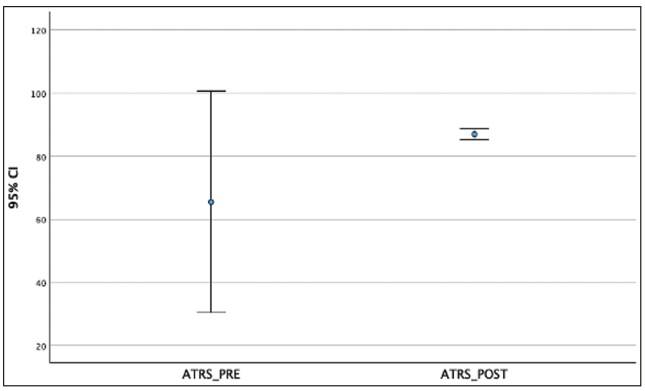
Z= Wilcoxon signed ranks test for paired nonparametric testing.

Figure 14



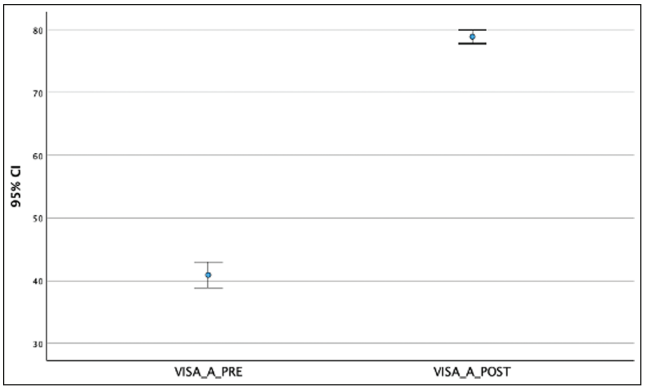
An error bar showing a significant improvement between the preoperative and postoperative physical SF-12 quality of life score.

Figure 15



An error bar showing a significant improvement between the preoperative and postoperative Achilles tendon total rupture score.

Figure 16



An error bar showing a significant improvement between the preoperative and postoperative Victorian Institute of sport assessment-Achilles score.

Regarding the complications, two cases had postoperative adherent scar, two cases had postoperative deep vein thrombosis (DVT) that was managed medically, 2 cases had a mild superficial skin infection that was managed surgically with early debridement. However, 4 cases had poor gait push-off at the final follow-up. (Fig. 18).

There was no correlation between the occurrence of complications and final follow-up scores. All cases achieved good to excellent scores regardless presence of the reported complications. (Table 3).

There was a significant positive correlation between the final AOFAS score and final follow-up planter flexion power (Pearson correlation R=0.666, *P* value = 0.001). The more powerful the planter flexion, the better the AOFAS score. (Fig. 19).

Discussion

Numerous autologous tendon transfers have been portrayed for chronic Achillies ruptures, but the tendons commonly described were the FHL and peroneus brevis. The transferal of the FHL is widely used because; this tendon is the 2nd powerful ankle plantar flexor; its line of work is parallel with that of the AT; It preserves mechanical ankle muscles equilibrium; its harvest conveys a minimal risk of complications; it upsurges the blood supply to the repair [21].

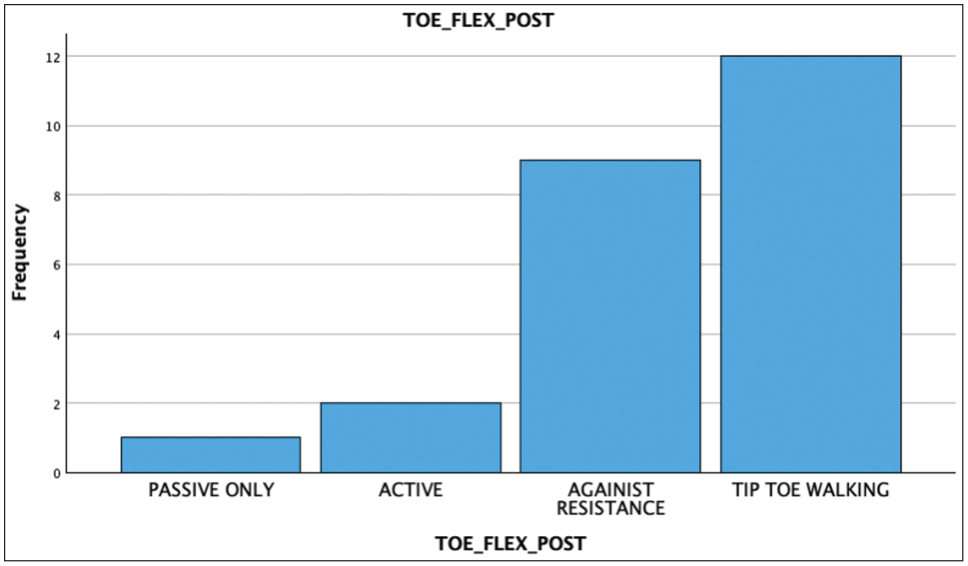
A hypothetical unscrupulous consequence of FHL harvest is the cost of loss the big toe flexion, with diminished gait push-off power. Conversely, despite the failure of the big toe flexion, almost all patients do not complain of perceptible deformities or weakness and recommence their previous usual doings with no limitations. The indisposition accompanying FHL tendon transfer appears not to be clinically significant, even in running activities that require powerful push-off and muscle equilibrium [22].

A systematic review by Maffulli and colleagues in 2023 reported the percentage of mishaps after the usage of FHL transfers was about 14.8%. The chief impediments were one DVT, four deep infections, and one re-tear [3]. In our series, no single case of re-rupture has been reported.

AT rupture leans to strike almost 2–6 cm superior to the insertion of the tendon as the blood vessel dissemination and blood source are somewhat sparse. The chief cause of the Achilles tear is the disintegration of fibers affected by humble blood supply and kinematic considerations [23].

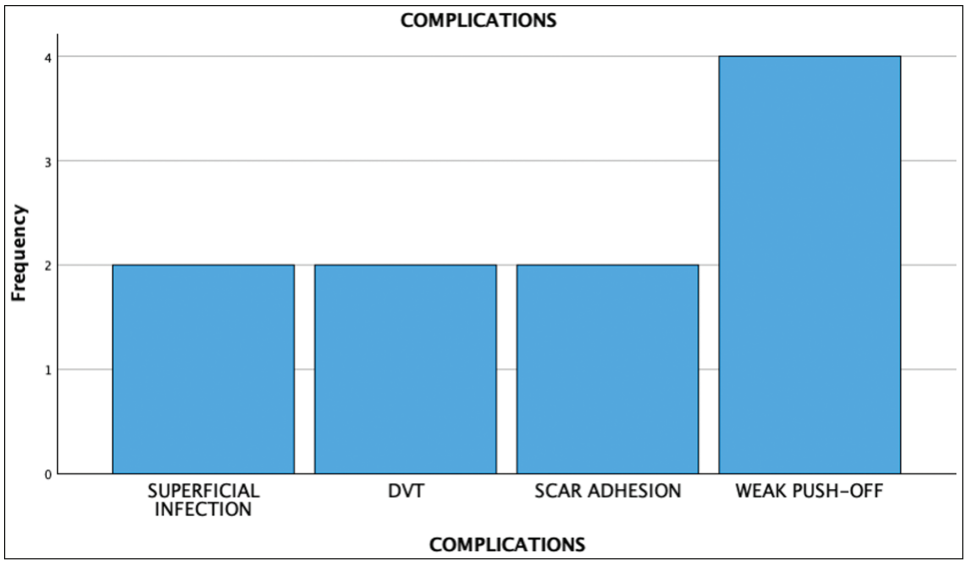
The outcome of conservative protocols is poor in comparison to surgical interventions, and the overall patient satisfaction is less than 50% with nonoperative protocols. Surgical management of old neglected

Figure 17



The postoperative hallux plantar flexion grading.

Figure 18



The reported postoperative complications.

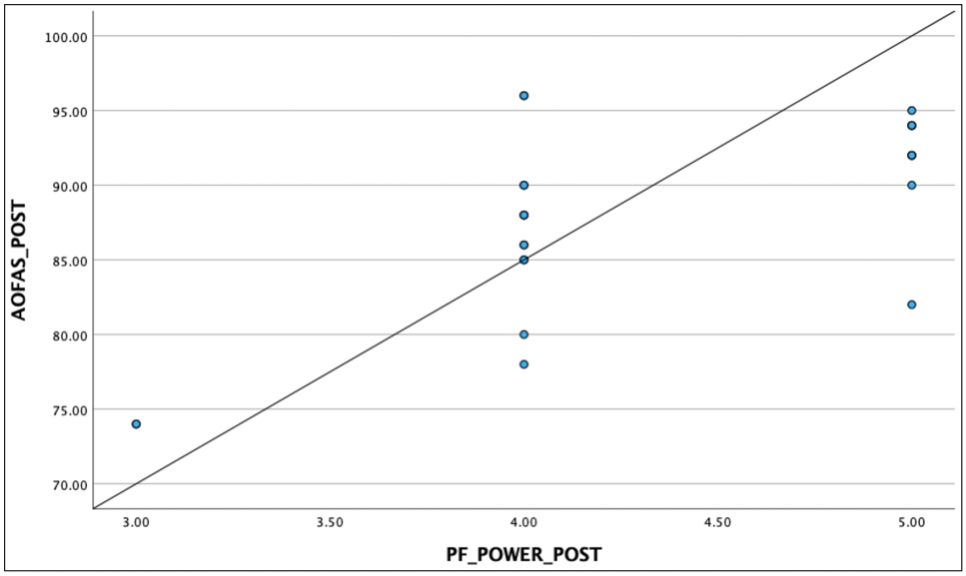
Table 3 Chi square values for the final scores in correlation to occurrence of complications

	Final AOFAS	Final FFI	Final SF-12	Final ARTS	Final VISA-A
Pearson Chi Square (X^2)	25	25	17	25	9
P value	0.247	0.125	0.319	0.247	0.342

Achilles tears has been extensively acknowledged by surgeons. Numerous options have been described, including direct suturing, gastrosoleal rotation, V-Y plasty, tendon transfer, synthetic tendon grafts, and allograft tendon grafts. Nevertheless, there are quiet debates concerning the optimal techniques for chronic gaps of Achilles. The occurrence of re-tears after standard surgical management is prohibitive. Furthermore, standard invasive protocols has shortcomings such as challenging technique necessitating expertise, bad graft power and humble blood supply mainly if the gap is larger than 5 cm [24].

FHL transfer procedure has been progressively documented and incessantly amended over the years. Literature has proved that FHL transfer is a harmless and successful surgical protocol for patients with chronic AT gaps. Yet, the proof of that procedure is

Figure 19



The positive correlation between postoperative final American Orthopedic foot and ankle society score and final planter flexion power.

lacking because of the inadequate sum of cases, and the shortage of prolonged follow-up studies. It has been stated that the FHL transfer can be harvested via a one or two wounds. Yet, which practice is superior and if the inferior stump of the FHL should be weaved to the FDL still debatable [25,26].

Reconstruction of Achilles with FHL transfer may decrease the plantar flexion power of the big toe, causing decreases balance and propulsion hypothetically. Richardson *et al.* stated that diminished distal phalangeal pressure and FHL weakness in 22 cases [26]. Yet the plantar flexion of the big toe was firm in most of cases. The postoperative AOFAS hindfoot at last follow-up visit was good to excellent.

The suturing of FHL to flexor digitorum leads to floating halluces with hyperextension and alignment troubles were reported in some papers. Some surgeons do not regularly execute a tenodesis of FHL to FDL, they also observed the feeble big toe flexion postoperatively, however, it was not clinically relevant [27]. Conversely, in our series, all cases received FHL tenodesis to 2nd FDL tendon to preserve plantar flexion and gait push off. Neither of those complications were reported in our series.

The main limits of this study are its design type (observational case series prospective study) with a minor case series which may raise the risk of sampling bias, the inability to follow-up all cases with a complete clinical appraisal, and the deficiency of a control group. The strength points are that the cases of this study were followed-up for a comparatively longer duration, at least 12 months, and the preoperative and postoperative clinical assessments were comprehensive using multiple patients reported outcome measures and objective scores.

In conclusion, the FHL transfer for chronic Achilles ruptures is a harmless, reproducible, and simple technique with little risk of morbidity and complications. Though the harvest of FHL may results in likely weakness of plantar flexion power in the big toe, furthermost cases could recover to their previous daily doings with a high level of satisfaction.

Compliance with Ethical Standard

Informed consent was obtained from all individual participants included in the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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