Acta Orthop. Belg., 2022, **88**, 835-841

ORIGINAL STUDY

doi.org/ 10.52628/88.4.07

Results of a shuttle catheter technique for surgical repair of acute extensor hallucis longus tears

Osama Samir Gaarour, Amr Elshahhat

From the Mansoura University Hospital, Mansoura University, Egypt

Background and study aims: The proximal end of a torn Extensor hallucis longus (EHL) is usually so retracted that a proximal wound extension is always required to retrieve it; leading to more adhesions and stiffness. This study aims at assessment of a novel technique for proximal stump retrieval and repair of acute EHL injuries with no need for wound extension. Material and methods: Thirteen patients with acute EHL tendon injuries at zones III, IV were prospectively included in our series. Patients with underlining bony injuries, chronic tendon injuries and previous nearby skin lesions were excluded. Dual Incision Shuttle Catheter (DISC) technique was applied with subsequent evaluation by the American Orthopedic Foot and Ankle Society (AOFAS) hallux scale, Lipscomb and Kelly score, range of motion and muscle power. Results: Dorsiflexion at the metatarsophalangeal (MTP) joint significantly improved from a mean of 38.4±6.2º at one month to 58±9.6º at three months to 78.8±3.1º at one year postoperatively (P=0.0004). Plantar flexion at MTP joint significantly inclined from 16±3.8º at 3 months to 30.6±7.8º at the last follow-up (P=0.006). The big toe dorsiflexion power surged from 6.1±0.9N to 11.1±2.5N to 19.7±3.4N at 1 month, 3 months and one-year follow-up periods respectively (P=0.013). As per the AOFAS hallux scale, pain score was 40 of 40 points. The mean functional capability score was 43.7 out of 45 points. On Lipscomb and Kelly scale, all were graded "good" except for one patient who was graded "fair". Conclusion: Dual Incision Shuttle Catheter (DISC) technique represents a reliable method for repair of acute EHL injury at zones III, IV.

Keywords: Extensor; hallucis; shuttle catheter; dynamometer.

INTRODUCTION

Extensor hallucis longus (EHL) tendon injury is not uncommon. It often occurs after lacerations along the dorsum of the foot or ankle. The true incidence is unknown; however, it was reported to account for nearly 11% of lower extremity injuries *(1)*. Injuries may be classified into open lacerations or closed ruptures. Closed injuries have been described in the setting of extreme dorsiflexion against resistance *(2)*, as attritional ruptures due to tendon degeneration from local steroid injections *(3)* and iatrogenic thermal injury during ankle arthroscopy *(4)*.

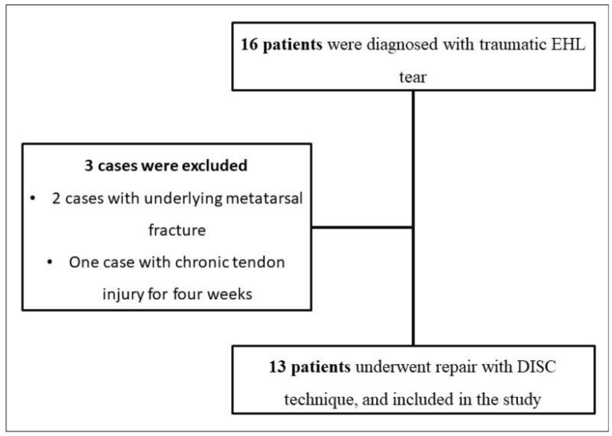
Open lacerations are also classified according to the site of injury into six zones; zone 1: at the

■ Osama Samir Gaarour, PhD, FRCSEng (Tr & Orth), FRCSGlasg (Tr & Orth),
■ Amr Elshahhat, PhD.
Mansoura University Hospital, Mansoura University, Egypt.
Correspondence : Osama Samir Gaarour, Algomhoria street, Mansoura University, Egypt. Postal code: 33516. Fax: +20 (50) 239733 / +20 (50) 2397900.
Email : osama_samir@mans.edu.eg

No benefits or funds were received in support of this study.
None of the authors have a conflict of interest.

insertion site on the distal phalanx, zone 3: over the metatarsophalangeal joint, zone 2 : between zones 1 and 3, zone 5: injury to the tendon under the extensor retinaculum, zone 4: dorsum of foot between zones 3 and 5, and zone 6: lower leg proximal to the extensor retinaculum *(5)*. Neglected injuries end by muscle atrophy, degeneration of the musculotendinous complex and progressive contracture deformity of the hallux *(6,7)*. Data in literature regarding treatment recommendation and results is scarce *(8)*.

The proximal end of the tendon is usually so retracted that a proximal wound extension is always required to retrieve the tendon stump. Moreover, the tendon stump could be crushed by the clamp if the surgeon naively tried to grasp and approximate it from the wound. Additionally, this superadded soft tissue dissection might eventually end with more fibrosis and nearby joint stiffness *(5)*. In this study, we proposed a new technique that we call Dual Incision Shuttle Catheter (DISC) technique for proximal stump retrieval and repair of acutely injured EHL tendon with minimal soft tissue dissection and less operative time. We aimed at evaluation of the functional results regarding joint stiffness, wound complications, and functional recovery. We hypothesize that our technique will provide an appropriate, applicable, and reliable method for repair of acute EHL injury at zones III, IV.



EHL: Extensor hallucis longus, **DISC**: Dual Incision Shuttle Catheter

Figure 1. — A flowchart for the study enrollment process.

Figure 2. — A 12F Nelaton catheter is pushed into the synovial sheath at the injury wound.

MATERIALS AND METHODS

Thirteen patients with acute EHL tendon open injuries at zones III, IV were prospectively included in our case series (Figure 1). All patients were admitted and managed at Mansoura Trauma and Emergency Hospital, Mansoura University at the period from January 2018 to October 2020. Patients with underlining bony injuries, accompanying ipsilateral lower limb injuries, chronic tendon injuries, previous nearby skin lesions and collagen disorders were excluded from this study.

All Patients underwent surgical repair under spinal anesthesia with a tourniquet applied. Repair was done within the first 5 days of the injury. Access to the EHL was obtained via a separate proximal midline ankle incision. This proximal incision was a 3cm longitudinal incision above the upper border of superior extensor retinaculum along the lateral border of tibialis anterior tendon. Care was taken to avoid injury to the anterior tibial vessels and the deep peroneal nerve. Subsequently, the tibialis anterior tendon was retracted medially and the extensor digitorum longus tendon was retracted laterally. The EHL tendon was identified in-between the retracted tendons guided by the accompanying hematoma. Afterwards, the tendon was hooked outside the incision.

At the injury wound, the synovial sheath of the injured tendon was identified to guide for the

Figure 3. — Retrieval of the catheter end and tendon stump through the ankle (proximal) incision.

catheter path. A 12F Nelaton catheter was pushed into the identified synovial sheath beneath the extensor retinaculum through the EHL tunnel and retrieved at the proximal incision (Figure 2). This step was not that difficult with injecting saline or sterile gel to smoothen the catheter passage. As a result, both the catheter end and the tendon stump were received through the ankle incision (Figure 3). The catheter and the proximal stump were sutured end to end using modified Kessler suture technique *(9)*. With the aid of a sterile gel, the catheter was pulled through the tendon tunnel, and the proximal end of the EHL tendon was freed from the catheter at the distal wound. Both ends of the tendon were approximated and repaired using synthetic, monofilament, nonabsorbable polypropylene United States pharmacopeia (USP) 3-0 sutures by the four-strand technique followed by epitendinous suturing *(9)*. After wound closure, a short plantar plaster splint was applied with the ankle at 0° of dorsiflexion and the hallux in neutral or slight dorsiflexion, allowing for passive and active dorsiflexion of the big toe *(10)*. At 4 weeks, the splint was removed. Physiotherapy started after 6 weeks including progressive passive and active range of motion of the hallux, strengthening, and gait training. Return to sport activities usually began after 3 months *(11)*.

All patients were followed up for at least one year regarding the pain and the functional recovery in terms of the range of motion (ROM) of the metatarsophalangeal (MTP) joint and the big toe dorsiflexion power. ROM was calculated in degrees using the orthopedic goniometer while the muscle

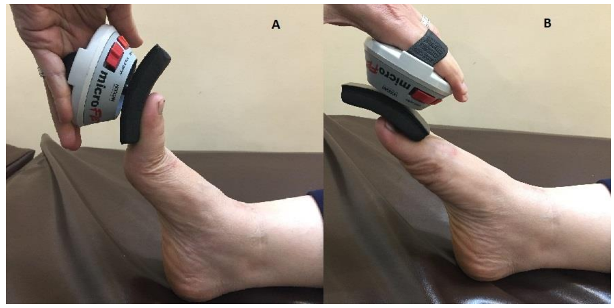


Figure 4. — Measurement of big toe dorsiflexion (A) and plantarflexion (B) muscle power at last follow-up using the microFET®2™ digital handheld dynamometer (Hoggan Industries, Inc., West Jordan, UT, USA).

Table I. — Lipscomb and Kelly scale *(12)*

Outcome	Description
Good	Normal function, strength, and pain free range of MTP joint motion compared with contralateral foot
Fair	Active pain free range of motion of MTP joint without hallux dysfunction but with some weakness compared with contralateral foot
Poor	Failed repair with lack of hallux function, pain, and loss of active extension of hallux

power was measured using the microFET®2™ digital handheld dynamometer (HOGGAN Industries, Inc., West Jordan, UT, USA) (Figure 4). Results were assessed as per the grading system of Lipscomb and Kelly as good, fair and poor *(12)* (Table I). Also we used the American Orthopedic Foot and Ankle Society (AOFAS) hallux scale (Table II) in terms of only pain (maximum score of 40 points) and functional capability (maximum score of 45 points) *(13)*. Additionally, complications as infection, neuromas, hypertrophic scars, and tendon rupture were documented.

Statistical analysis and data interpretation were fed to the computer and analyzed using IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Qualitative data were described using number and percent. Quantitative data were described using median (minimum and maximum) for non-parametric data and mean with standard deviation for parametric data after testing normality using Shapiro–Wilk test. One-way ANOVA test was utilized on testing significance between two

Table II. — The AOFAS hallux scale *(13)*

Criteria	**Score (points)**
(A) Pain	
□ None	40
□ Mild, occasional	30
□ Moderate	20
□ Severe, constant	0
(B) Functional capability	
(I) Activity limitation	
□ None	10
□ No limitation of daily activity but some limitation of recreational activity	7
□ Limitation of daily and recreational activities	4
□ Severe limitation of all activities	0
(II) Footwear	
□ Normal	10
□ Comfortable and/or insole	5
□ Orthopedic	0
(III) Metatarsophalangeal joint motion	
□ >75º	10
□ 30-74º	5
□ <30º	0
(IV) Interphalangeal joint motion	
□ <10º	
□ >10º	5
(V) Joint stability	0
□ Stable	
□ Unstable	5
(VI) Callus	0
□ None or asymptomatic	
□ Symptomatic	5
	0

matched groups, P value was considered significant when less than 0.05.

RESULTS

Out of thirteen patients, seven males and six females underwent surgical repair of acute EHL tendon injury by our technique. The mean age was 31.3±7.7 years. No comorbidities were documented except for two patients with hypertension and two patients with controlled diabetes mellites type II. All patients had their repair within 5 days of the injury with average of 1.4±1 day.

The dorsiflexion ROM at metatarsophalangeal (MTP) joint showed a statistically significant improvement from a mean of 38.4±6.2º at 1month to 58±9.6º at 3months to 78.8±3.1º in the final follow up one year postoperatively(P=0.0004) (figure 5).

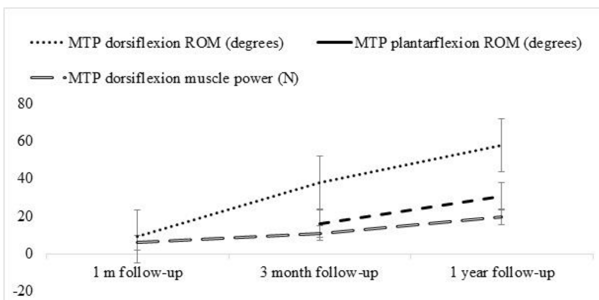


Figure 5. — Curve graph showing the change in the average MTP dorsiflexion ROM, plantarflexion ROM, and dorsiflexion muscle power at subsequent follow up periods.

Similarly, plantar flexion at MTP joint significantly inclined from 16±3.8º at 3 months follow-up to 30.6±7.8º at the last follow-up (P=0.006) (figure 5). The mean 1st MTP dorsiflexion power significantly improved from 6.1±0.9N to 11.1±2.5N to 19.7±3.4N at 1 month, 3months and one-year follow-up periods respectively (P=0.013) (figure 5).

One year postoperatively, the functional results as per the grading system of Lipscomb and Kelly were graded "good" in all cases except for one patient who was graded "fair". As per the AOFAS hallux scale, all patients were free of pain with pain score 40 out of 40 points. The mean functional capability score was 43.7 out of 45 points (range from 37 to 45 points).

All patients healed with neither painful neuromas nor tendon rupture. One patient had experienced superficial infection at distal wound that was resolved with oral antibiotics. Another case suffered from hallux stiffness with limited ROM at the MTP joint at the end of the follow up.

DISCUSSION

Extensor hallucis longus tendon is the primary dorsiflexor of hallux that contributes also to 15% of the dorsiflexion strength of the ankle *(14)*. Acute surgical repair is the recommended management for most of EHL lacerations with reports of "fair" to "good" Lipscomb and Kelly outcomes *(15)*. Direct tendon repair is most successful when the tendon retraction is minimal. When the tendon is severed at zones III, IV, the proximal end usually escapes and retracts more proximally as ligamentous and retinacular structures do not tether the tendon at these sites, besides, the extension posture at the time of injury *(5,11)*.

Tendon retractions possess an intraoperative challenge when attempting to identify and reapproximate the free tendon ends. Significant retraction can harden the direct repair and indicate wound enlargement *(8)*. Retrieval of the proximal end of a retracted tendon via the site of injury usually leads to more manipulation and crushing of the tendon ends that might require debridement, further shortening and repair under tension. Furthermore, it could disrupt synovial sheath lining and retinacula. There is no doubt that all these factors might lead to poor healing, more adhesions *(16)*, and increased complication rates as stiffness and tendon rupture *(17)*.

Nearly most studies indicated wound enlargement in the repair of acute tendon laceration with retraction in all zones for a better exposure and a sound repair. A separate incision was utilized in chronic cases only either on occasions of tendon lengthening or tendon grafting *(11)*. To the best our knowledge, nothing is available in literature concerning the use of a catheter with a separate proximal incision for tendon retrieval while addressing acute injuries at zones III, IV.

On reviewing literature, only few studies used patient-rated objective outcome measures to quantify the functional outcome after repair. Wong et al. conducted one of the largest retrospective case series with average 5-year follow-up period. Eighteen out of 20 patients had significant tendon retraction with average 3.3 cm. Only 16 patients out of those 18 underwent primary repair, whilst the remaining 4 patients underwent tendon transfer after failure to approximate tendon ends. Twelve cases had injuries at zone III, IV; of whom acute repair was possible only in 9 cases, whilst management in the remaining three cases required tendon transfer. The resultant average AOFAS Hallux pain score was 34.3 (range 20-40), average AOFAS Hallux function score was 42.9 (range 33-45). Patients had overall satisfactory functional results. However, a case with hallux stiffness and one with wound dehiscence were reported with acute repair *(18)*.

Another retrospective case series was conducted by Al-Qattan who managed 17 patients with acute open EHL laceration with an average follow-up of 5 years. The incision was enlarged when needed with opening the tendon sheath to reach a good repair. No patients experienced any wound complications. Overall AOFAS Hallux pain score was 40 of 40 (no pain). The average AOFAS Hallux function score was 42.1 (out of 45 points), indicating very little functional limitation *(5)*.

Similarly, our study revealed satisfactory results for tendon retrieval and repair by DISC technique after one-year follow-up. All cases experienced no pain with AOFAS hallux pain score 40 of 40 points (no pain). Twelve of 13 cases were graded as good according to Lipscomb and Kelly grading system. The mean AOFAS functional score was 43.7 out of 45 points (range from 37 to 45 points).

These comparable results highlight the efficacy of our technique compared to the conventional wound enlargement and more tissue dissection.

The most reported complication of EHL tendon repair was wound complications such as painful scar formation *(18,19)*. In our series, no patient had a painful scar. However, one patient with DM type II was presented with superficial wound infection which resolved by oral antibiotics with no impact on the functional outcome and tendon healing.

Hallux stiffness usually represents a challenging problem to the patients especially with wound enlargement. Stiffness might occur with more soft tissue violation, more dissection, and tendon synovial sheath injury. Excessive scaring tissue resulting from the healing process usually represents constricting points that limit the tendon glide and cause tendon triggering *(17)*. In our study, only one case suffered from stiffness; a 32-year-old female patient who was totally non complaint to physiotherapy.

Weakness of ankle and hallux dorsiflexion is also reported as a possible complication *(18)*. This could occur by violation of the superior extensor retinaculum on further dissection. Superior extensor retinaculum is often so thin at the ankle joint level that its repair can be extremely difficult *(11)*. Moreover, adhesions of the repaired tendon to the retinaculum are common and difficult to avoid because of the immobilization required in the postoperative protocol. By then, tendon bowstringing and weakness of dorsiflexion might occur. Our study showed a surge in muscle power of dorsiflexion when assessed by handheld dynamometer, from 6.1±0.9N to 11.1±2.5N to 19.7±3.4N at 1 month, 3 months and one-year follow-ups, respectively. We can attribute this to the minimal injury to the synovial sheath, retinaculum and the skin which represents the main advantage of our technique.

Limitations of this study include short follow-up period. The strength of our study is represented in the large series of patients managed by the same technique, besides, assessment of the outcome using a validated functional scoring system. Future randomized controlled trials comparing our technique to the conventional technique will be needed.

CONCLUSION

In conclusion, using DISC technique in retrieval and repair of acute EHL injury at zones III, IV represents an appropriate, applicable, and reliable method. By such technique, we can avoid more soft tissue violation, crushing proximal tendon end and further debridement. Subsequently, this limits the risk of tendon shortening, triggering, and hallux stiffness. Hence, faster recovery and return to preinjury functional activity could be possible.

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