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Technique tip: EDL-to-EHL double loop transfer for extensor hallucis longus reconstruction

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ABSTRACT

Background: Extensor hallucis longus (EHL) tendon injuries often occur in the setting of lacerations to the dorsum of the foot. End-to-end repair is advocated in acute lacerations, or in chronic cases when the tendon edges are suitable for tension free repair. Reconstruction with allograft or autograft is advocated for cases not amenable to a primary direct repair. This is often seen in cases with tendon retraction and more commonly in the chronic setting. In many countries the use of allograft is very limited or unavailable making reconstruction with autograft and tendon transfers the primary choice of treatment. Tendon diameter mismatch and diminished resistance are common issues in other previously described tendon transfers.

Methods: We present the results of a new technique for reconstruction of non-reparable EHL lacerations in three patients using a dynamic double loop transfer of the extensor digitorum longus (EDL) of the second toe that addresses these issues.

Results: At one-year follow up, all patients recovered active/passive hallux extension with good functional (AOFAS Score) and satisfaction results. No reruptures or other complications were reported in this group of patients. No second toe deformities or dysfunction were reported.

Conclusions: Second EDL-to-EHL Double Loop Transfer for Extensor Hallucis Longus reconstruction is a safe, reproducible and low-cost technique to address EHL ruptures when primary repair is not possible.

Level of evidence: IV (Case Series).

1. Introduction

Lacerations to the dorsum of the foot are commonly associated with extensor hallucis longus (EHL) injuries [1,2] and accounts for approximately 1.6% of all the extensor tendon lesions of the foot [3]. In the acute setting, the preferred treatment is a direct, end-to-end repair [4,5]. In most chronic cases or neglected EHL tendon lacerations, a symptomatic chronic EHL dysfunction develops, leaving a flexion deformity of the toe at the interphalangeal joint that requires surgical correction (Fig. 1A–B) [5,6].

There is no consensus in the literature regarding the ideal reconstruction of chronic EHL ruptures, as evidenced by the numerous different procedures previously described [1,3–10]. Therefore, our objective was to contribute to this growing body of knowledge with a previously unreported technique to address the surgical reconstruction of the extensor hallucis longus tendon.

2. Surgical technique

Active function of the extensor digitorum longus (EDL) of the second toe is tested before surgery, particularly in cases in which the laceration is extended to the lateral aspect of the foot (Fig. 1B). The patient is placed in supine position on the operating table. Either general or regional anesthesia can be used as long as

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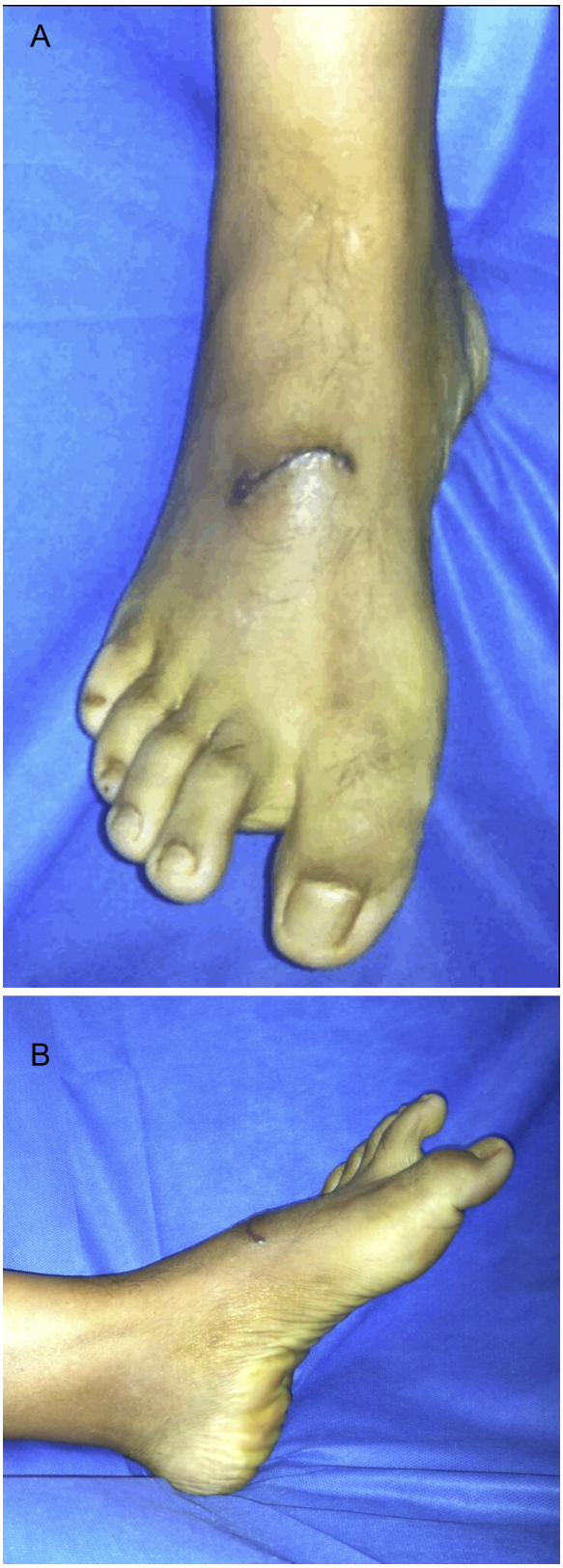

Fig. 1. Dorsal laceration on the foot associated with EHL injury. **A**, Frontal view. **B**, Lateral view, note the extensor lag of the hallux in comparison of the lesser toes and IP flexion deformity.

muscular paralysis is obtained. A thigh tourniquet is used. A direct longitudinal dorsal approach along the axis of the first metatarsal is made, centered over the site of rupture, and the distal stump of

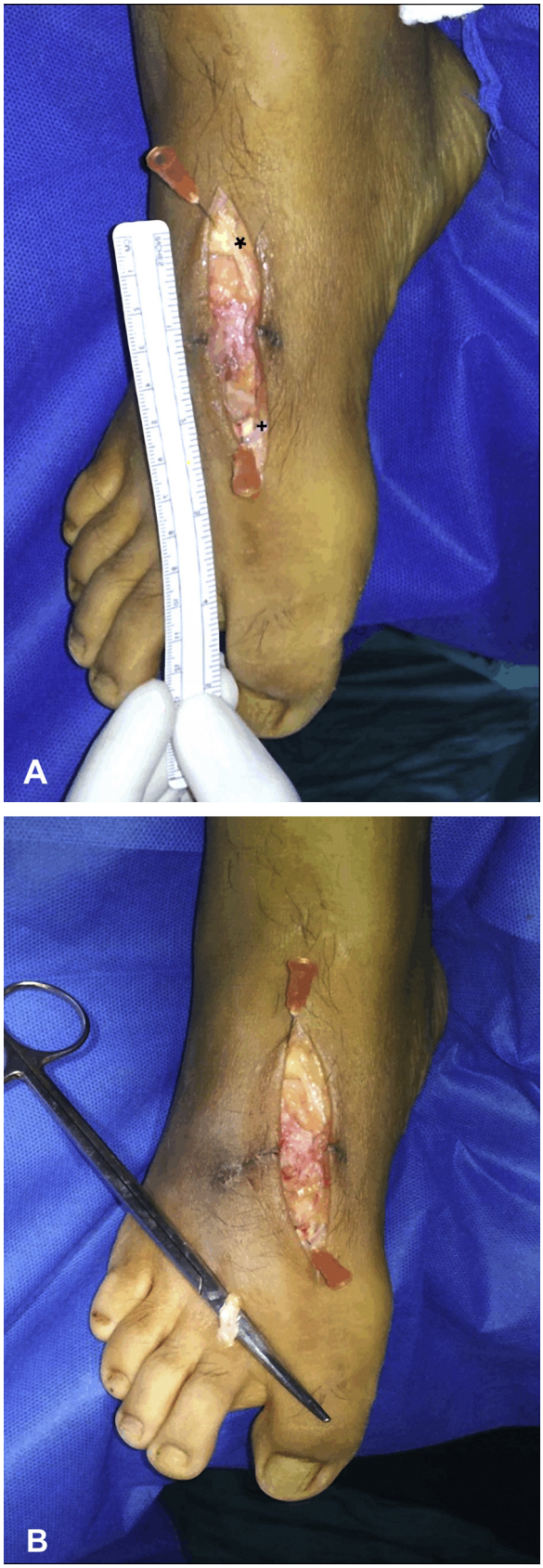

Fig. 2. **A**, Proximal (*) and distal (+) stumps are identified. Gap is measured after debridement. **B**, Extensors of the second toe are identified through a one centimeter approach over the 2nd MTP joint.

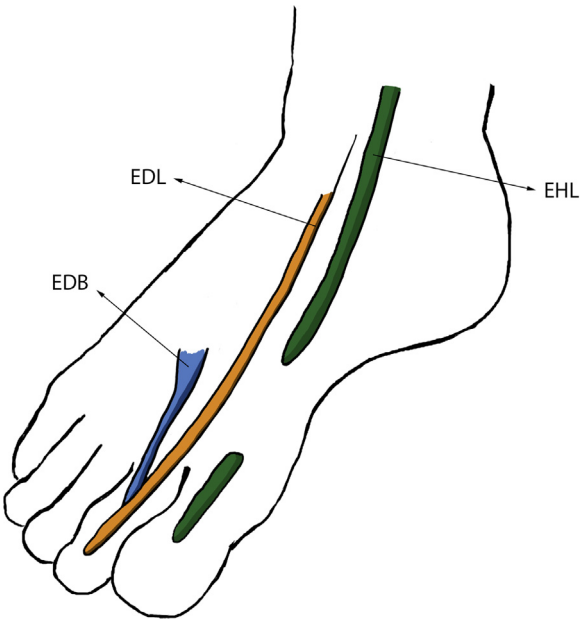

Fig. 3. Anatomical relationships between extensor hallucis longus (EHL), Extensor Digitorum Longus (EDL) and Extensor Digitorum Brevis (EDB). The EDL is medially located in relation to EDB.

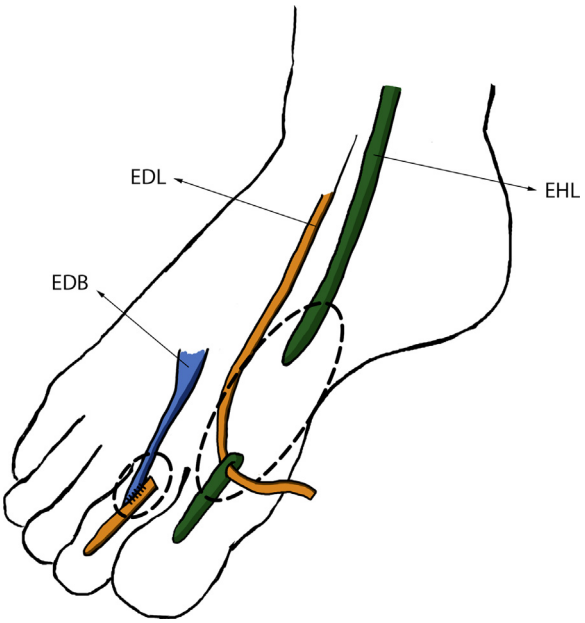

Fig. 5. Tenodesis of the remaining distal stump of the EDL to the EDB tendon. The proximal stump of the EDL is then passed through the slit of the distal end of the EHL.

Fig. 4. The proximal stump of the EDL is retrieved through the primary approach.

the EHL is exposed. The proximal stump is often retracted to the midfoot, and can be explored through the same approach or through an ancillary small incision made proximally at the level of the extensor retinaculum. The scar tissue and fibrotic adherences of both proximal and distal stumps of the EHL are excised in order to mobilize the tendon and both ends are regularized. Once the tendon edges are debrided, a hypodermic needle is placed into the tendon edges to prevent retraction. The remaining gap is measured in neutral position, and if the tendon edges are not opposable for tension-free primary repair, we proceed to a reconstruction using the second toe EDL (Fig. 2A).

A one centimeter longitudinal incision is centered over the metatarsophalangeal joint of the second toe. The extensor digitorum longus (EDL) and brevis (EDB) tendons of the second toe are identified (Fig. 2B). The EDL tendon is the more medial of the two tendons (Fig. 3). A tenotomy of the EDL is performed proximal to the extensor expansion. The proximal stump of the EDL is then rerouted subcutaneously and retrieved through the first incision (Fig. 4) in order to obtain a direct tendon pull optimizing function and prevent hallux valgus.

A tenodesis of the remaining distal stump of the EDL is then performed to the EDB with a 4-0 non-absorbable suture. A standard longitudinal single weave incision is made in the distal stump of the EHL at least 5 mm distal to its end, in order to create a buttonhole and prevent a split. A stop suture can be placed also in order to avoid further splitting of the tendon. This procedure is repeated at the proximal stump of the EHL. The proximal stump of the EDL is then passed through the slit of the distal end of the EHL (Fig. 5), followed by a pass in the buttonhole of the proximal end of the EHL and finally reflected again to the distal stump of the EHL, creating a loop (Fig. 6). Shortening or lengthening the loop can easily control the tension of the transfer. We use the resting tension of lesser toes while the foot is placed in neutral dorsiflexion as reference. When the appropriate functional tension is achieved, the proximal three-bundle union of the loop is sutured with a 4-0 non-absorbable suture using locking stitches. The distal three-bundle union is now sutured in the same way. Finally, the double bundle EDL middle portion is tubularized from distal to proximal, allowing an adequate excursion (Fig. 7).

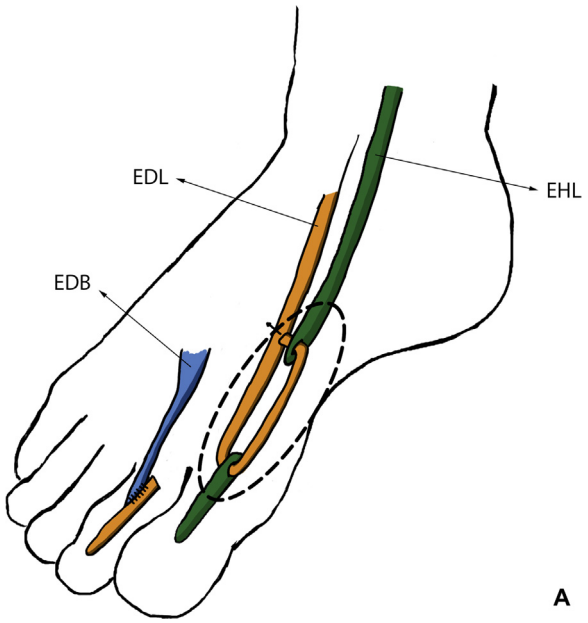

Fig. 6. The reflected EDL is passed through a buttonhole created on the proximal end of the EHL and finally reflected again towards the distal stump of the EHL creating a second loop. Shortening or lengthening the loop can easily control the tension of the transfer.

At the completion of the tendon transfer, we again compare the resting tension of the hallux with the lesser toes to ensure the correct tension (Fig. 8A–B). Reconstruction of the tendon sheath should be attempted whenever it is possible in order to enhance tendon healing. Wound closure is performed in a layered fashion.

3. Postoperative management

A well-padded, short leg plaster cast with toe extension is placed in the operating room. Patients remain non-weight bearing for 3 weeks. Patients are seen again in the outpatient office at 3 weeks, when their sutures are removed. At this time, a cam walker boot is used for another 3 weeks, allowing partial weight bearing as tolerated. At 6 weeks, physical therapy is initiated including progressive passive and active range of motion of the hallux. Return to sport activities usually begins progressively at 3 months postoperative.

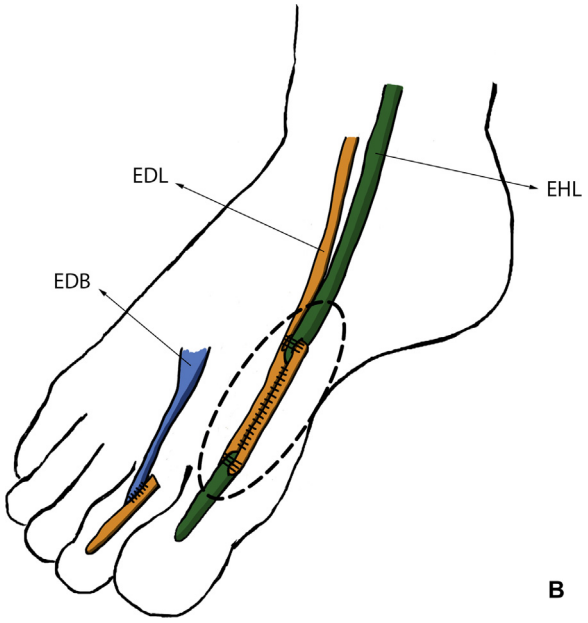

Fig. 7. The proximal and distal three bundle union of the loops are sutured. Then, the double bundle EDL middle portion is tubularized from distal to proximal.

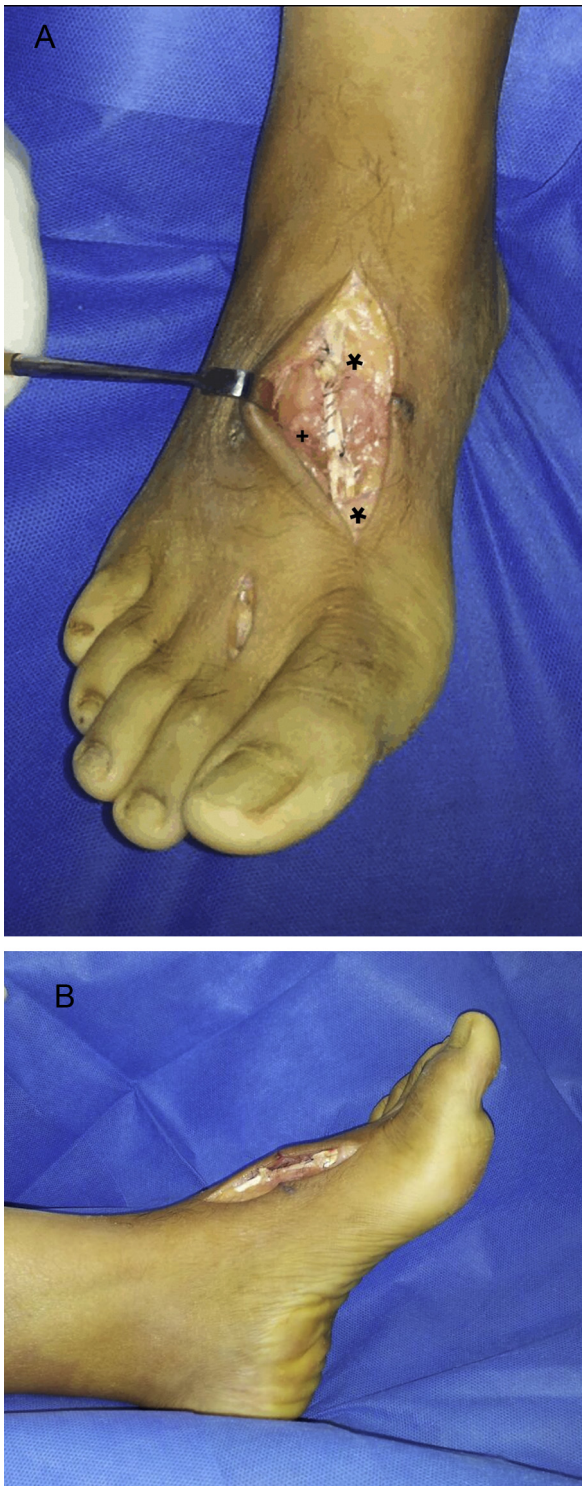

Fig. 8. Completed double loop EDL transfer. **A**, Reconstructed three bundle proximal and distal portions (*) and double bundle midportion (+). **B**, Lateral view demonstrating restored passive position of the hallux relative to the lesser toes.

Table 1
Al-Qattan [7] classification for extensor hallucis longus lacerations.

Zone	Description
1	At the insertion site on the distal phalanx.
2	Area between zones 1 and 3.
3	Over the first metatarsophalangeal joint.
4	On the dorsum of the foot between zones 3 and 5.
5	Laceration of the tendon beneath the extensor retinaculum.
6	In the lower leg proximal to the extensor retinaculum.

4. Results

Three patients were treated using this EHL reconstruction technique in our institution between 2014 and 2016. Patients with at least one-year follow-up were included. All patients sustained lacerations at the dorsum of the foot and were sutured primarily in other institutions. Clinically, they presented with progressive extensor lag of the hallux secondary to undiagnosed EHL injury, affecting the normal gait pattern in all patients. The latter usually described as the hallux catching on the ground. AOFAS score was used to objectify the patient's dysfunction on their first visit. Ultrasound examination at the time of consult in our institution demonstrated complete EHL tendon rupture in all three cases. Injuries were classified using the Al-Qattan topographic classification (Table 1) [7].

Reconstruction took place between 8 to 16 weeks after the initial injury. Surgical exploration of the EHL was performed using the previous dorsal wound as a reference, extending the approach proximally when necessary, in order to find the proximal stump. The mean intraoperative measured gap between the proximal and distal stump was 5.5 cm and were deemed intraoperatively not suitable for primary tension-free repair. Therefore, we proceeded with the EHL reconstruction using the second toe EDL tendon as described in the technique above.

At one year follow up, all patients recovered active and passive hallux extension at the metatarsophalangeal joint. There was no loss of active or passive plantarflexion in the hallux interphalangeal joint. Regarding the second toe, none of the patients reported dysfunction and no secondary deformities were developed at follow up. At this point patients were revaluated using the American Orthopedic Foot and Ankle Society (AOFAS) Hallux Metatarsophalangeal Interphalangeal score and the Lipscomb and Kelly grading system for EHL tendon repairs (Table 2) [11,12]. No wound complications or reruptures were encountered and all patients reported full satisfaction with the procedure at final follow-up. Results are summarized on Table 3.

5. Discussion

A myriad of surgical techniques have been described to reconstruct the extensor hallucis longus tendon with satisfactory outcomes [1,6–9,13], including interpositional fascia lata allograft [9], EDL tenodesis [1] or free tendon autograft reconstruction using semitendinosus [3,8], gracilis [10] or EDL [1,4], to address small segment defect reconstruction. The use of palmaris longus [7], plantaris and peroneus tertius [6] tendons have been described when a longer graft length is required. While the advantages of allograft reconstruction include lack of donor site morbidity and decreased surgical time; their limited availability, higher cost, susceptibility to rejection and potential risk of infection limit their use to selected cases only [14]. Regardless of the selected tissue to bypass the defect, an important surgical consideration is the graft — native tendon diameter matching. It has been documented that the diameter of the graft tendon should be similar to the injured tendon in order to prevent adhesions due to fibrotic projections that would develop at both ends of the tendon due to unequal anastomosis [8]. Many of these grafts, particularly plantaris and peroneus tertius present a smaller diameter. In order to avoid this complication, other authors suggest using semitendinous tendon autograft, due its similar width with EHL, with the disadvantage of theoretically jeopardizing an otherwise healthy joint to reconstruct the defect [3,8].

Leung [4] described the use of a dynamic transfer of the second toe EDL to the distal stump of the EHL using end-to-end suture or Pulvertaft technique, not exploring the proximal stump, to achieve a functional result. In our opinion, this technique does not entirely address the diameter mismatch between the second toe EDL and the lacerated EHL. Therefore, we present a modification of the technique that matches this width difference by creating a triple-bundle tendon interface that emulates the width of the native EHL, thus reducing the potential risk of adhesion formation due to graft — native tendon mismatch. Our technique also includes the proximal stump of the EHL in order to create a double bundle EDL midportion, increasing the transfer extension force which correlated with favorable clinical outcomes in our patients.

All of our patients presented with lacerations distal to the extensor retinaculum (Al-Qattan types 3 and 4). In this context, retraction of the stumps is more common than in more proximal lacerations at the level or proximal to the extensor retinaculum where the proximal stump is usually located in situ allowing a primary end-to-end repair in most cases.

Table 2
Lipscomb and Kelly [12] grading system for EHL tendon repairs.

Grade	Description
Good	Normal range of motion of the big toe (compared to the normal contralateral big toe) and no pain.
Fair	Recovery of the active extension of the big toe with no pain and no tripping over the big toe on walking bare-foot.
Poor	Failed repair (no active extension), persistent pain or tripping over the big toe on walking bare-foot.

Table 3
Patients and results at 1-year follow-up.

Patient	Age	Gender	Zone of injury Al-Qattan	Timing from initial injury (weeks)	Intraoperative tendon gap (cm)	Preoperative AOFAS	Postoperative AOFAS	Lipscomb & Kelly
1	42	Male	4	10	4.8	40	88	Good
2	22	Male	3	16	6.2	47	95	Good
3	57	Male	4	8	5.5	39	85	Fair

6. Conclusion

Second EDL-to-EHL Dynamic Loop Transfer for extensor hallucis longus reconstruction is a safe, reproducible, low-cost and useful technique to address EHL ruptures when primary repair is not possible. We present favorable functional and satisfaction outcomes with active extension of the hallux in all patients at one-year follow-up.

Conflicts of interest

All the authors state that there are no possible conflicts of interest, including financial, consultant, institutional and other relationships that might lead to bias or a conflict of interest. Additionally, there are no sources of funding of this study.

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