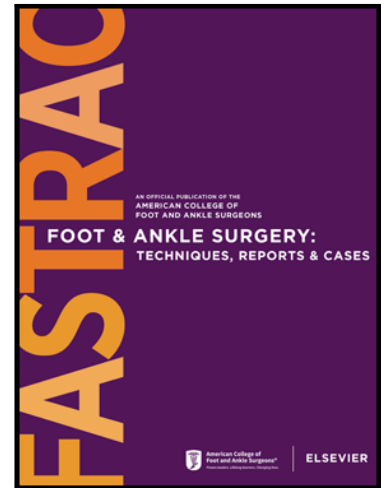


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A novel method of treating and rehabilitating patients with flexor tendon injuries to the lesser toes.



Daniel J Youlden MBBS (Hons), MS ,  
Moussa Farhat MBBS, MS (Orth), MPH, GDAAD ,  
Clancy A Kemety BAppSc (Physio), AHTA, CHT ,  
David J Graham B.Phty(hons), MBBS ,  
Andrew Wines MBBS, FRACS(Orth), FAOrthA ,  
Brahman Sivakumar MBBS, B Sci [Med], MS, MSc ,  
Michael Symes BAppSc (Physio), MBBS, FRACS, MPH, FAOrthA

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# **A novel method of treating and rehabilitating patients with flexor tendon injuries to the lesser toes.**

## **Authors:**

**Daniel J Youlden.** MBBS (Hons), MS. Department of Orthopaedic Surgery, St George Hospital, Sydney.

**Moussa Farhat.** MBBS, MS (Orth), MPH, GDAAD. Department of Orthopaedic Surgery, Westmead Adults Hospital, Sydney.

**Clancy A Kemety.** BAppSc (Physio), AHTA, CHT. North Shore Hand Therapy, North Shore Private Hospital, Sydney.

**David J Graham.** B.Phty(hons), MBBS. Griffith University School of Medicine and Dentistry Southport Queensland. Gold Coast University Hospital Department of Musculoskeletal services Southport Queensland. Swggpuncpf"Ejknftgpøu" J qurkvcn" Fgrctv ogpv"qh"Qtvjqrcgfk"Uwtigt{"Uqvwj" Brisbane Queensland Australia. Australian Research Collaboration on Hands [ARCH], Suite 4 / 75, Railway Street, Mudgeeraba, Queensland.

**Andrew Wines.** MBBS, FRACS(Orth), FAOrthA. Royal North Shore Hospital, Sydney Orthopaedic Foot and Ankle Research Institute.

**Brahman Sivakumar.** MBBS, B Sci [Med], MS, MSc. Department of Hand & Peripheral Nerve Surgery, Royal North Shore Hospital, Sydney. Department of Orthopaedic Surgery, Hornsby Ku-ring-gai Hospital, Sydney. Department of Orthopaedic Surgery, Nepean Hospital, Sydney. Discipline of Surgery, Sydney Medical School, the Faculty of Medicine and Health, the University of Sydney. Australian Research Collaboration on Hands [ARCH], Suite 4 / 75, Railway Street, Mudgeeraba, Queensland.

**Michael Symes.** BAppSc (Physio), MBBS, FRACS, MPH, FAOrthA. St George and Sutherland Clinical School, University of New South Wales Medicine. The Orthopaedic Research Institute & Department of Orthopaedic Surgery, St George Hospital, Sydney. Sydney Orthopaedic Foot and Ankle Research Institute (SOFARI). Department of Orthopaedics & Trauma Surgery, Royal North Shore Hospital, Sydney.

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## **1. Abstract**

Descriptions of the management of lesser toe flexor tendon injuries are scarce in the literature. Lesser toe injuries and deformities can result in problems with footwear, function and aesthetics, therefore optimal management is key. We present a case of injury to the flexor digitorum brevis and longus to the third toe, and discuss the subsequent surgical management and novel method of rehabilitating the injury, using principles gleaned from hand surgical practice. We anticipate superior outcomes for patients being managed with this surgical and postoperative protocol as compared to alternative repairs and static immobilization.

## **Keywords**

Flexor tendon, lesser toe, forefoot, injury, foot

## 2. Main Text

### Introduction

Tendon injuries of the foot and ankle are uncommon, and usually occur following high energy foot and ankle fracture-dislocations, or following penetrating injuries from sharp objects that are either trod on or fall from height. Reports of tendon injuries in the literature focus on those involving the extensor hallucis longus, flexor hallucis longus and extensor digitorum longus tendons; descriptions of the management of lesser toe flexor tendon injuries [although likely just as common] are scarce (1). Lesser toe injuries and deformities can result in problems with footwear, function and aesthetics, and optimal management of this pathology is key.

Although there is little information guiding the treatment and rehabilitation of lesser toe injuries, there is a wealth of information available regarding their counterparts in the hand (2). Klifto et al. (2018) highlights the science of tendon healing and recovery, all of which can be applied to the tendons of the foot. We postulate that the fundamentals of easy to place sutures, secure knots, minimal gapping or interruption to the tendon vascularity with early controlled rehabilitation protocols are relevant in the foot (2). Thus, we aim to present a case of injury to the flexor digitorum brevis and longus to the

third toe, and discuss the subsequent surgical management and novel method of rehabilitating the injury, using principles gleaned from hand surgical practice.

### Case Report

A 35-year-old female office worker presented to the Emergency Department after stepping on a piece of glass. She was otherwise well, and did not smoke. On examination, a 5 mm puncture wound was noted on the plantar surface of her forefoot. The third toe was held in an extended position, with no active flexion possible (figure 1). The remainder of the foot and ankle assessment was not remarkable, with no neurovascular compromise and normal radiography. After appropriate administration of antibiotics and a tetanus booster, the wound was irrigated with saline and dressed.

The patient underwent exploration of the laceration the following day, and complete lacerations of the flexor digitorum brevis (FDB) and flexor digitorum longus (FDL) tendons to the third toe were discovered (figure 2). These were repaired by the senior authors via a 4/0 Ti-Cron four-strand Adelaide core repair (3) and reinforced with a 5-0 epitendinous PDS II (polydioxanone) oversew. Post-operatively, a relative motion splint adopting principles of the Wyndell Merritt protocol to hold the injured toe in flexion relative to the adjacent tendons from the same muscle belly, and thus diminishing tension from and protecting the site of the operative repair was fashioned by a hand therapist (figure 3) (4). She was allowed to weight bear as tolerated in a post-operative stiff soled shoe. For the first 8 weeks, the patient was instructed to flex and extend the toes within the confines of the relative motion splint 10 times, four times per day. The splint and shoe could be removed for hygiene purposes. The splint and shoe were weaned at 8 weeks post-operatively and the patient commenced active ankle flexion, extension, circumduction and toe flexor strengthening exercises 10 times, four times per day. At week 12, heel raise exercises were commenced. The wound healed without complication by ten days post the operation, and was satisfied by the end of the protocol, having regained normal gait, tendon excursion and flexor function (figure 4).

## Discussion

Flexor tendon injuries to the lesser toes of the foot are uncommon. Each lesser toe is powered by the flexor digitorum longus (FDL) and flexor digitorum brevis (FDB) muscles (5, 6). Isolated injury to either tendon will produce minimal functional loss, due to effect of its intact partner. However, when both tendons are dysfunctional, the toe assumes an initially correctable [and later static] extension posture at the metatarsophalangeal joint, with associated loss of active flexion.

There is a dearth of reports, and resultant lack of equipoise, regarding lesser toe tendon injuries in the forefoot. Yancey et al (1977) (7) surveyed the opinions of 88 surgeons affiliated with the American Orthopaedic Foot Society and Association of Bone and Joint Surgeons, reporting that more than half preferred to manage isolated flexor tendon injuries non-operatively. Floyd et al (1983) assessed seven patients with ten lesser toe tendon injuries within a larger cohort of these, five patients underwent primary tendon repair; one patient had a delayed reconstruction; and one received skin closure only (8). All but one patient reported a satisfactory outcome. The single unsatisfied patient represented with a failed repair, resulting in a hyperextension deformity to the second and third toes. Similarly, a hyperextension deformity was noted in the patient who received skin closure without tendon repair. Although both patients reported no functional limitations, Floyd et al. (1983) (8) recommended early and aggressive operative intervention in foot lacerations with associated tendon injuries. Patients with common lesser toe deformities such as hammer, claw and mallet toes complain about dysfunction, lack of cosmesis and difficulty with application of footwear of injury to the flexor tendons of the lesser toes will result in similar deformities due to an imbalance between the flexor and extensor musculature (5). Thus, appropriate and timely operative intervention and rehabilitation in these injuries is key to preserving lesser toe form and function.

By comparison, there is a wealth of information guiding intervention and rehabilitation in tendon injuries of the upper limb. As the anatomy of the toe flexors is similar to that of the hand in form and structure (6), similar operative principles and rehabilitation techniques may be useful. Flexor tendon repair techniques in the hand have evolved since their introduction, with current protocols recommending a core repair consisting of at least four-strands, although up to eight have been used (9). The calibre of suture utilized has traditionally been a 3/0, although 4/0 may be appropriate in more gracile tendons. (9, 10). A bite of at least ten millimetres with each suture pass has been advocated (11), whilst an epitendinous suture [usually of 6/0 calibre] increases tensile strength and decreases bulk and gapping (9). Either monofilament or braided multifilament sutures can be used, with each possessing unique advantages - braided sutures are stiffer, stronger and handle more easily, but do not run smoothly through tissues like monofilaments (9, 12). We recommend incorporating these principles when repairing flexor tendon injuries to the lesser toes. As in the case described above, our preference is to implement a four-strand repair in a locked Adelaide configuration (3) using a braided 4/0 core suture, combined with an epitendinous oversew utilizing a monofilament 5/0 or 6/0 suture.

Many post-operative rehabilitation protocols can be applied to flexor tendon repairs in the hand, with most incorporating the use of a dorsal blocking splint to protect the surgical repair (12). However, the application of a similar design is impractical for the foot. Thus, we decided to incorporate principles gleaned from the Wyndell Merritt extensor tendon immediate controlled active motion protocol (4). Cadaveric research investigating tendon injuries in hand extensor zones IV to VII showed that splinting the metacarpophalangeal joint of the involved digit in 25° to 30° of extension relative to the adjacent uninvolved digit diminishes tension in the repaired tendon, due to the extensor tendons sharing a single muscle belly and motor. This allowed adequate tendon glide to prevent adhesions and preserve range whilst avoiding the use of often bulky dynamic orthoses which limit functional use. (13). The rehabilitation protocol itself is defined by three phases over a period of 49 days. Phase one is 0-21 days, during which the patient performs full active composite flexion and extension within the



splint. Phase two is 22-35 days after repair, where the patient wears the yoke splint at all times, whilst beginning to engage in medium to heavy duty tasks with both components of the splint. The final phase until day 49 requires use of the yolk splint only with activity (4). Outcomes following the implementation of this protocol demonstrate very few cases of extensor lag, with no reports of re-rupture (4). We encourage the implementation of a similar protocol in patients undergoing repair of flexor tendons of the lesser toes, instructing the patient to mobilise in a stiff-soled post-operative shoe and wear the custom-made splint at all times [except for hygiene in protected positions] for the first 56 days. Active motion is permitted within the limits of the splint. At day 56 post repair, the splint and shoe are discarded and the patient commences unrestricted ankle and toe motion. The patient begins calf raise exercises and a gradual return to full activities from three months (table 1). We anticipate superior outcomes for patients being managed with this surgical and postoperative protocol as compared to alternative repairs and static immobilization in a cast or camboot.

## **Conclusion**

This report describes a novel method of treating and rehabilitating patients with flexor tendon injuries to the lesser toes, and demonstrates that these injuries, although uncommon, can be effectively managed by utilising principles gleaned from the hand surgery literature. Further research comparing the cost and outcomes with static protocols as well as biomechanical and cadaveric testing of relative motion splinting in the toes would be useful.

## Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Informed Patient Consent

Complete informed consent was obtained from the patient for the publication of this study and accompanying images.

### 3. Figure Legends

**Figure 1:** Injury to the 3<sup>rd</sup> toe demonstrating a loss of flexion



Figure 1: Injury to the 3<sup>rd</sup> toe demonstrating a loss of flexion

Figure 2: Intraoperative findings showing complete lacerations of FDL and FDB to the 3<sup>rd</sup> toe

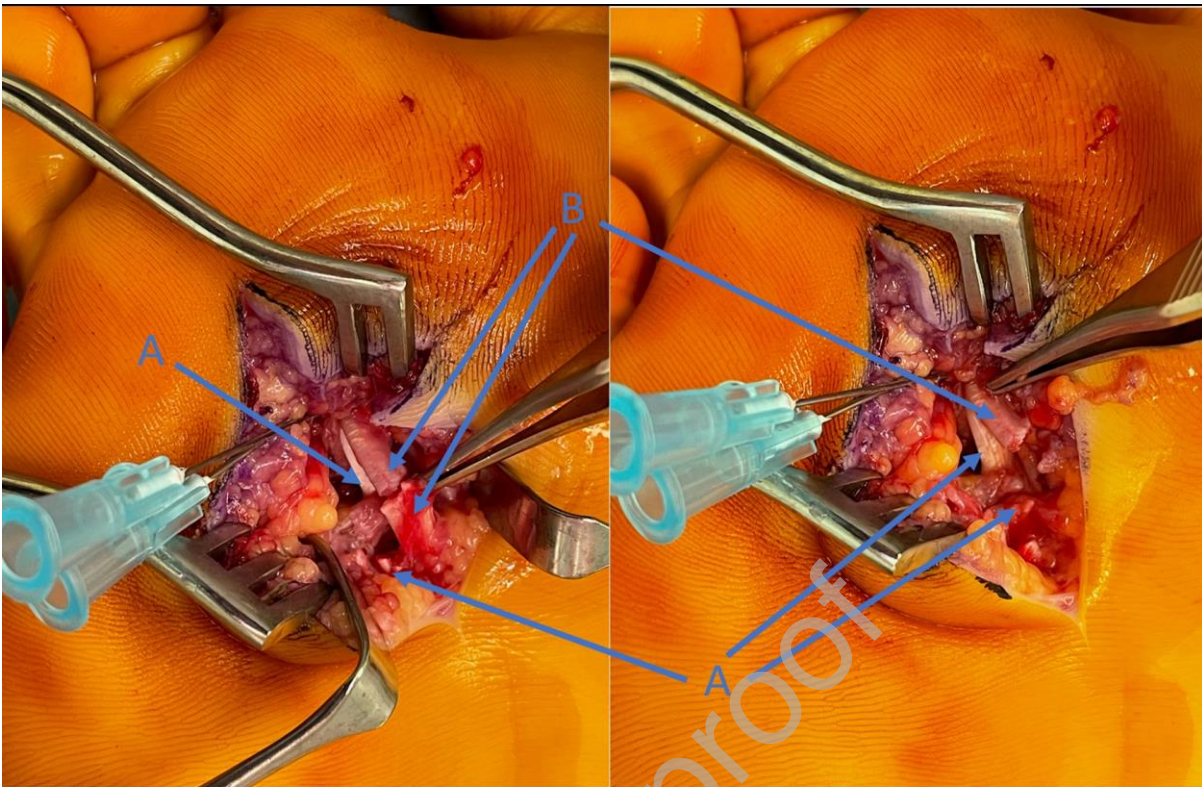


Figure 2: Intraoperative findings showing complete lacerations of FDL (A) and FDB (B) to the 3<sup>rd</sup> toe

Figure 3: Relative motion splint



Figure 3: Relative motion splint

Figure 4: Post-operative form and function

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Figure 4: Post-operative form and function

#### 4. References

1. Geert I. Pagenstert VV, Beat Hintermann. Tendon injuries of the foot and ankle in athletes. *Sportmedizin und Sporttraumatologie*» 52 (1), 11–21, 2004. 2004.
2. Klifto CS, Capo JT, Sapienza A, Yang SS, Paksima N. Flexor Tendon Injuries. *JAAOS - Journal of the American Academy of Orthopaedic Surgeons*. 2018;26(2):e26-e35.
3. Sandow MJ, McMahon M. Active mobilisation following single cross grasp four-strand flexor tenorrhaphy (Adelaide repair). *The Journal of hand surgery, European volume*. 2011;36(6):467-75.
4. Howell JW, Merritt WH, Robinson SJ. Immediate controlled active motion following zone 4-7 extensor tendon repair. *Journal of hand therapy : official journal of the American Society of Hand Therapists*. 2005;18(2):182-90.
5. Malhotra K, Davda K, Singh D. The pathology and management of lesser toe deformities. *EFORT Open Rev*. 2017;1(11):409-19.

6. McMinn RMH. Last's Anatomy Applied and Regional (Ninth Edition). Livingstone C, editor. Best Hope Printing Co, Hong Kong.: Elsevier; 2009. 195 p.
7. Yancey HA, Jr. Lacerations of the plantar aspect of the foot. Clinical orthopaedics and related research. 1977(122):46-52.
8. Floyd DW, Heckman JD, Rockwood CA. Tendon Lacerations in the Foot. Foot & Ankle. 1983;4(1):8-14.
9. Singh R, Rymer B, Theobald P, Thomas PBM. A Review of Current Concepts in Flexor Tendon Repair: Physiology, Biomechanics, Surgical Technique and Rehabilitation. Orthop Rev (Pavia). 2015;7(4):6125-.
10. Tang JB, Lalonde D, Harhaus L, Sadek AF, Moriya K, Pan ZJ. Flexor tendon repair: recent changes and current methods. Journal of Hand Surgery (European Volume). 2022;47(1):31-9.
11. Kim JB, de Wit T, Hovius SE, McGrouther DA, Walbeehm ET. What is the significance of tendon suture purchase? The Journal of hand surgery, European volume. 2009;34(4):497-502.
12. Griffin M, Hindocha S, Jordan D, Saleh M, Khan W. An overview of the management of flexor tendon injuries. The open orthopaedics journal. 2012;6:28-35.
13. Burns MC, Derby B, Neumeister MW. Wyndell merritt immediate controlled active motion (ICAM) protocol following extensor tendon repairs in zone IV-VII: review of literature, orthosis design, and case study-a multimedia article. Hand (N Y). 2013;8(1):17-22.

Table 1: Foot Flexor Tendon Post-Operative Rehabilitation Protocol

Period	Splint	Footwear	Exercises
Day 0-56	Wear at all times	Always mobilize in stiff-soled shoe	Active motion permitted within the splint
Day 57-90	Discard Splint	Transition to normal footwear	Commence unrestricted ankle and toe range of motion
Day 90+			Begin calf raise exercises and a gradual return to full activities