

## Clinical Outcomes and Complications of Flexor Digitorum Profundus (FDP) Tendon Repair in Zone II: Review and Analysis

MOHAMED IBRAHIM HASSAN ZEIDAN, M.D.

The Department of Plastic and Reconstructive Surgery, Faculty of Medicine, Al-Azhar University, Cairo

### ABSTRACT

Although outcomes after flexor tendon repair have been improved with modern treatment, complications of these procedures still common. Zone II flexor tendon repair is the zone within the finger in which there are tight pulleys around both flexor tendons (the profundus and superficialis), therefore, it is the most difficult site of flexor tendon repair and is known as “No Man’s Land” (Fig. 1). The ideal flexor tendon repair in zone II should be strong enough to allow early postoperative mobilization. It is generally accepted that zone II flexor tendon repair demonstrate inferior outcomes compared with repairs in other zones. So, a better understanding of clinical outcomes and the true frequency of complications after flexor tendon repair and factors that may potentially contribute to complications is helpful to address this difficult problem.

We completed a retrospective study using data from patient who underwent zone II flexor digitorum profundus tendon repair between January of 2009 and January of 2012 with at least 12-month follow-up. There were 104 patients with flexor tendon injury repaired using modified Kissler, cruciate, two “Fig. of 8”, and three “Fig. of 8” looped suture repairs (Fig. 2). Repairs were then classified according to Range of motion (Strickland-Glogovac criteria [20]). Our results were 84 excellent patients (80.8%), 12 good patients (11.5%), 6 fair patients (5.75%), and 2 poor patients (1.95%) (Table 2).

The aim of our study was to determine outcomes of Zone II flexor tendon repairs, mechanism of injury, and the incidence of complications and potential contributory factors.

### INTRODUCTION

Flexor tendon repair, especially in zone II, continues to be a problem with imperfect solutions, it is the most difficult site of flexor tendon repair and is known as “No Man’s Land” (Fig. 1). Little literatures has been published to describe the incidence of flexor tendon injuries treated surgically [1], and the rarity of these injuries makes it difficult to characterize the epidemiology without using population based data [1]. Improved surgical repair techniques and rehabilitation protocols have had a positive impact on the outcomes in these patients [2-4]. It is generally accepted that zone II flexor

tendon repair demonstrate inferior outcomes compared with repairs in other zones [5-8]. Factors that have been shown to play a role in outcomes of flexor tendon repair include associated fracture [9], concomitant nerve injury [10,11], multiple digit injuries, post operative therapy protocol [12], and a history of smoking [1].

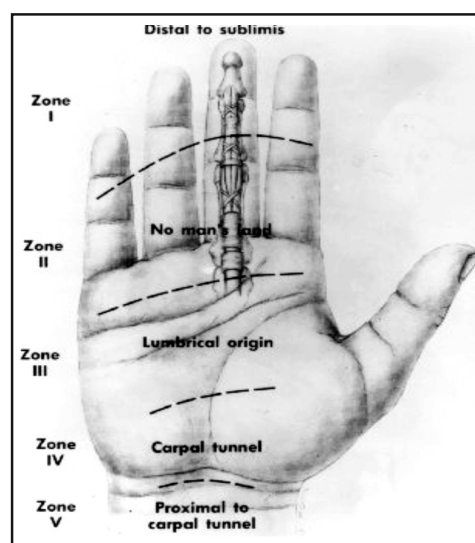


Fig. (1): Zones of flexor tendon injury. Zone II=“No Man’s Land”.

(Quoted from Brown and Neumann, 1995 [13]).

Intensive efforts of both clinicians and researchers are focused on improving outcomes after flexor tendon repair, to minimize the frequency of repair rupture and adhesion formation. A non-systematic review of the published literature estimated a rupture rate ranging from 0% to 9% and a rate of restrictive adhesions requiring a second procedure of 10% [8]. A better understanding of the true frequency of complications after flexor tendon repair and factors that may potentially contribute

to complications is helpful to address this difficult problem.

We were interesting in comparing zone II flexor tendon repair outcomes based primarily on mechanism of injury. Historically, investigators have combined multiple mechanism of injuries to make generalizations regarding the outcomes for zone II flexor tendon repair [6,7,14,15]. At the 1967 American society for surgery of the hand (ASSH) meeting, Klieinert et al., [16] reported on primary repair of lacerated flexor tendon in “no man’s land”. A subsequent paper by the group in 1973 [17] summarized their results and techniques. In that landmark paper, the authors stated that “the superior function obtained in repair of sharply incised tendons as opposed to crushing injuries is a well known fact” [16]. Although this statement was no doubt based on a collective vast experience at the time, no direct references or comparative study characteristics based on mechanism of injury were listed. Although most surgeons would likely agree with this statement, studies that examine the influence of mechanism of injury on outcome for zone II flexor tendon repairs are limited.

In the current study, we have used a wide hospital database to determine the incidence of operations, outcomes of flexor tendon repair in zone II, and to determine and analyze the complications and its potential contributory factors.

## PATIENTS AND METHODS

### *Inclusion criteria:*

We completed a retrospective study using data from patient who underwent zone II flexor digitorum profundus tendon repair between January of 2009 and January of 2012 with at least 12-month follow-up. Only patients who had repair of flexor digitorum profundus tendon laceration in zone II of the fingers were included. Surgeons preserved as much of the flexor pulley system as possible to maintained a sufficient amount of the A2 and A4 pulleys, to prevent flexor tendon bowstringing and allow postoperative rehabilitation [18,19].

### *Exclusion criteria:*

Patient younger than 16 and older than 65 years, fingers with concomitant fractures, crush injury or devascularisation, involvement of more than 2 fingers, Intact superficialis tendon, delayed presentation beyond 3 days, fingers that required pulley reconstruction or had evidence of flexor tendon bowstringing at the end of the operative procedure, and Loss of follow-up before 10 weeks. A final evaluation of included patients was completed by

a single certified hand therapist who performed all range of motion and strength measurements. From the medical records we gathered the mechanism of injury and surgical treatments provided and confirmed this information at follow-up clinical evaluation. All patients had postoperative hand therapy with various early motion protocols for the digits that were included in the study. We conducted a Meta analysis for proportion of repairs, complications, adhesion, and potential contributory factors to identify the effects of mean follow-up, age, zone of injury, surgical technique, and use of epitendinous suture and date of the operative procedure.

### *Range of motion:*

The certified hand therapist measured active and passive range of motion and flexion contractions for each injured digit at the proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints using the Strickland’s original equation:

$[(\text{Active PIP+DIP flexion}) - (\text{PIP+DIP extension deficit})] / 175 \times 100$  [20].

### *Grip and pinch strength:*

The certified hand therapist measured grip strength for every patient preoperative. The patient was seated with the elbow joint flexed at 90° and the forearm in the neutral position. The patient’s wrist was maintained between 0° and 30° of extension and 0° and 15° ulnar deviation. The hand therapist asked the patient to gasp with maximum effort for 3 seconds and recorded the average of 3 measurements. Lateral pinch strength measured also. The patient was positioned identically as for the grip measurements. The hand therapist asked the patient to pinch between her or his thumb pad and the lateral aspect of the index finger middle phalanx with maximum effort for 3 seconds and recorded the average of 3 measurements.

### *Clinical outcome:*

We administered the disability of the arm, shoulder, and hand outcome to each participant.

### *Statistical analysis:*

We compared the demographic data of the injured patients. Also, we performed injured digit analysis, surgical intervention, and complication analysis. We analysed range of motion, strength, and disability of the arm, shoulder, and hand. We completed a multifactorial analysis of variance to determine the outcome of total active motion at the proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints.

## RESULTS

Our current search included 252 patients with documented complete laceration of the FDP in zone II. We include 104 patients of them who underwent zone II flexor digitorum profundus tendon repair, and excluded 148 patients for different reasons. We exclude 45 patients secondary to concomitant fracture in the injured digit, 23 patients with flexor pollicis longus tendon repair, 14 patients with crush injury, 8 patients with devascularisation of the injured finger, 18 patients with Involvement of more than 2 fingers, 8 patients with Intact superficialis tendon, 6 patients with delayed presentation beyond 3 days, 12 fingers that required pulley reconstruction, 4 patients with evidence of flexor tendon bowstringing at the end of the operative procedure, and 10 patients with Loss of follow-up before 10 weeks. From the 104 included patients, 66 were male (63.5%) and 38 were female (36.5%), the average age was 38 years (range, 16 to 65 years). Demographic data recorded in Table (1).

We analyze FDP repair type, number of FDP suture strands, type of core suture used, use of an epitendinous suture, range of motion outcomes because of the significant amount of variation for some categories. All the patients had documentation of at least a 4- strand core suture repair of each FDP tendon. Of these patients, all except 5 patients had an epitendinous suture placed in the FDP tendon.

There were 20 patients (19%) with flexor tendon injury repaired using modified Kissler technique, 12 patients (11.5%) using cruciate technique, 34 patients (33%) using two "Fig. of 8" technique, and 38 patients (36.5%) using three "Fig. of 8" looped suture repairs (Fig. 2).

Only the profundus tendon was repaired and a continuous epitendinous suture using 3/0 and 5/0 prolene sutures respectively. The flexor pulleys were "vented" to prevent impingement of the repair site against the pulleys. Postoperative dorsal splint with the wrist neutral, metacarbo-phalangeal joint (MPJ) 30°, interphalangeal joint (IPJ) fully extended. Immediate physiotherapy performed to ensure full extension of the IPJ. The splint is removed at 4 weeks. Rehabilitation was started on the first postoperative day with a passive flexion and active extension protocol using a rubber band and a dorsal splint (Kleinert technique) (Fig. 3). The rubber band was attached to an elastic bandage around the wrist for an additional 2 weeks. The rubber band was discarded 6 weeks after surgery and the

patients were then allowed to perform active flexion exercises.

The average duration of follow-up was 18 months (range, 12-24 months). Postoperative assessments were performed by an independent examiner who was unaware of the repair type. Functional evaluation of all digits was performed taking into account the range of motion in flexion as well as the extension lag in the PIP and DIP joints. Total active motion (TAM) was calculated by summing up the distal interphalangeal and proximal interphalangeal joints active flexion [20]. The percentage of normal PIP and DIP motion as then calculated using the Strickland's original equation:

$$[(\text{Active PIP+DIP flexion}) - (\text{PIP+DIP extension deficit})] / 175-100 \text{ [20]}.$$

Repairs were then classified according to Range of motion (according to Strickland-Glogovac criteria [20]) as excellent (85% to 100%), good (70% to 84%), fair (50% to 69%), or poor (<50%). Our results were 84 excellent patients (80.8%), 12 good patients (11.5 %), 6 fair patients (5.75%), and 2 poor patients (1.95%) (Table 2).

Table (1): Patient demographic (preoperative data).

Item	No.	Percentage
No. of patients	104	
Average age, yr	38	
Male sex	66	63.5
Female sex	38	36.5
<i>Hand dominant:</i>		
Right	80	76.9
left	24	23.1
<i>Occupation:</i>		
Unskilled manual	56	53.9
Skilled manual	38	36.5
Nonmanual/office work	6	5.8
Professional/management	4	3.8
<i>Education:</i>		
High school	62	59.5
College degree	34	32.8
Graduate degree	8	7.7
<i>Tobacco use:</i>		
Yes	48	46
No	56	54

Table (2): Results according to strickland-glogovac criteria.

Result	No. of digits	Percent
Excellent	84	80.8
Good	12	11.5
Fair	6	5.75
Poor (including rupture)	2	1.95
Total	104	

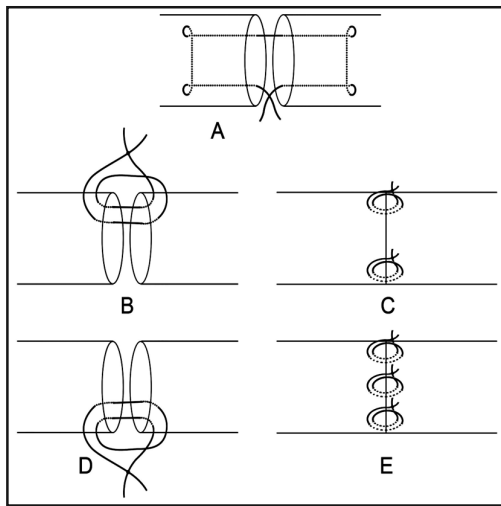


Fig. (2): Suture techniques for repair transected FDP tendon. (A) Modified Kissler. (B & D) cruciate. (C) Two "Fig. of 8". (D) Three "Fig. of 8".



Fig. (3): Kleinert rehabilitation method.



(A)



(B)



(C)



(D)



(E)

Fig. (4): Clinical example (excellent result).

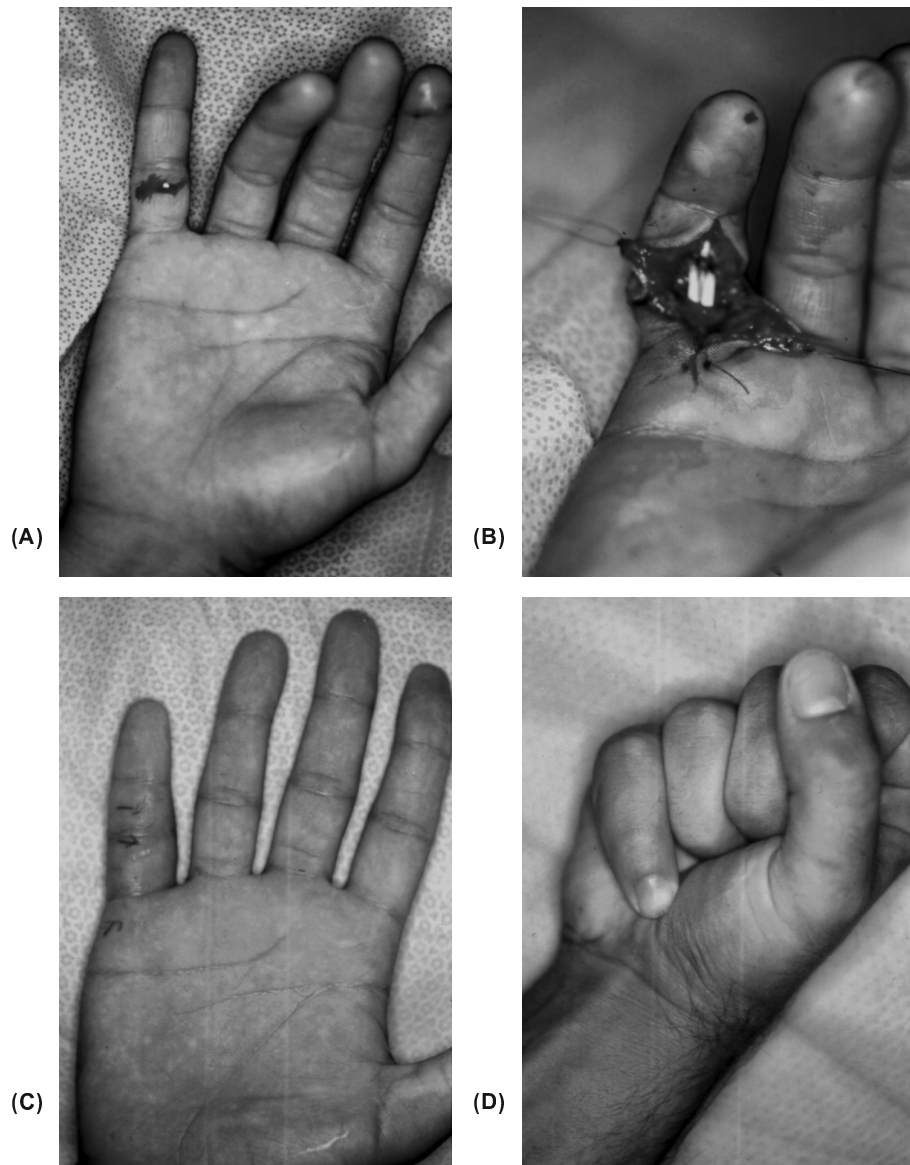


Fig. (5): Clinical example (good result).

## DISCUSSION

The technique of surgical repair for zone II flexor tendon injuries has been debated extensively through the years but adhesion formation, suture rupture, and suture locking on the pulley edge remain possible consequences of a poor repair [21]. Although increasing the repair strength through increasing the number of strands crossing the repair site to allow active postoperative mobilization without increasing the risk of rupture is logical, it can compromise tendon gliding function. The increased handling of the tendon, particularly in inexperienced hands, increases adhesion formation which is a biological response to tendon damage and suture material and the increased number of

strands increases the tendon bulk and surface irregularity which has mechanical implications on gliding function.

Clinical studies of flexor tendon repair have focused less on comparing repair techniques and more on methods of rehabilitation [20]. Since Kleintert et al., [16] reported on primary repair of zone II flexor tendon laceration in 1967 at the annual ASSH meeting, surgical repair and research have evolved to focus on completing the strongest biomechanical construct with the best patient outcomes. Zone II flexor tendon outcome studies review the techniques of repair within the tendon sheath and emphasize the importance of meticulous tendon handling techniques. Multiple studies have

also focused on postoperative therapy protocols that have advanced from immobilization to early passive flexion motion protocols such as the Kleinert et al., [22] or Duran and Houser [23] protocols to, more recently, early active flexion therapies [12].

Multiple Zone II flexor tendon outcome studies have combined various mechanisms of injuries. Outcomes are worse with concomitant fracture [9], nerve injury [11], and contaminated wounds [9]. Kleinert et al., [17] stated that crush injuries do worse than sharp lacerations. In our study, we noticed that digits with Zone II flexor tendon repair and concomitant digital nerve repair are not rehabilitated differently from those that do not have nerve injuries. Our study results led us to reject the relation between mechanisms of injury in relation to range of motion. However, the nerve injury itself may be an independent factor for a worse range of motion outcome. The type of postoperative therapy protocol itself could not be included in our analysis of independent factors affecting range of motion but is known to have an effect of overall outcome [12,24,25]. The presence of associated injuries in other digits may also have led to slower rehabilitation protocols or just to poorer outcomes owing to great trauma to the hand.

There is limited comparative information about flexor tendon repair techniques and suture material impact on range of motion outcomes. Hwang et al. [26] performed a biomechanical study and found that suture material did not affect work of flexion whereas repair of both FDP and FDS compared with FDP repair alone did increase work of flexion. Hoffman et al., [27] found that zone II FDP repair with a 6- strand core suture repair compared to 2-strand core suture repair, was associated with better range of motion and strength and fewer complications at relatively early 8 to 17 weeks follow-up. In a dog study, Winters et al., [28] found that 4 different suture techniques did not affect joint range of motion at 3 and 6 weeks after surgery but the 8 strand technique led to a stronger tendon repair than other techniques. Because all of our patients had at least a 4- strand core suture repair of the FDP tendon injury and there was only 2 postoperative flexor tendon rupture, we believe the differences in repair technique are not clinically meaningful. However, we did not design the study to evaluate repair technique as an independent variable for range of motion outcome.

There is controversy regarding repair of both FDP and FDS or just FDP in zone II flexor tendon lacerations. Previous biochemical studies have

demonstrated that partial or complete FDS excision decreases gliding resistance in zone II flexor tendon repair [29]. Tang [30] has also demonstrated this clinically with a non significant trend toward increased total active motion in patients in which only the FDP was repaired. However, others have suggested the importance of maintaining at least part of the FDS as a gliding bed for the FDP repair to decrease the work of flexion [26] or to increase active PIP joint flexion excursion and power. Our study suggests that further research is necessary to define outcomes of FDP repair for these types of injuries.

In our study, we noticed that lacerated or crushed injuries do worse than clean/sharp tendon injuries even when fractures, nerve injuries, or other digit injuries are not present. For digits with lacerated injuries, we may vein graft injured vessels, graft or use synthetic conduit for nerve injuries, and even graft or perform local flaps for soft tissue coverage. We repair the flexor tendon injuries primarily if the debrided tendon ends can be approximated without excessive tension or digital flexion. We tried to eliminate variables, such as fracture and replantation that would alter our typical postoperative therapy protocol for zone II flexor tendon repairs. We believe that the positive results for zone II repairs reported first by Kleinert and then by many others to excessively generalize recommendations for primary repair in all of most traumatic cases regardless of mechanism of action, need for replantation, revascularization, or presence of associated injuries.

#### *Conclusion:*

This study serves as a prognostic guide for patients with injuries of flexor tendons in zone II. It will help guide the surgeon in providing expected outcomes to patients who sustain zone II flexor tendon injuries based on mechanism of action, and determine the incidence of complications and its potential contributory factors.

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