

## Zone II Thumb Flexor Tendon Repair: A Functional Outcome Report

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### ABSTRACT

**Background:** Although the utmost importance of the thumb to hand biomechanics, the reports discussing thumb flexor tendon repair are few if compared to other digits. A reliable report for flexor tendon repair should include a standard surgical technique, rehabilitation and evaluation protocols, and the outcomes in correlation to the surgeons' level of expertise. We report our experience in management of flexor pollicis longus (FPL) tendon injuries at zone II.

**Patients and Methods:** Between 2015 and 2022, a retrospective study included 26 patients with zone II FPL tendon injuries were included. By using a goniometer, the percent of the total active range of motion in comparison to the contralateral thumb was assessed and graded according to Tang criteria of assessment.

**Results:** The follow-up period ranged from 7 to 28 months with average 10.5 months. The total active thumb range of motion was graded excellent in 15.3% (n=4), good in 42.3% (n=11), fair in 30.7 (n=8), poor in 11.5% (n=3), and zero incidence of tendon rupture. The only documented major complication was poor functional outcome that needed a session of tenolysis. The remaining of the complications were managed conservatively. The zone V retrieval incision showed the least functional outcome and were used in 8 patients. Seven out of the 8 patients were graded as poor to fair and only one patient was graded as good. Among 20 repairs done by level 4 surgeons, 60% (n=12) of patients showed excellent to good functional outcome grading, and 25% (n=5) incidence of minor complications. Among 6 repairs done by level 3 surgeons, only 50% (n=3) of patients showed excellent to good functional outcome grading, and 33% (n=2) incidence of complications, one was major complication that needed another session of tenolysis.

**Conclusion:** In consideration to its importance, more studies should be directed to report the FPL tendon injuries. The reports including the surgeons' level of expertise are more informative and reliable for interpretation of the functional outcome.

**Key Words:** *Thumb – Flexor tendon – Zone II repair.*

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### INTRODUCTION

The anatomical location of the flexor pollicis longus (FPL) tendon makes its injury not uncommon,

particularly during forceful grip [1]. For normal gripping and fine pinching to occur the thumb biomechanics should be regained after injury. [2]. This makes the FPL tendon repair utmost importance for hand functions. Several studies have reported flexor tendons repair, especially injuries at Zone II. These injuries were specifically discussed because of the higher incidence of the post-operative complications that can lead to reoperation [3,4,5]. Notably, the reports discussing thumb flexor tendon repair are few if compared to other digits. Moreover, the reports discussing FPL tendon injuries at zone II are even more scarce. This literature deficiency opens the field for more reports that discuss the functional outcomes after FPL tendon repair [6].

A reliable report for flexor tendon repair should include standard surgical technique, rehabilitation, and evaluation protocols. To be mentioned that the results of flexor tendon repairs are expertise dependent. So, including the surgeons' level of expertise is a prerequisite for the reliable interpretation and comparing of different reports' outcomes [7,8].

In the current study, we report our experience in management of FPL tendon injuries at zone II. Also, we evaluate the functional outcome and complications in relation to the surgeons' level of expertise.

### PATIENTS AND METHODS

In a retrospective study, 26 consecutive patients with FPL tendon injuries were included. Only zone II FPL tendon injuries were included with or without associated neurovascular bundle injuries. All patients had a primary tendon repair during the interval between 2015 and 2022. During patients' selection, other inclusion and exclusion criteria were applied (Table 1). The expected outcomes and complications were explained to the patients in a detailed informative consent. The ethical research committee of our institution approved the protocol of the study.

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Table (1): The inclusion/exclusion criteria applied for patient selection.

Inclusion	Exclusion
1- Complete cut of the FPL tendon	1- Associated fractures and/or joints dislocations, or amputations
2- Zone II FPL tendon injuries	2- Presence of thumb ischaemia
3- Primary tendon repair	3- Other long flexor tendon injury in the same traumatized hand
4- At least 6 months follow-up period	4- Associated soft tissue loss
5- Surgeon's level of expertise 3 or higher	5- Avulsion or crushing tendon injuries
	6- Uncooperative patient (not fitting for the active motion rehabilitation protocols)

*Surgical technique:**Aesthesia:*

The principal steps for hand flexor tendon injuries repair were applied. The procedure was done under regional or general anaesthesia. The wide-awake local anaesthesia no tourniquet (WALANT) approach was used only in 4 cases. The procedure started with wound preparation and extension if needed to achieve adequate exposure and tendon retrieval. During tendon retrieval, the FPL tendon vincular system was carefully preserved. First, through the atraumatic technique then through judicious use of proximal exploratory incisions. Using zone V (the distal forearm) exploratory incision was considered as the last resort for FPL tendon retrieval.

Four strands cruciate core suture was the standard technique used. With considering the FPL tendon size, the selected suture was 3/0 or 4/0 polypropylene (Prolene™, Ethicon Inc, Johnson & Johnson Medical N.V.). Minimal over tightening was intentionally performed to avoid tendon gapping post-operatively. Epi-tendinous continuous running suture 5/0 polypropylene (Prolene™, Ethicon Inc, Johnson & Johnson Medical N.V.) was added to strengthen the core suture.

Extension/Flexion test was a check point after tendon repair to check for tendon gapping, grante tendon smooth gliding through the flexor sheath, and to detect impingement of the tendon repair sheath at the proximal pulley edge (Fig. 1). In zone II injuries the oblique pulley was either cut during trauma or vented to allow free tendon gliding after repair.

Intraoperatively, we released the area in between A1 and A2 pulley in case of ill identified oblique pulley anatomy. Additionally, the A2 pulley venting was done if the site of tendon injury was nearer to Zone I. While A1 pulley was partially vented if the site of injury was more proximal nearer to zone III. Routinely, the vented flexor tendon sheath area was 1-1.5cm in length. This released interval was enough in all our cases to achieve smooth gliding.

In cases associated with neurovascular bundle injury, nerve repair was done before skin closure.

*Post-operative dressing:*

A dorsal splint was applied with sperate wing to control thumb extension (Fig. 2). The wrist was positioned in a neutral or a comfortable position for the patient without exerting any tension on the repaired FPL tendon. The splint was applied to put the thumb basal joint in midway to palmar abduction, the first Metacarpophalangeal (MP) joint in 20-30 degrees of flexion, and interphalangeal (IP) joint fully extended.

*Occupational therapy protocol:*

Early active motion was incorporated in our rehabilitation protocol. The protocol started with 3-5 days of complete rest. This was followed with 4 weeks of active motion sessions. The active motion sessions started with warming up exercise through full passive flexion/active extension motion to eliminate joint stiffness and extension lag. Following the warming up period, the main session targeted an active flexion motion. The active flexion motion started gradually from 10-20% of the full thumb flexion reaching at maximum to 50% at the end of the session. Full active flexion motion was totally prohibited to avoid unnecessary stresses exerted on the FPL tendon repair site that may lead to tendon disruption in the first 4 weeks. Starting from the 5<sup>th</sup> to the 8<sup>th</sup> week post-operatively, the active motion sessions targeted the full active thumb flexion. After 6 weeks, the splint was removed except at bedtime for 2 more weeks, and exercises were continued to achieve full active thumb range of motion (ROM) and eliminate the remaining extension lag and/or joint stiffness.

*Evaluation of the functional outcome:*

At the final evaluation visit, the occupational therapist or the hand surgeon use a goniometer to measure the thumb total active (ROM) (Fig. 3). The percent of the total active (ROM) in comparison to the contralateral thumb was assessed and graded according to Tang criteria of assessment [7].

Fig. (1): A twenty-three-year-old female patient with cut FPL tendon zone II and ulnar digital nerve of the left thumb. (A) Intra-operative extension test to check for free tendon gliding and exclude gapping at site of repair. (B) Intra-operative photo showing preservation of the vinculum mesentery at zone II after tendon repair (yellow arrow pointing to the vinculum mesentery).

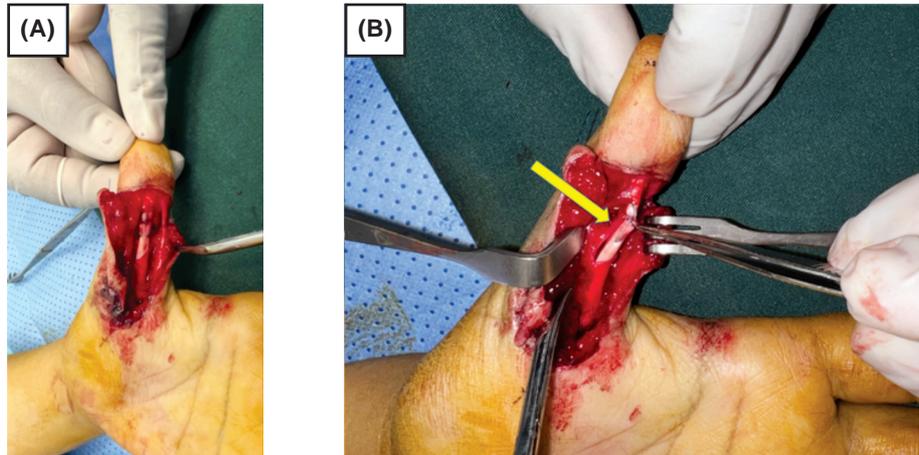


Fig. (2): (A) A forty-nine-year-old male patient isolated cut FPL tendon at zone II. (B) Intra-operative photo for proximal stump retrieval through local wound extension with preservation of the vinculum mesentery at zone II. (C) Immediate post-operative splint with the wrist in neutral position, basal joint at midway to palmar abduction, MP joint in 20 degrees flexion, and IP joint in extension. (D) Seven weeks post-operatively, the patient was able to flex the IP joint actively 30 degrees after full extension.

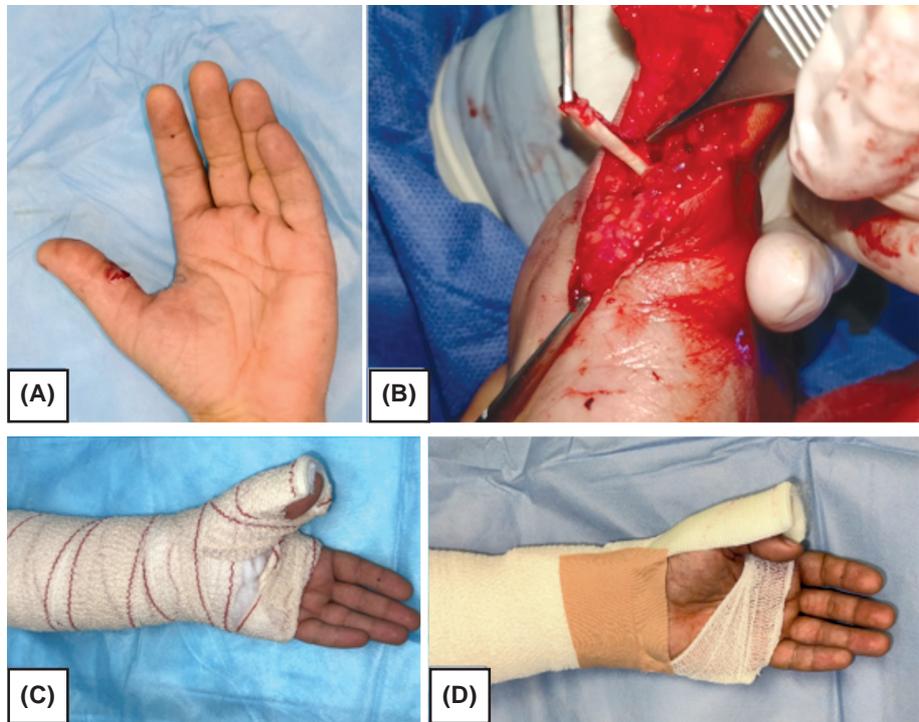
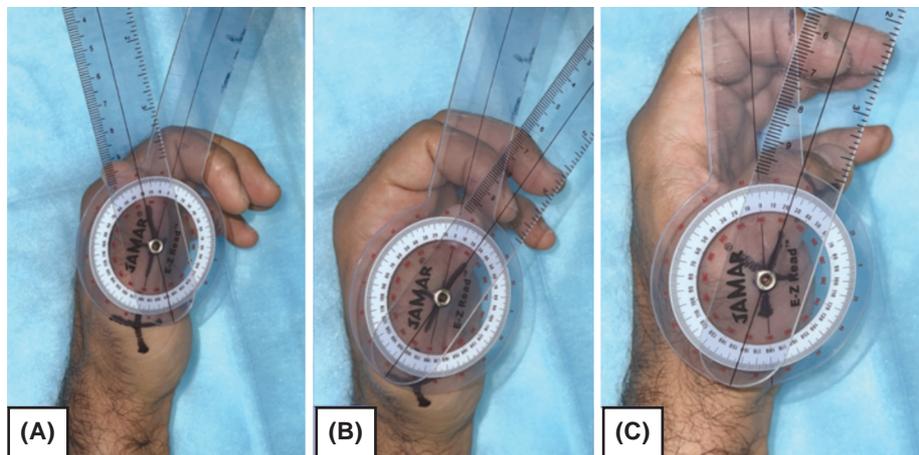


Fig. (3): A Forty-nine-year-old male patient with cut FPL tendon zone II of right thumb. One-year post-operatively, a goniometer was used to measure the IP and MP joints active range of motion (ROM). (A) The IP joint hyperextension was 30 degrees. (B) The IP joint flexion was 25 degrees. (C) The MP joint flexion ROM was 23 degrees. The total active ROM was 78 degrees whilst the contralateral normal thumb was 94 degrees. The injured thumb achieved 82.9% of the active ROM of the contralateral normal thumb and was graded as good functional outcome.



**RESULTS**

The patients' demographic data and etiology of FPL injury were documented (Table 2). For FPL tendon proximal end retrieval, the already presented wounds with/without proximal extensions into zone III were used in 57.7% of patients (n=15). Sperate incisions at zone V (the distal forearm) were used in 30.7% of patients (n=8). Sperate incision at zone IV (the Carpal tunnel) was used in none of our patients. In 11.5% of patients (n=3),

Table (2): The patients' demographic data and aetiology of FPL tendon injury.

Age (Years)	Range (20-66), Mean (34.9)
Sex	Male 73% (n=19), Female 26.9% (n=7)
Injured thumb	Right 30.7% (n=8), Left 69.2% (n=18)
Injury of the non-dominant thumb	69.2% (n=18)
Associated neurovascular injury	Isolated 19.2% (n=5) Digital neurovascular bundle 80.7% (n=21)
The mode of injury	Sharpe (sharp tin, glass) 88.4% (n=23) Sharpe revolving (saw) 11.5% (n=3)

The follow-up period ranged from 7 to 28 months with average 10.5 months. The total active thumb (ROM) was documented during

a distal extension of the already presented wound was used to retrieve the distal end of the FPL tendon (Table 3).

The oblique pulley was vented in 15.3% of patients (n=4). Venting of the oblique pulley in addition to A2 pulley was done in 26.9% of patients (n=7). Venting of the oblique pulley in addition to partial A1 pulley was done in 57.7% of patients (n=15) (Table 3).

Table (3): The FPL tendon retrieval incisions and the intra-operative pulley venting used among the included population.

	Number of patients
<b>A- The FPL tendon Retrieval incision:</b>	
1- Same wound	(n=6)
2- Wound extension distal	(n=3)
3- Wound extension proximal into zone III	(n=9)
4- Sperate incision at zone IV (Carpal tunnel)	(n=0)
5- Sperate incision at zone V (Distal forearm)	(n=8)
<b>B- Pulley venting:</b>	
1- Oblique pulley	(n=4)
2- Oblique pulley + A2 pulley	(n=7)
3- Oblique pulley + A1 pulley partial	(n=15)

the final evaluation visit and graded according to Tang criteria of assessment (Fig. 4) [12] (Table 4).

Fig. (4): (A) Intra-operative photo of a 51-year-old male patient with isolated FPL zone II injury by sharp metal. (B) Intra-operative photo of the tendon retrieval and repair. (C) and (D) Ten month post-operatively, the total active ROM of the left thumb was 80 degrees which is 84.2% of the contralateral normal thumb active ROM and was graded as a good functional outcome.

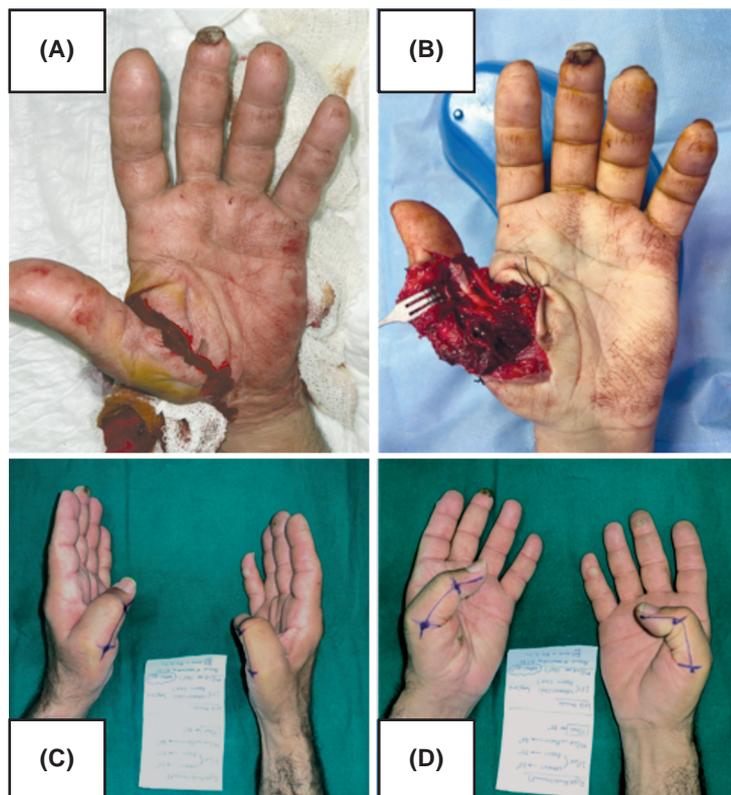


Table (4): Criteria of assessment of the FPL tendon repairs among the included population.

Function Grade	Return of Motion*	Percent of patients %/Number (n)
Excellent	90-100	15.3% / (n=4)
Good	70-89	42.3% / (n=11)
Fair	50-69	30.7% / (n=8)
Poor	30-49	11.5% / (n=3)
Failure	<30	zero

\*The percent of the total active range of motion (ROM) in comparison to the contralateral thumb.

For one patient, the FPL tendon adhesions resulted in poor functional outcome and the patient was scheduled for tenolysis session. Two more patients with poor functional outcome declined any surgical intervention, as both patients considered the outcome satisfactory in terms of their daily activities. Other complications were considered minor and managed conservatively. Delayed wound healing was documented in two patients and was related to the uncontrolled diabetes mellitus in one patient and bad hand hygiene in another manual worker patient. Also, two patients had observable bowstringing of the FPL tendon with good final functional outcome as per the assessment criteria (Table 5).

Table (5): The incidence of complications among the included population.

Complications	Number of patients	Management
1- Tendon adhesion	(n=1)	Tenolysis session
2- Delayed wound healing	(n=2)	Conservative
3- Numbness	(n=2)	Conservative
4- Bowstringing	(n=2)	Conservative

By relating the functional outcome to the retrieval incision used during repair, zone V incision showed the least functional outcome. The fair and poor functional outcome represented 87.5% (n=7) among the 8 repairs used separate zone V (Distal forearm) retrieval incision. Only 12.5% (n=1) showed good functional outcome.

On the other hand, the excellent and good functional outcome represented 77.7% (n=14) among the 18 repairs done through local wound extensions without using the separate retrieval incision at zone V. The fair functional outcome in this group of patients represented 22.2% (n=4), no patient showed poor functional outcome.

#### Surgeon expertise level:

The study included 26 patients with cut FPL tendon zone II. The surgical repair was done by 3 surgeons. Two of them were of level 4 (highly experienced specialist). Both surgeons underwent 20 FPL tendon repairs out of the 26. The third surgeon was of level 3 (experienced specialist) who underwent 6 FPL tendon repairs.

By relating the functional outcome to the level of surgeons' expertise, the excellent and good outcome represented 60% (n=12) among the repairs done by the level 4 expertise surgeons on the other hand, only 50% of the repairs done by the level 3 expertise surgeon recorded excellent and good functional outcome.

Moreover, by relating the incidence of complications to the level of surgeons' expertise, the incidence of complications was 25% (n=5) among repairs done by level 4 expertise surgeons. This incidence of complications increased to be 33.33% (n=2) among repairs done by the level 3 expertise surgeon, where one patient presented with sever FPL tendon adhesions that dictated a following tenolysis session.

## DISCUSSION

Surgeons have long been aware of the problems associated with repair of the flexor pollicis longus (FPL) tendon and have recognized the associated challenges that do not present in other finger tendons [10,11]. The reports of FPL tendon injuries repair are few and not all the available reports are fulfilling the criteria of a standard report as recommended by Tang [12]. So, we described the functional outcome of FPL tendon repair specifically after zone II injuries. Moreover, the authors implemented a combination of a strong repair technique, judicious pulley venting approach, incorporation of early active motion rehabilitation protocol, and using stringent criteria for functional outcome assessment.

The strong repair techniques and incorporation of early active motion protocol are considered the standard of care in most of the specialised hand units [13]. Yet judicious pulley venting still an intra-operative decision that is affected by the bulk of repair and tendon gliding through the flexor sheath. In turn, both factors are affected by the surgeon's level of expertise [14,15,16].

Here comes the surgeon's level of expertise as a control switch that balances the benefit of free

tendon gliding against the negative effect of bowstringing on the biomechanics of thumb. At zone II FPL tendon injuries, the oblique pulley is vented to ensure free tendon gliding after repair [7,12].

Due to the anatomical variation of the oblique pulley, [17] the area between A1 and A2 is vented whenever the oblique pulley could not be clearly identified. Additionally, partial A1 or complete A2 pulleys venting might be needed to get free tendon gliding during extension/flexion test intra-operatively [18].

An intact oblique or A1 pulley can maintain normal excursion of the FPL tendon and the func-

tion of the thumb [19]. Zissimos and his colleagues sequentially sectioned the thumb pulleys and found that cutting both the A1 and oblique pulleys led to considerable bowstringing [20]. In our study, it is possible that bowstringing can exist anatomically, but the extent of this bowstringing is still functionally tolerable if A1 pulley is preserved at least partially (Fig. 5). To be mentioned that Pan et al., even went further and reported in their study a non-significant bowstringing despite the complete A1 pulley venting [6,21]. In our study, the length of the vented flexor tendon sheath ranged from 1 to 1.5cm. Other than thumb, this conclusion was reported during long flexor tendon repair to be 1.5 up to 2cm [22-25].

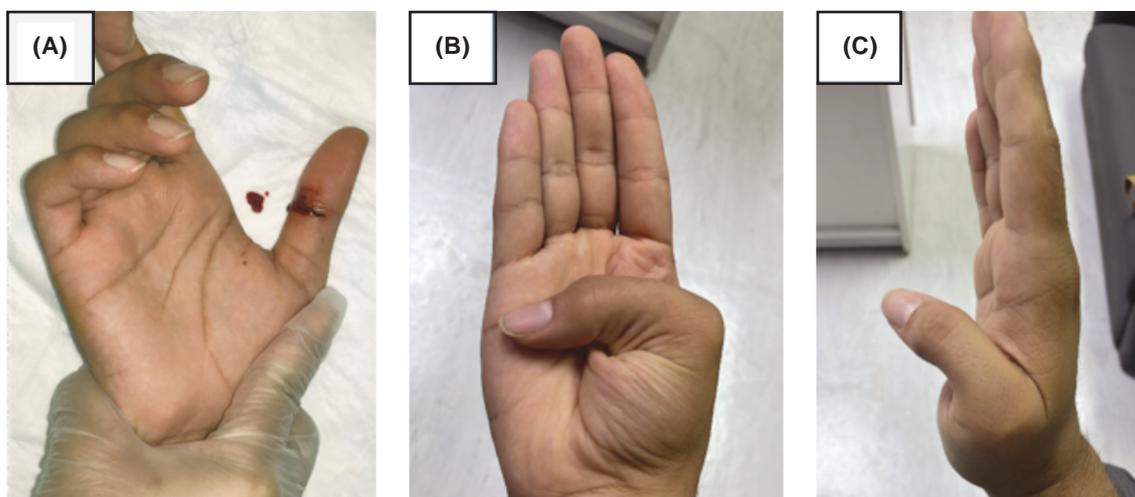


Fig. (5): A 29-years old male with cut FPL tendon zone II of the right non-dominant hand. (A) A pre-operative photo showing a cut wound of the right FPL tendon zone II. (B) The oblique pulleys venting led to considerable bowstringing, but the extent of this bowstringing was functionally tolerable. (C) Twenty-eight-month post-operative, the evaluation visit showed 90.2% total active ROM if compared to the contralateral normal thumb total active ROM.

The wide-awake local anaesthetic non-tourniquet (WALANT) approach is gaining more popularity in the field of hand surgery for many reasons. The golden benefit of this approach is the intra-operative active flexion motion which allows immediate evaluation of the tendon repair and the adequacy of pulley venting. Consequently, in case of tendon gapping and/or triggering, tendon repair revision and/or more pulley venting is feasible before skin closure. Certainly, the WALANT approach improves the results, cost effectiveness, and patient satisfaction during flexor tendon repair [26]. Nevertheless, the WALANT approach requires high surgical expertise and collaborative work with other specialities as anaesthesia and radiodiagnosis. Currently, the ultrasound guidance becomes very beneficial to plan surgical exploratory incisions and consequently the safety of the local anaesthetic solution infiltration [27].

At the digital zone of the FPL tendon, the extrinsic blood supply was described to be condensed proximal to the MP joint and just distal to the IP joint under cover from the A2 pulley, leaving zone II relatively avascular area [28,29]. Rushing to retrieve the proximal end of the FPL tendon through distal forearm wrist incision is not recommended. Proximal exploratory incisions through thenar or carpal tunnel zone are more advisable to avoid unnecessary disruption of vincular vascular supply. In the current study, we observed the presence of a vincular mesentery at zone II just distal to the MP joint. The mesentery held the proximal end of the FPL tendon from retraction proximal to zone III on many occasions. Yet, more studies are needed in the future to describe the detailed anatomy of the extrinsic blood supply of the FPL tendon to prove or deny this anatomical observation (Figs. 1,2,6).

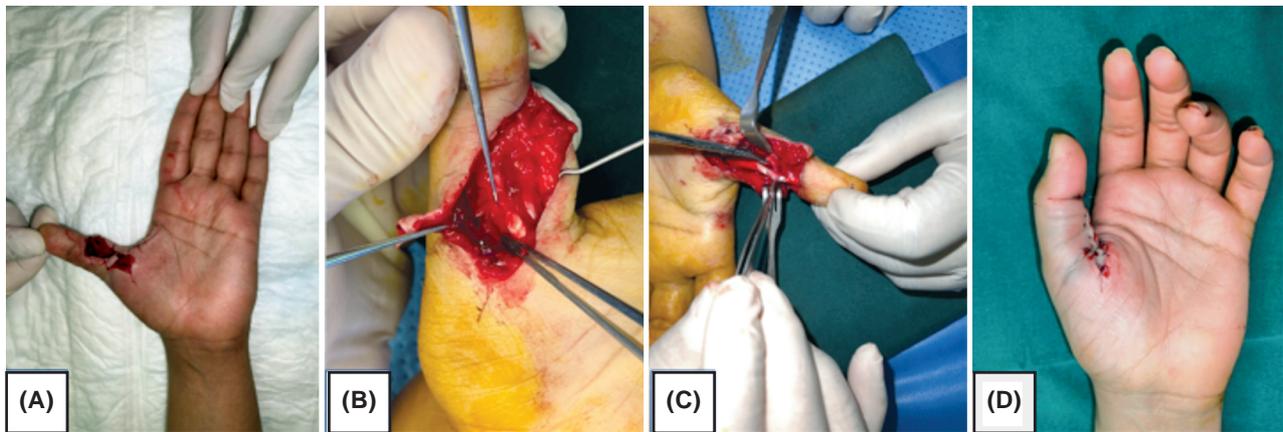


Fig. (6): (A) Zone II injury of left FPL tendon by sharp object (Glass). (B) The proximal FPL stump was hanged by the vinculum mesentery at zone II originating from underneath the oblique pulley at zone II. (C) The proximal stump was passed through the tunnel under the oblique pulley with preservation of the vinculum mesentery. (D) Immediate post-operative photo, the thumb regained normal flexion cascade.

Also, the retrieval of the FPL tendon proximal end through zone V (Distal forearm) incision disrupts the tendinous communication between the FPL tendon and the flexor digitorum profundus (FDP) of the index. This communication is considered a normal variation (Linburg-Comstock variation) in 13-66% of population [30-33]. In conclusion, the disruption of the extrinsic blood supply and the presence of the Linburg-Comstock variation might be behind the higher incidence of adhesions and decreased functional outcome seen among patients where zone V retrieval incisions were used.

Since 1980 and up till now, the most popular assessment protocol had been the Strickland criteria for hand long flexor tendon injuries zone II. Till now there is no thumb specific functional outcome evaluation protocol [11]. In 2009 Giesen and colleagues used the white criteria and Buck-Gramcko criteria to evaluate the functional outcome of FPL tendon repair among 50 patients by calculating only the total active (ROM) of the IP joint only [34]. In 2007 Tang, proposed a more stringent criteria which was derived from the original Strickland criteria; to evaluate the flexor tendon repair zone II but not for the thumb [12]. In the current study, we adopted the Tang modified Strickland criteria to evaluate the functional outcome among the included population. The IP and the MP joints were evaluated instead of the DIP and PIP joints to calculate the total active (ROM) after FPL tendon repair.

The active (ROM) of the thumb joints (IP and MP) are more variable than other digits [35, 36]. This variability in the (ROM) is attributed to the anatomical configuration of the MP joint and the mutual functional relation with the adjacent IP and basal joints [37]. Therefore, this variability stands against a standard assessment of the functional outcome after FPL

tendon repair. So, we used the contralateral thumb as a reference to evaluate the final total active (ROM) for the injured thumb post-operatively. Undoubtedly, there is difference between active (ROM) of the dominant and non-dominant thumbs, and this can be considered as one of our study limitations. Also, the number of the included sample can be considered as another limiting factor, whereas a larger sample size would have enforced the significance of our results.

In the last decade, the reports published by specialised hand units showed remarkable improvement in the functional outcome and diminished incidence of rupture after long flexor tendons repair. This fact is not completely correct in case of non-specialised practice where there is still incidence of tendon rupture [13]. This increases the importance of including the surgeons' level of expertise in reports of specialized surgeries, especially hand flexor tendon repairs. Moreover, the comparison with other reports would become more reliable with more sensible justification of the outcomes [7]. Of course, in depth statistical analysis of the active range of motion values will show significant difference between different group of patients who was operated upon by different level surgeons. Yet, the number of patients was our main limiting factor as mentioned earlier. So, we resorted to analysis the outcome and incidence of complications in relation to the different level surgeons' group of patients. Aiming in the future to collect more institutional data that will include bigger sample size with more statistical significance.

In the current study, the FPL tendon repairs done by level 4 expertise surgeons showed 10% higher incidence of excellent and good functional outcomes, whilst 8.3% less incidence of complications. Furthermore, the only reoperated patient was among the group operated by level 3 expertise surgeon.

**Conclusion:**

More reports should study the FPL tendon injuries because of its utmost importance to the whole hand function. The reports including the surgeons' level of expertise are more informative and reliable. The main factors behind successful FPL tendon repair at zone II are the strong tendon repair techniques, adequate tendon gliding ensured by judicious pulley venting, incorporation of early active motion protocols for rehabilitation, and standard reliable criteria of assessment that facilitates the comparison between different reports and adds to the field of hand surgery.

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