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Flexor Digitorum Superficialis Tendon Injuries in Zone II: To Repair or Not

AHMED GADALLAH, M.Sc.; ADNAN GAMAL ETMAN, M.Sc. and MOHAMED M. ABDELHALIM, M.D.

The Department of Plastic, Burn and Maxillofacial Surgery, Faculty of Medicine, Ain Shams University

ABSTRACT

Background: Attaining favorable functional results after flexor tendon repair in zone II has always been a complex task. This is primarily due to the cramped positioning of the flexor digitorum profundus (FDP) and the two slips of the flexor digitorum superficialis (FDS) within a narrow fibro-osseous tunnel. Such a confined space significantly increases the risk of postoperative adhesions and consequent limitations in postoperative range of motion and strength. The primary objectives of tendon restoration revolve around enhancing tendon healing and minimizing adhesion formation.

Objective: The objective of this study is to evaluate the clinical outcomes after surgery by assessing postoperative range of motion (ROM) and radiological findings using Musculoskeletal Ultrasound (MSK US). Specifically, we aim to compare the results between cases where both the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) tendons are repaired in Zone II flexor tendon injuries, and cases where only the FDP tendon is repaired. Additionally, we will examine the formation of granulation tissue as a parameter in our evaluation.

Patients and Methods: This interventional clinical trial involves a total of fifty individuals who have experienced flexor tendon injuries in zone II. The patients were selected from those who underwent surgery at El Dmerdash Hospital, based on the inclusion and exclusion criteria outlined in our study. A random sampling method was employed to divide the patients into two groups. Group I consist of twenty-five patients (the study group) who underwent repair of both the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) tendons. Group II comprises twenty-five patients (the control group) who underwent repair of only the FDP tendon.

Results: In our investigation, 50 cases with four strand repairs of zone II flexor tendon injuries were considered. The rehabilitation and follow-up procedures were the same for both groups. According to Strickland criteria, the results were measured in terms of total range of motion and revealed significant differences between the two groups. Group with repair of both FDP and FDS has a higher range of motion. MSK US showed a higher rate of granulation tissue formation in group I but was not statistically significant.

Conclusion: In management of flexor tendon injuries zone II, we recommend repairing both FDP tendon and FDS tendon to keep the integrity of full motion of the digit. Repairing both slips of FDS in addition to FDP tendon may increase the granulation tissue formation which impairs gliding but that can be avoided by routine post operative physiotherapy and avoid bulky intra operative repair.

Key Words: *Flexor Tendon – Zone II – FDP – FDS – Adhesion – Range of motion – Flexor repair.*

Ethical Committee: The ethical committee of the college of Medicine at Ain Shams University had approved the study. All patients received written informed consent detailing the methodology used in this study, particularly care and attention to the confidentiality of patient identities and addresses.

Disclosure: No conflict of interest.

INTRODUCTION

For several reasons, flexor tendon regeneration, particularly zone II, is a challenging procedure for patients and surgeons. The main cause is the requirement for surgery to restore these tendons after injury. To reduce adhesions and improve gliding, which increases the risk of an early tendon rupture, they also require diligent post-operative early physiotherapy. Finally, because of the unique anatomy of the tendon passage via the tight tendon sheath **[1]**.

Despite the advancements in suture materials, surgical techniques, and early post-operative supervised physiotherapy **[2-4]**, surgeons continue to face significant challenges in managing tendon adhesions and the resulting limitations in range of motion.

Concern continues to surround the recognized causes of repair failure, such as adhesions and postoperative triggering. There will always be challenges for researchers looking at the biology and mechanics of flexor tendon repairs, particularly in zone II.

Correspondence to: Dr. Ahmed Mahmoud Abd Elkader Gadallah, E-Mail: ahmed.gadallah93@gmail.com

Better results were achieved from improvements in suture material **[5]**, suture technique **[3,6]**, and early postoperative mobilization and rehabilitation programs **[7]**.

To repair the flexor tendon surgically, tendon grafting was once a frequent practice **[2]**. However, in recent years, numerous articles have noted that primary and delayed tendon repair is a superior modified surgical technique to grafting. In the 1950s and 1960s, Verdan et al., **[8]** served as examples of this transition.

Full restoration of tendon function requires mandatory postoperative physiotherapy. It is highly recommended to initiate early physiotherapy to enhance tensile strength and minimize adhesion formation **[9]**.

Limited research has been conducted on the simultaneous repair of the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) tendons within the same finger. Additionally, while there is ample information on the mechanical characteristics of different suture techniques for FDP repair, there is a lack of knowledge regarding the mechanical behavior of FDS repair during tendon motion **[10]**.

Repair of zone II flexor digitorum superficialis (FDS) injuries remains controversial. There is consensus that when FDS and flexor digitorum deep (FDP) injuries are combined, the FDP should be repaired with a multi-strand core suture technique. There is no clear agreement on the management of FDS. In the literature, studies have shown that by repairing both FDS slips **[1]**, repairing one FDS slip and removing the other slip **[11,12]**, or completely removing the FDS **[5,6]**. Removing the FDS avoids the volume associated with repairing inside A2 pulley.

Aim of work:

The goal is to assess the post operative clinical outcomes according to ROM (range of motion) and radiologically using MSK US (Musculo - skeletal ultrasound) according to granulation tissue formation if we repair both FDP (flexor digitorum profundus) and FDS (flexor digitorum superficialis) in Zone II flexor tendon injuries compared to repair of FDP only.

PATIENTS AND METHODS

Patients: Our clinical study targeted patients with acute zone II flexor tendon injuries admitted to El Demerdash Hospital and followed-up for at least twelve weeks at our outpatient clinic.

Type of study: This is a prospective clinical single blinded controlled clinical study.

The Ethical Committee of the College of Medicine at Ain Shams University had approved the study. All patients received written informed consent detailing the methodology used in this study, particularly care and attention to the confidentiality of patient identities and addresses.

Inclusion criteria:

- Patient-related criteria: Patients 15-40 years old of both genders, cooperative and fit for surgery.
- Flexor tendon injury related criteria: Zone of the injury: Zone II, time of trauma: (Acute trauma) less than 48 hours.

Exclusion criteria:

Patient-related criteria for exclusion from the study include individuals with conditions such as Buerger's disease, Raynaud's disease, mental disabilities, coma, liver or renal failure, patients requiring intubation and/or mechanical ventilation, as well as pregnant women.

Tendon related criteria: Trauma lasting longer than 48 hours, associated extensor tendon lacerations, bony fractures, vascular or nerve injury, and loss of tendon segment.

Methods:

Initial evaluation: At the emergency department, all patients were examined. Examinations and assessments were conducted including:

History taking:

Personal history: Personal history includes patient's name, age, sex, occupation, hand dominance, time, type of trauma.

Previous medical and surgical history: None of the patients in the current research had other debilitating diseases that can affect the post-operative outcomes.

History of the injury: Mechanism of injury, etiology, timing, side, and site.

The fifty patients were randomly allocated into two groups. Group I consisted of twenty-five patients (the study group) who underwent repair of both the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) tendons. Group II comprised twenty-five patients (the control group) who underwent repair of only the FDP

tendon. The random division ensured unbiased distribution of patients among the two groups for the study.

Clinical evaluation:

Examination of the neurovascular bundle: In the current study, all patients had normal distal vascularity. The average time it takes to refill digital pulp capillaries (2-6 seconds). The radial and ulnar digital nerves of the injured finger were examined. All patients with nerve or vascular injury were excluded.

Evaluation of soft tissue and skin condition: All patients' wounds were repaired with sutures. No skin or soft tissue loss occurred in the patients was included.

Assessment of tendon function: Assess the FDP tendon by flexing the distal interphalangeal joint and assess the FDS tendon by flexing the proximal interphalangeal and metacarpophalangeal joints.

Radiological assessment: Patients had three views of hand X-ray (Antero Posterior, lateral and oblique). There were no concomitant skeletal fractures, joint dislocations, or foreign bodies in any of them.

First aid management: In all patients the wound was kept clean by applying a sterile dressing after washing and irrigation by saline. A splint was then placed under the elbow in a neutral posture until the time of surgery to better protect the injury site and prevent tendon retraction. Antibiotics and analgesics were also prescribed.

Laboratory tests: Complete blood count, chemistry, clotting profile, virology.

Anesthesia: All patients were operated on by general anesthesia.

Surgical approach: After sterilization and applying a tourniquet to the arm, a mid-lateral or zigzag incision is used for surgical exposure (Bruner's approach). Flexor tendons were checked again under anesthesia to confirm preoperative provisional diagnosis with better visualization of tendon's ends through the incision.

Tendons are repaired using Prolene 3/0 or 4/0 by 4-strand techniques supplemented with 5-0 or 6-0 Prolene epitendinous sutures **[13]**.

Tendon repair: All FDP tendons repaired in the current study used a core suture of 3/0 or 4/0 polypropylene (Prolene TM) 4 strand and a single continuous epitendinous suture of 5/0 or 6/0 Prolene strands. It was restored using the 4-strand technique. Meanwhile, the injured two slips of FDS tendon were reconstructed in the same manner as the FDP tendon. A technique involving the release of entire A3 pulley to facilitate tendon repair and most distal part of the A2 pulley or the proximal part of the A4 pulley were employed to enable the retrieval of the proximal or distal stump of the injured tendon.

Finally, the wrist was fixed in a neutral position using a postoperative splint. During the surgical procedure, the interphalangeal joints were maintained in a fully extended position, while the metacarpophalangeal joints were flexed to approximately 90 degrees. After suturing the skin with a simple 4/0 Prolene strand suture.

Postoperative rehabilitation: Within the first 24 h, the neurovascular integrity of the affected finger and the patient's ability to follow a trained wound care and mobilization program were confirmed.

Postoperative medications were prescribed (antibiotics, antiedema drugs, analgesics).

Passive finger movements were initiated in the first week to provide ideal passive range of motion, especially for fingers with severe edema, prior to the initial active protocol. Once edema resolves, patients are instructed to begin early active movement with splints of moderate active flexion and extension 10 times per hour, with range of flexion over the first 3 weeks.

Sutured wound healing was examined during our follow-up. While wearing the splint, the patient was instructed to gradually improve range of motion. In most cases, skin sutures were not removed until 2 weeks to avoid skin dehiscence during active movement. After 6 weeks, the splint was removed, and weight-bearing exercise and light daily activities were allowed. After 3 months, continued reinforcement activities and full hand use were allowed.

At the sixth and twelfth weeks after the surgery, finger range of motion was assessed using a standard goniometer. Total active movement (TAM) was measured for the proximal and distal interphalangeal joints. The assessment followed the original Strickland system, and the results were recorded according to the guidelines outlined in Table (1). This approach allowed for objective evaluation of finger range of motion during the postoperative period.

Table (1): Strickland evaluation system **[14]**.

Score	Original Strickland (TAM / 175) (%)	TAM (PIP + DIP flexion minus extensor loss) (degree)
Excellent	85-100	>150
Good	70-84	125-149
Fair	50-69	90-124
Poor	<50	<90

RESULTS

As shown un Table (2): Most of our patients were males (88%), non-highly educated (76%) with right hand dominance (80%).

As shown un Table (4): The most common cause of injury assault (70%), with glass as most common cause (60%). The most common finger to be injured was the little finger (40%).

Statistically significant difference between both groups regarding ROM measured in 6th week post operative with *p*-value 0.026.

Statistically significant difference between both groups regarding ROM measured in 12th week post operative with *p*-value 0.019.

Granulation tissue formation was higher in group I than group II with no statistically significant difference *p*-value 0.306.

Table (2): Demographics of both groups.

Variable	Total cases (n=50)	
	No.	%
Age:		
Adolescent (15-19 years)	15	30
Adult (20-40 years)	35	70
Gender:		
Male	44	88
Female	6	12
Dominant hand:		
Right	40	80
Left	10	20
Occupation:		
Manual worker	45	90
Others	5	10
Education:		
Low or intermediate	38	76
High	12	24
Special habits of medical importance:		
Smoking	38	76

Table (3): Comparison between group I (study group) and group II (control group) according to age.

Age (years)	Group I (n=25)	Group II (n=25)	Independent *t*-test	
			Test value	*p*-value
Range	15-40	15-40	3.837	0.458
Mean ± SD	35.14±5.39	32.72±4.55		

Table (4): Injury associated data.

Variables	N	Total cases	
		No	%
Mechanism:			
Glass	50	30	60
Sharp instrument		8	16
Knife		12	24
Aetiology of injury:			
Accidental	50	15	30
Assault		35	70
Side of injury:			
Right	50	38	76
Left		12	24
Digital distribution:			
Index	50	8	16
Middle		6	12
Ring		16	32
Little		20	40

Table (5): TAM of repaired digits at 6 and 12 weeks in both groups.

TAM	Group I (n=25)	Group II (n=25)	Independent *t*-test	
			Test value	*p*-value
After 6th week	292.10±69.87	264.5±59.57	1.297	0.201
After 12th weeks	442.2±98.03	404.07±91.67	0.847	0.401
Paired *t*-test	–7.016	–6.712		
p-value	<0.001	<0.001		

Table (6): ROM in both groups in the 6th week.

ROM	6th weeks Group I		6th weeks Group II		Chi-square test	
	No	%	No	%	X^2	*p*-value
Excellent	12	48	4	16	9.269	0.026
Good	7	28	6	24		
Fair	5	20	8	32		
Poor	1	4	7	28		

Table (7): ROM in both groups in the 12th week.

ROM	12th weeks Group I		12th weeks Group II		Chi-square test	
	No	%	No	%	X^2	*p*-value
Excellent	13	52	5	20	9.956	0.019
Good	8	32	7	28		
Fair	4	16	8	32		
Poor	0	0	5	20		

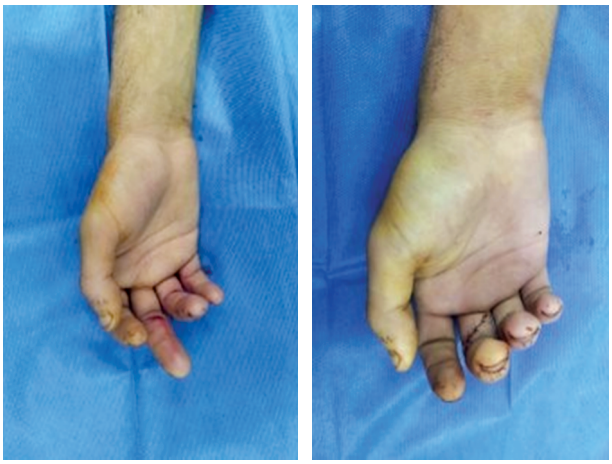

Fig. (1): Hand cascade after 4 strand repairs.

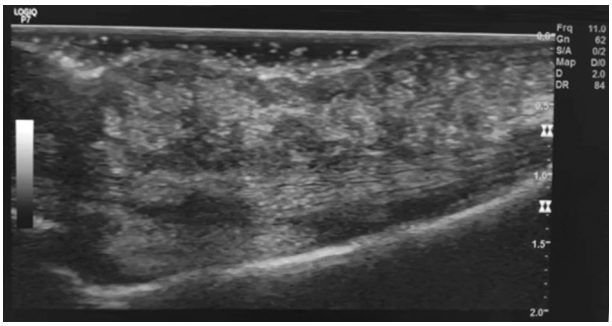

Fig. (2): Granulation tissue in MSK US.

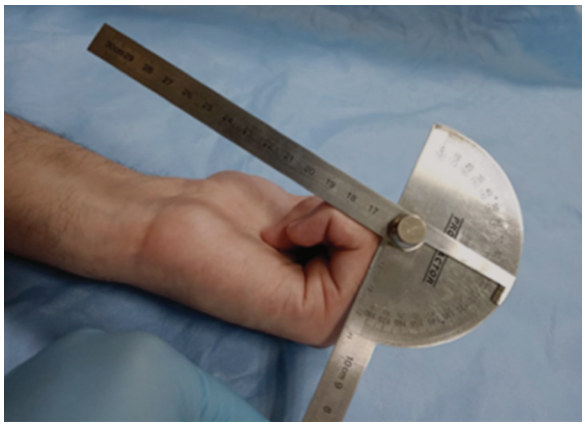

Fig. (3): Using goniometer to measure ROM.

Table (8): Granulation tissue formation.

Granulation tissue	Group I N=25		Group II N=25		Chi-square test	
	No	%	No	%	X^2	*p*-value
Normal	21	84	18	72	1.049	0.306
Extensive	4	16	7	28		

DISCUSSION

Comparing the findings of the current study with existing literature is challenging due to the diverse factors that influence the outcomes of flexor tendon repair. These factors encompass patient age, the nature and extent of the injury, case selection criteria, preoperative delay, repair technique employed, postoperative rehabilitation program, and patient adherence to the treatment plan **[15]**. Therefore, establishing direct comparisons between the results of the present study and those of previous research poses difficulties due to the multitude of variables involved.

However, a lot of work was put into finding studies that were comparable and, to a significant extent, matched the current study, making this comparison significant. In this study, individuals with acute zone II flexor tendon injuries underwent tendon primary repair. In the rehabilitation process, an Early Active Motion Protocol was implemented, similar to the protocols utilized by Caulfield et al. **[16]**, Sandow and McMahon **[17]**, Braga-Silva and Kuyven **[18]**, Starnes et al. **[19]**, Al-Qattan **[20]**, and Klein **[21]**. These studies involved primary repair of flexor tendons in zone II and employed the original Strickland evaluation system was utilized to articulate their findings.

There are multiple debates around the repair of flexor tendon Zone II injuries. The studies conducted by Klein **[21]**, Caulfield et al. **[16]**, Starnes et al. **[19]**, Braga-Silva and Kuyven **[18]** and Sandow and McMahon **[17]** have provided support for the notion that repairing both FDP and FDS tendons leads to improved range of motion (ROM). While Al-Qattan **[20]**; Tang **[22]** have recommended repairing only FDP tendons in zone II injuries.

50 patients ranging in age from 15 to 40 made up our sample. 88% of respondents clearly males. This is because they are more likely to sustain injuries than other groups.

Patients with finger fractures, soft tissue loss, vascular injuries requiring revascularization, and ages below fifteen have been eliminated from the study as exclusion criteria. The exclusion criteria in Caulfield et al. **[16]**, Sandow and McMahon **[17]**, and Klein **[21]** are comparable to this. These criteria were disregarded to create a study group that was well matched and to identify variables that might affect the repair's results.

In our study, the most prevalent category among the participants was non-highly educated individuals, accounting for 76% of the sample. Additionally, manual workers constituted 90% of the participants. When comparing these findings to the study conducted by Starnes et al. **[19]**, it is evident that there are notable differences. In Starnes et al.'s **[19]** study, it was observed that 62% of their patients were non-university graduates, while manual workers constituted only 29% of the participant population. These differences suggest a social dependency in our study population, this trend can be attributed to the higher vulnerability of non-highly educated individuals and manual workers to occupational injuries.

In our study, smokers accounted for 76% of the patients, whereas Starnes et al. **[19]** reported a lower percentage of 28.6% smokers among their patients. This difference can be attributed to diverse cultural and behavioral factors in different societies.

Regarding the causative agents, glass was the primary cause of injury in 60% of cases in our study, which closely aligns with the findings of Starnes et al. **[19]** where knives caused 61.1% of cases. Additionally, in our study, acts of violence emerged as the primary cause of injury, accounting for 70% of patients.

In terms of the involved digits, our study found that the little finger was the most frequently injured (40%), followed by the ring finger (32%), index finger (16%), and middle finger (12%). This distribution can be attributed to the fact that the ring and little fingers are more exposed during defensive actions, considering that violence was the primary etiology. Starnes et al. **[19]** excluded the thumb finger from their study and reported a distribution where the little finger had the highest involvement (41.2%), followed by the ring finger (29.2%), index finger (25%), and middle finger (4.2%).

In the repair of tendons, our study utilized a 3/0 or 4/0 prolene cruciate single cross-stitched locked four-strand core suture and a 5/0 or 6/0 prolene simple continuous epitendinous suture. Barrie et al. **[23]** conducted a biomechanical study that demonstrated the superior fatigue strength and holding capacity of the four-strand cross-stitch locked repair with a 3-0 suture compared to other repairs.

In a study by Caulfield et al. **[16]**, tendon injuries in zones I to IV were repaired using both absorbable and non-absorbable sutures, and no notable distinction was observed between the two groups. However, in our study, all injured tendons were repaired using non-absorbable sutures to standardize the repair method and minimize its impact on the outcomes.

The significant increase in total active movement (TAM) and Strickland scores from 6 to 12 weeks post-repair highlights the importance of extending follow-up and rehabilitation programs up to 3 months to observe the improvements in range of motion.

In group I of our study, the final range of motion was excellent to good in 80% of the involved digits and fair to poor in 20% of the digits. In group II, the final range of motion was excellent to good in 64% and fair to poor in 36%. These findings are comparable to the study described by Braga-Silva and Kuyven **[18]**, where excellent to good results were observed in 72.2% of the involved digits and fair to poor results in 27.8% of the digits.

Regarding detection of granulation tissue formation by MSK US, we found that the incidence was 28% in group I and 16% in group II. This clarifies that repair of both FDP and FDS tendons may increase the risk of post operative granulation tissue formation, but the comparison was non statically significant. Also, granulation tissue formation can be managed by strict post operative physiotherapy to avoid any effect on tendon gliding.

In our study, we tried to unify patients' criteria as much as possible. We selected the patients who had bilateral hand injuries and compared the same digit in both hands of the same person with the same status of pulley system (e.g., male presented with bilateral index fingers injury, so we repair both FDP and FDS in one index and we repair only FDP in contralateral index) to avoid any bias.

Conclusion:

Our study recommended repairing both FDP and FDS tendons in zone II flexor tendon injuries to increase the range of motion and to achieve a satisfactory result for both patient and surgeon.

Continuous practice and better patient compliance will improve the post operative outcomes. Also, we recommend further clinical studies on the relationship between the pully system and the repair of flexor tendons.

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