

# Comparative study between early active and passive rehabilitation protocols following two-strand flexor tendon repair: can two-strand flexor tendon repair withstands early active rehabilitation?

Hala M. Abdel Sabour<sup>a</sup>, Amir Labib<sup>b</sup>, Ahmed Abel Sallam<sup>b</sup>, Mohey Elbanna<sup>c</sup>

Departments of <sup>a</sup>Physical Medicine, Rehabilitation and Rheumatology, <sup>b</sup>Plastic Surgery, <sup>c</sup>General Surgery, Faculty of Medicine, Ain Shams University, Cairo, Egypt

Correspondence to Hala M. Abdel Sabour, MD, Department of Physical Medicine, Rheumatology and Rehabilitation, Faculty of Medicine, Ain Shams University, 56 Ramsis Street, Abbasseya, Cairo 11566, Egypt. Tel/fax: 02 26830729; e-mail: halams@medu.asu.edu.eg

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## Background

Restoration of full range of motion of digits as well as prevention of joint contracture following flexor tendon repair is a challenge. There is lack of solid evidence regarding the most suitable rehabilitation protocol following flexor tendon repair. This is owing to the limited number of studies comparing different rehabilitation protocols. Moreover, the present studies advocate a specific technique with no comparative group. Even the few controlled studies conducted vary in methods of repair and rehabilitation, and outcome assessment. To our knowledge, the only randomized controlled trial comparing early passive rehabilitation with early active rehabilitation is the one done by Trumble and colleagues in 2010, which was done on four-strand repaired tendon. These authors concluded that active rehabilitation program had better range of motion with less flexion contractures and greater satisfaction scores than those subjected to passive rehabilitation protocol.

## Aim

This conclusion stimulated us to study the effect of early active mobilization versus early passive mobilization following two-strand repair.

## Patient and methods

We conducted our study for 12 weeks comparing early active mobilization protocol 'place and hold' with early passive mobilization 'modified Kleinert' after standard two-strand modified Kessler repair in different hand zones.

## Results and conclusion

We concluded that early active mobilization had better tendon gliding and excursion even with the two-strand repair as active motion will decrease adhesion formation, with significant difference compared with the passive group. Moreover, there was no significant difference in the rupture rate and significant difference for combined tendon lag and flexion deformity owing to the tenodesis mobilization between both the groups.

## Keywords:

flexion deformity, flexor tendon repair, rehabilitation, tendon lag, two-strand suture, modified Kleinert

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## Introduction

Despite the great advance in understanding flexor tendon anatomy, physiology, biomechanical mechanism of excursion and gliding, healing process and postoperative rehabilitation, still there is a significant rate of failure [1].

There are multiple points to keep in mind regarding tendon function postoperatively. There is always a problematic dilemma to balance between decreased rupture rate and return of the full range of tendon excursion [1].

Before the mid-1970s, most of the flexor tendon rehabilitation programs focused on late mobilization after the first 3 weeks following tendon repair as tendon tensile strength was considered low to perform active

exercise during this period of time, but this ended in a high rate of tendon adhesions and limitation of range of movement [2].

Chow *et al.* in 1987 stated that only 3–5 mm tendon excursion was sufficient to prevent adhesion formation postoperatively [3]. Moreover, Edinburg *et al.* in 1987 showed good results of tendon function following immediate postoperative active extension passive flexion with attached rubber band and dorsal blocking splint [1]. Since this time, there is an accumulated expanding knowledge regarding suture

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materials, methods of tendon repair, and rehabilitation programs, which evolves toward early mobilization [4].

As it become evident that early passive rehabilitation programs are superior to prolonged immobilization regarding tendon excursion and gliding [5,6], several studies began investigating early active rehabilitation programs and found them more beneficial regarding tendon gliding and excursion [6,7].

There is a gap in knowledge regarding the most appropriate rehabilitation program following flexor tendon injury because of sparse number of head-to-head comparison between early active rehabilitation programs protocols and early passive rehabilitation programs. To our knowledge, only Trumble *et al.* [8] discussed this point and stated that 'Active motion therapy provides greater active finger motion than passive motion therapy after zone II flexor tendon repair without increasing the risk of tendon rupture.' Yet this study was limited to four-strand repair and did not assess two-strand repair.

In our study, we randomized patients to an early active (place and hold) rehabilitation protocol compared with an early passive rehabilitation protocol (modified Kleinert) following two-strand repair of flexor tendon injuries, with validated outcome assessments of motion and patient satisfaction.

## Patients and methods

### Patients

This study was conducted in Physical Medicine and Rehabilitation Department, El Demerdash Hospital, Ain Shams University after approval of Ethical committee, and performing patient consent, over a period of 12 months between August 2015 and August 2016. It included 33 patients with 45 injured flexor tendons who presented to the emergency unit of the corresponding hospital fulfilling the following criteria:

- (1) All flexor tendon injuries at all zones of the hand.
- (2) Patients between the age of 15 and 75 years.

### Exclusion criteria

The following were the exclusion criteria:

- (1) Patients younger than 15 years, because of higher incidence of tendon rupture [9].
- (2) Patients who are older than 75 years, as they have been shown to have deterioration of hand function scores, and normative data for these patients are not available [10].

- (3) Patients with crush injury with extensive soft-tissue loss.
- (4) Documented compliance problems (e.g. substance abuse).
- (5) Those with medical conditions preventing repair and pre-existing problems such as arthritis limiting joint motion were also excluded.

A total of 33 patients (45 injured tendons) were enrolled in the study, and only 26 patients (36 tendons) continued the study, as seven patients were lost to follow-up. Overall, 20 (55.5%) tendons were on early passive protocol (modified Kleinert) and 16 (44.4%) tendons were on the early active protocol (place and hold).

The patients comprised 21 (80.7%) males and five (19.2%) females; their age ranged from 15 to 60 years, with a mean of 26.8 years. Regarding the patients' occupation, 15 (57.67%) patients were manual workers, four (15.3%) patients were housewives, four (15.3%) patients were students, and three (11.5%) patients had professional jobs (Table 1).

Of the patients' injuries, seven (19.4%) tendon injuries occurred in zone I, 22 (61.1%) tendon injuries occurred in zone II, seven (19.4%) tendon injuries in zone III, and 0% in zone IV and zone V. There were eight (22.58%) patients with more than one tendon affection. There were 11 (35.48%) fingers that had associated neurovascular injuries.

The distribution of the injured fingers was as follow: six (16.6%) tendons were flexor pollicis longus, 13 (36.1%) tendons were index finger, eight (22.2%) tendons were middle finger, three (8.3%) tendons were ring finger, and six (16.6%) tendons were little finger. Of the injured fingers 47.2% (17 tendons) occurred in the nondominant hand, and 52.7% (19 tendons) occurred in the dominant hand (Table 2)

### Surgical technique

All tendons were repaired by experienced hand surgeons who had at least between 4 and 6 years of training in hand

**Table 1 Demographic data**

Categories	n (%)
Sex	
Male	21 (80.7)
Female	5 (19.2)
Occupation	
Manual worker	15 (57.67)
Housewife	4 (15.3)
Student	4 (15.3)
Professional job	3 (11.5)

**Table 2 Details of the injuries**

	<i>n</i> (%)
Dominant hand	13 (50)
Nondominant hand	13 (50)
Affected finger	
Thumb	6 (16.6)
Index finger	13 (36.1)
Middle finger	8 (22.2)
Ring finger	3 (8.3)
Little finger	6 (16.6)
Associated injuries	
Associated nerve injury	7 (22.58)
Associated arterial injury	7 (22.58)
Associated fracture	3 (9.7)
Zones	
1	7 (19.4)
2	22 (61.1)
3	7 (19.4)
4	0 (0)
5	0 (0)

surgery. The wound was extended using Bruner incisions, and a flap was raised to expose the tendon, preserving the functionally important A2 and A4 pulleys. Pull out suture was made for zone 1 injury with short distal stump (<1 cm). The used suture materials were 3/0 or 4/0 prolene for core suture modified Kessler technique and 5/0 or 6/0 prolene for epitendinous sutures. Associated digital nerve and arterial injuries were repaired by the 8/0 or 9/0 ethibond, and the tendon rehabilitation protocol was not altered.

### Postoperative rehabilitation

All the patients were splinted in dorsal blocking splint with wrist in 20° flexion, Metacarpo-phalangeal joint (MCP) joint in 70° flexion and interphalangeal joints in full extension. The splint was removed after 6 weeks. We randomized patients into two groups by random sequence-generating website [11]: both groups started rehabilitation program within the first 3 days after tendon repair under the supervision of a hand rehabilitation consultant.

One group underwent early passive rehabilitation program by modified Kleinert method (passive flexion and active extension) in addition to passive range of motion for all joints.

The other group received early active rehabilitation programs (place and hold) wherein the digit is passively flexed by the unaffected hand and then the patient tries to maintain the flexed posture through active contraction of the involved muscle for 5 s [12], in addition to passive range of motion for all joints, and passive flexion active extension, progressed to active tenodesis. Each patient

was instructed to do these exercises 25 times per waking hours for the first 6 weeks.

Then assessment began at sixth week postoperatively measuring the following outcomes:

- (1) Flexion deformity and tendon lag: by using goniometer, this will be done by measurement of degree of flexion deformity in proximal interphalangeal (PIP) and distal interphalangeal (DIP). Then measuring the difference between active and passive range of motion for both joints to assess flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP).
- (2) Disability assessment by validated Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was done at 6 months from the time of surgery to compare outcomes [13].
- (3) Patients' satisfaction with their hand function was measured on an analog scale from 0 (completely dissatisfied) to 10 (completely satisfied).
- (4) Postoperative complications including the following:
  - (a) Rupture rate.
  - (b) Adherent scar formation.

### Data management and analysis

The collected data were revised, coded, tabulated, and introduced to a PC using statistical package for the social science (SPSS 15.0.1 for Windows, 2001; SPSS Inc., Chicago, Illinois, USA). Data were presented, and suitable analysis was done according to the type of data obtained for each parameter.

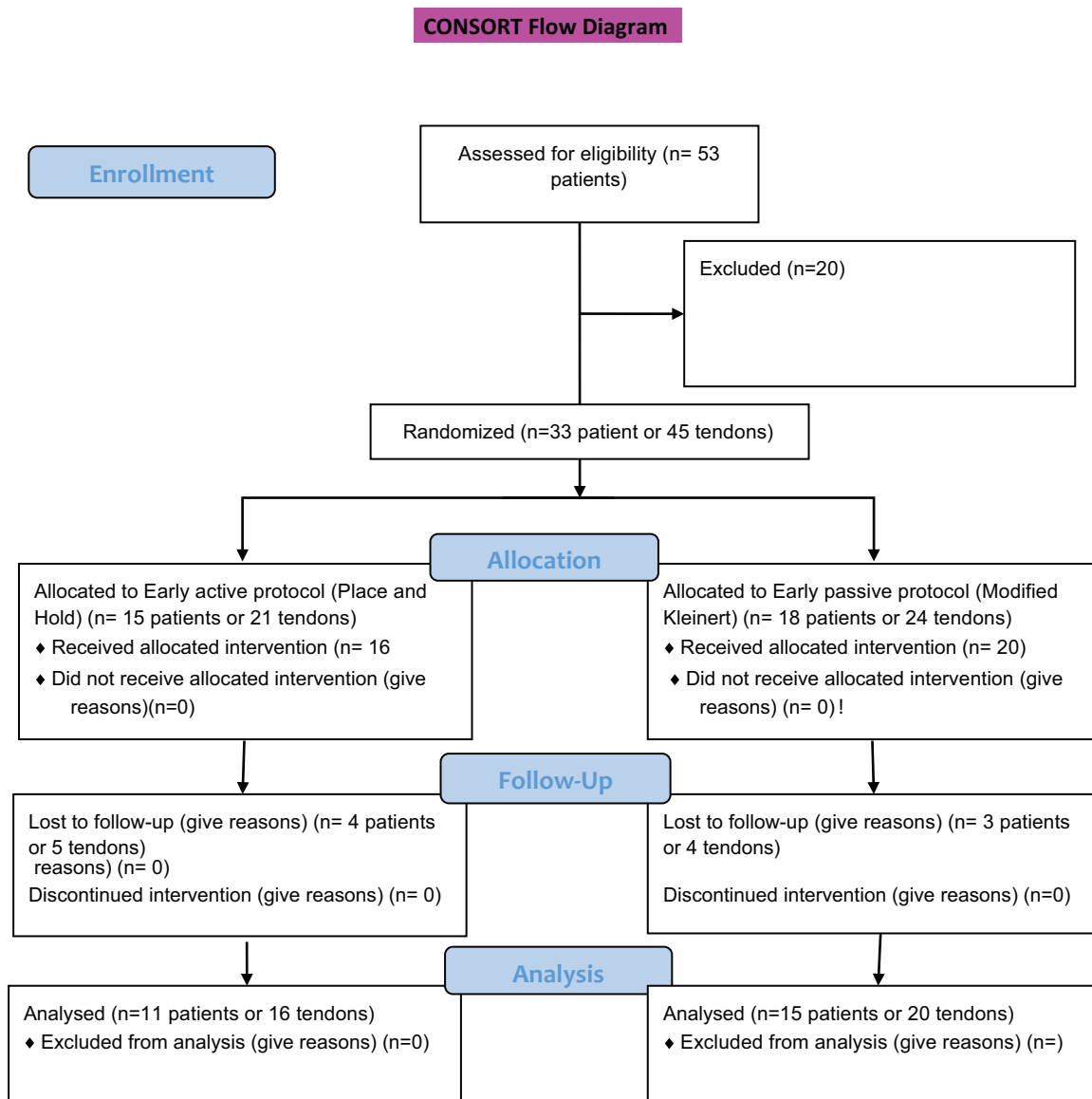
### Descriptive statistics

Mean±SD and range for parametric numerical data whereas median and interquartile range (IQR) for nonparametric numerical data were used. Frequency and percentage were used for non-numerical data.

### Analytical statistics

Mann–Whitney test (*U* test) was used to assess the statistical significance of the difference of a nonparametric variable between the two study groups. Student's *t* test was used to assess the statistical significance of the difference between the two study groups. The *P* value was considered significant if less than 0.05%. No data were available on DASH to assist with the power analysis. The primary outcomes of this study were range of motion and rupture rate. The secondary outcomes were scar formation, patient satisfaction assessed by DASH score and analog score from 0 to 10 (Diagram 1).

Diagram 1



CONSORT flow diagram.

## Results

Of the 33 enrolled patients (45 injured tendons), only 26 patients (36 tendons) continued the study, as seven patients were lost to follow-up. A total of 20 (55.5%) tendons were on early passive protocol (modified Kleinert) and 16 (44.4%) tendons were on the early active protocol (place and hold). The patients comprised 25 (80.6%) males and six (19.3%) females, and their age ranged from 15 to 60 years, with a mean of 26.8 years.

Overall, 10 (50%) tendons of the 20 tendons underwent passive program showed flexion deformity in DIP, whereas in the active program, one (6.2%) of 16 tendons showed DIP flexion deformity. There was a statistically significant

difference between the two groups ( $P=0.004$ ). Regarding the flexion deformity in the PIP joint, 40% (eight tendons) of the passive group had a degree of flexion deformity and 18.7% (three tendons) of the active group also complained of a degree of flexion deformity, with no statistically significant difference between the two groups ( $P=0.1$ ). However, combined flexion deformities of both DIP and PIP joints showed significant difference between active and passive groups ( $P=0.02$ ) (Fig. 1).

There was a degree of tendon lag in FDP and FDS in both groups. The FDS tendon lag in passive group was 50% (10 tendons) and 12.5% (two tendons) in active group, with statistically significant difference ( $P=0.012$ ). The FDP tendon lag also showed

statistically significant difference between the two groups ( $P<0.001$ ) with 75% (15 tendon) in passive group and 12.5% (two tendons) in active group, and also for combined tendon lag for both tendons, there was a significant difference ( $P<0.001$ ) (Fig. 2).

The patient satisfaction with their hand function was measured on an analog scale from 0 (completely

dissatisfied) to 10 (completely satisfied). The median score for the patient satisfaction in the active group was 6 with IQR between 4 and 8.5, whereas in the passive group, it was 4 with IQR between 2 and 7. These values showed a statistically significant difference between the two groups ( $P=0.049$ ).

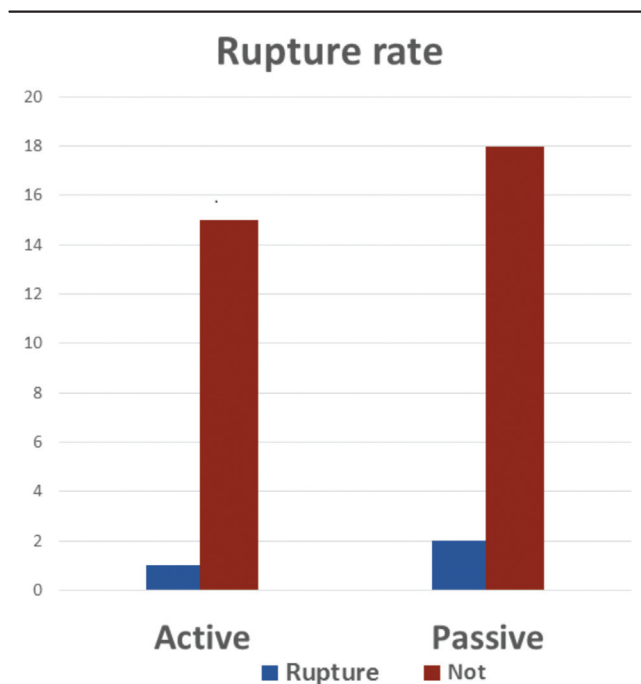
DASH questionnaire, which was used for objectively assessing the hand function from the patient perspective, revealed that the passive group showed a median of 15 with IQR between 10 and 30, whereas the active group showed a median of 23 with IQR between 2 and 26. These results show no statistically significant difference ( $P=0.62$ ).

Regarding the adherent scar formation, there was a statistically significant difference between the two groups ( $P=0.001$ ) with 70% (14 tendons) in the passive group and 0% (0 tendons) in the active group (Fig. 3).

Regarding the rupture rate, the passive group showed two (10%) rupture tendons of the 20 tendons, whereas the active group has one (6.25%) rupture tendon of the 16 tendons, with no statistically significant difference between the two groups (Fig. 4).

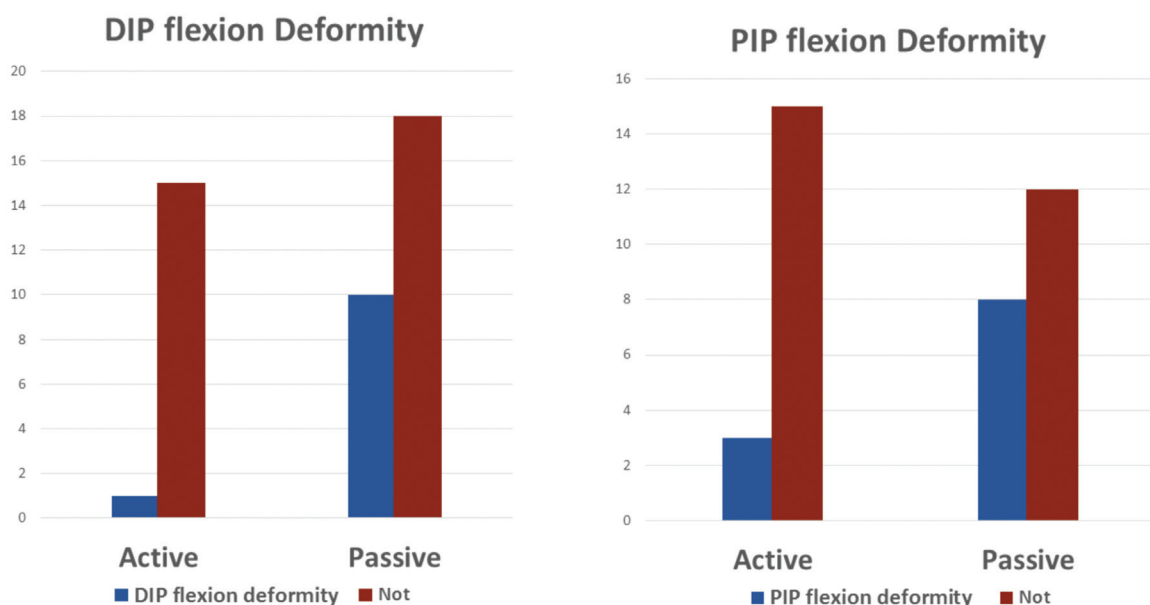
There were 11 patients with associated repaired digital nerve and vessels, four in the active rehabilitation group and seven in the passive group, who continued on the

Figure 1



Flexion deformity in both distal interphalangeal (DIP) joints and proximal interphalangeal (PIP) joints.

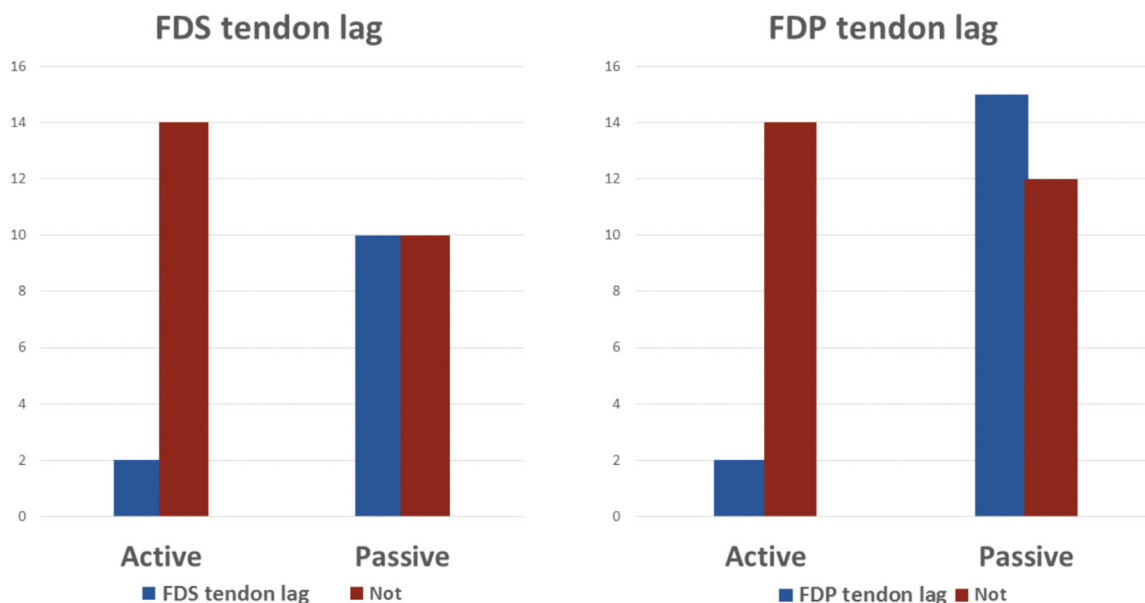
Figure 2



Flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) tendon lag.



Figure 3



Adherent scar rates in both groups.

Figure 4

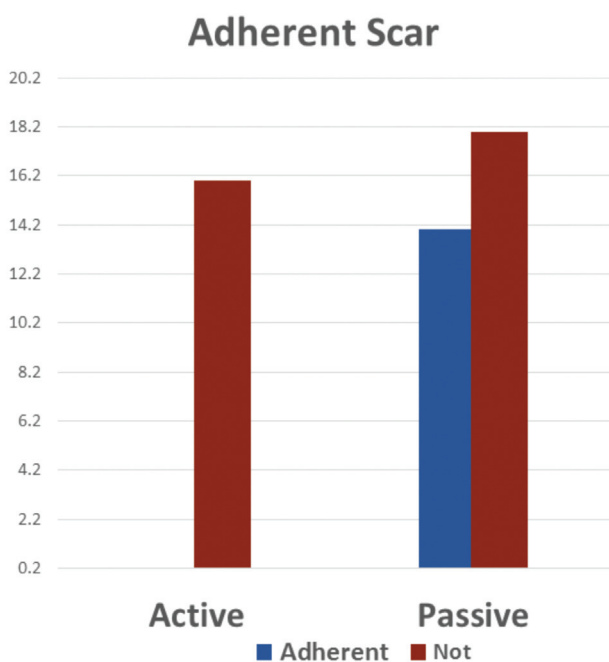


Diagram showing tendon rupture rates in both groups.

same program with no incidence of rupture in any of them.

### Discussion

Full return to the active digital range of motion as well as prevention of joint contraction and adhesions following flexor tendon repair is a challenging problem facing hand surgeons worldwide. Many

modalities of rehabilitation program were advocated since 1960 [14]. The immobilization program was the first program to be considered. Then, because of the poor results of the previously advocated immobilization programs [1], Kleinert and colleagues [15–18] developed controlled motion protocol based on active extension passive flexion of the injured digit within a dorsal blocking splint.

As it became evident that early passive mobilization has a superior outcomes over immobilization [18–20], several authors began to think about controlled early active mobilization. Their studies yielded that early active mobilization has better tendon gliding with fewer adhesions [21,22]. Yet, the risk tendon rupture was still one of the obstacles against early active mobilization protocols [23].

There is a great gap of knowledge in the literature about the most appropriate rehabilitation programs after flexor tendon injury. This is owing to the sparse number of randomized control trails comparing different rehabilitation protocols. On the contrary, this puts a great burden upon the hand surgeon when choosing studies advocating a specific technique, with no controls. Even the few controlled studies conducted vary in methods of repair, splinting positions, start time of rehabilitation, and outcome assessment [19,24].

Silfverskiöld and May [7] demonstrated that the tendon excursion and gliding was better in the active

extension passive flexion group compared with the only passive motion protocol. Trumble *et al.* [8], after performing a randomized study comparing active versus passive programs following standard four-strand repair of flexor tendon injuries in zone II, stated that patients on active rehabilitation program had better range of motion with less flexion contractures and greater satisfaction scores than those in the passive rehabilitation protocol.

In our study, we postulated that early active mobilization will lead to better tendon gliding and excursion even with the two-strand repair as active motion will decrease adhesion formation.

Comparing our findings with the results of Trumble *et al.* [8], who found that the rupture rate in active group was 4.4% (two of 45 tendons) and the rupture rate in passive group was 4.5% (two of 44 tendons). Of these four ruptures, three occurred in the little finger. In our study, we have one rupture case in the active group of the 16 (6.25%) tendons and two (10%) rupture cases in the passive group of 20 tendons, with no statistically significant difference ( $P=0.6$ ), denoting that the active program with two-strand repair can withstand early mobilization with place-and-hold technique.

Regarding the tendon lag and flexion deformity, Trumble *et al.* [8] found that at 6 weeks there is a statistically significant difference between active and passive groups. The combined flexion contracture of the PIP and DIP joints for active group averaged  $27\pm 12$  at 6 weeks, and the flexion contracture in the passive group averaged  $42\pm 19$  at the same time [8].

In our study, we found that the combined flexion deformity of DIP and PIP in active group at 6 weeks averaged  $3.1\pm 6.3$  and for the passive group averaged  $27.8\pm 43.8$ , with  $P$  value of 0.02, denoting a statistically significant difference, which occurs owing to the tenodesis mobilization that is performed in the early active mobilization group, as during wrist flexion, the tension on extensor tendons brings the digits into extension, whereas during extension of the wrist, tension in flexor tendons brings digits into flexion. This mobilization helps to reduce edema and joint stiffness and promote proximal gliding of flexor tendons.

However, for the tendon lag, there is significant difference between active and passive groups for combined tendon lag for both FDS and FDP ( $P<0.001$ ), and that is owing to active mobilization with maximal extension of the

interphalangeal joints that promote passive gliding of the flexor tendons [22]. When performed carefully, this can give rise to good clinical results, although there is a risk of rupturing the repair [23]. Moreover, active flexion of the finger contributes toward differential gliding between the flexor tendons. Moreover, active muscle contraction promotes recovery of muscle tone and strength. The loading that is applied to the repaired tendon during active finger flexion improves the tensile strength after healing [24].

On the contrary, the DASH score at 6 months postoperatively for the active group averaged  $19.1\pm 18.9$ , whereas for the passive group averaged  $20.2\pm 14.4$ , with no statistically significant difference ( $P=0.84$ ). In the study by Trumble *et al.* [8], DASH score at 1-year postoperatively showed significant difference between the two groups ( $P=0.09$ ), as the active group averaged  $2\pm 3.7$ , whereas the passive group averaged  $3.1\pm 4.3$ .

Regarding adherent scar formation, there was a statistically significant difference between healing processes. Moreover, a difference in the beneficial effect of increased blood flow and increased oxygenation was seen in the two groups ( $P=0.001$ ), with 70% (14 tendons) in the passive group and 0% (0 tendons) in the active group.

The median of the patient satisfaction score in the passive group was 4 with IQR of 4–8.5, whereas in the active group was 6.00 with IQR of 4–8.5. There was a statistically significant difference between the two groups ( $P=0.049$ ).

Previously, Charles *et al.* [25] showed that active exercises has a beneficial effect on wound healing, via neuroendocrine regulation and changes in cortisol responsivity, which result in immune function changes relevant to the wound, thereby enhancing wound-healing rates.

All of these agree with the study of Mikkawy *et al.* [26], which showed that early active mobilization in flexor tendon has a higher mean average grip strength and earlier improvement than the passive mobilization program.

The limitations in our study was the number of patients that continued the total follow-up which were for 6 months, so we lost a lot of patients. This is attributed to the economic burden of the follow-up period, as most of the patients are manual workers so they could not complete their regular visits.

## Conclusion

Early active mobilization had a better tendon gliding and excursion even with the two-strand repair, as active motion will decrease adhesion formation, with significant difference to the passive group. Moreover, there was no significant difference in the rupture rate and significant difference for combined tendon lag and flexion deformity owing to the tenodesis mobilization between both the groups.

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Nil.

## Conflicts of interest

There are conflicts of interest.

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