Comparison between early active and passive mobilization programs after hand flexor tendon repair in zone II
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Objective
The objective of this study was to study the efficacy of an early active mobilization program in comparison with passive mobilization on the range of motion (ROM) and grip strength after flexor tendon repair in zone II.

Patients and methods
The Modified Kessler technique, followed by a continuous epitendon suture was used to repair 21 digits in 18 patients with hand flexor tendon injury in zone II (which extends from the distal palmar crease to the middle of the intermediate phalanx of the digit). Early active mobilization of the repaired digit was started 1 day postoperatively in nine digits (group I), whereas early passive mobilization with the use of elastic bands was started in the other 12 digits (group II). ROM was monitored and compared in the two groups at 4, 8, and 12 weeks using the Total Active Motion (TAM) Score of the American Society for Surgery of the Hand, whereas hand grip strength was assessed at 8 weeks.

Results
There were better improvements in the TAM score in the early active mobilization group than in the passive mobilization group (11.1% excellent grade compared with 0%, 33.3% good grade compared with 8.3%, 55.6% fair grade compared with 58.3%, 0% poor grade compared with 33.3%, respectively). Comparison between progression of the TAM score at 4, 8, and 12 weeks postoperatively showed a highly significant improvement in the early active mobilization group ($P=0.002$, 0.0001, and 0.002, respectively), whereas improvement in the passive mobilization group was found to be significant ($P=0.012$) only between 4 and 12 weeks. There were highly significant differences in grip strength between the normal and the affected side in both groups but the mean average grip strength was higher among the patients in the early active mobilization group.

Conclusion
An early active mobilization program after flexor tendon repair in zone II leads to better results in terms of the total active ROM. Progressive improvement occurred earlier than that in the passive mobilization program. The mean average grip strength was higher among the patients in the early active mobilization group.

Keywords:
early mobilization, rehabilitation, tendon injuries

Introduction
Flexor tendon injuries continue to be disabling diseases as the strength in the hand and finger is significantly reduced after flexor tendon repair and this causes disability [1]. Mobilization following flexor tendon repair is essential for healing and repair as early motion has been shown to stimulate tendon healing and decrease adhesions [2]. New techniques such as closure of the tendon sheath and multiple strand repairs with early active mobilization are believed to lead to better results [3]. The goal of rehabilitation following flexor tendon repair is to promote stronger repair to support normal forces acting on the tendon. Researches have shown that stresses on the tendon with early mobilization improve healing, tensile strength, and excursion, and minimize adhesion formation. The passive mobilization technique was included to preserve joint motion [4].

The aim of this study was to evaluate the range of motion (ROM) of digits as well as hand grip strength after early active mobilization in comparison with early passive mobilization in the rehabilitation program after tendon injury in zone II.

Patients and methods
This study was carried out in the Outpatient Clinic of Physical Medicine, Rheumatology & Rehabilitation in Ain Shams University Hospitals (Cairo, Egypt).
Patients with isolated injury of hand flexor tendons in zone II were randomly allocated postoperatively to two rehabilitation programs. Group I was subjected to early active mobilization whereas group II was started on early passive mobilization using elastic rubber bands. Patients with fractures, extensor tendon injuries, nerve injuries, crushing injuries, finger replantation, and children were excluded. All injuries were because of sharp cut injuries by knives or sharp instruments. Patients were examined and oral consent was obtained. The aim of the study and precautions to avoid tendon ruptures were explained and instructed to each patient. Patients were informed that they could accept or refuse to participate in the study and that if they did not wish to participate, they would receive their treatment as usual. Written consent of the patients was obtained for operative repair.

Operative technique [5]
After sterilization of the operative field, the injury was first explored through the already present wound. A trial was conducted to blindly retrieve the ends of the tendon. If not successful, extension of the wound was needed in a zigzag manner or an incision in the palm was made and the retrieved tendon was delivered into the wound using a nylon catheter. Both the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP) were repaired. The modified Kessler suture was used, followed by a continuous epitelenon suture. Injured A2 or A4 was also repaired. Gliding of the tendons was checked before closure. In the case of injury of both tendons at the same level and if there was a problem with the gliding, the FDS was sacrificed. A static dorsal forearm-based splint [dorsal blocking splint (DBS)] to maintain the wrist in 30° of flexion, the metacarpophalangeal joints in 70° of flexion, and the interphalangeal joints in extension was applied. In the second group, elastic bands were attached to the tips of fingers.

Group I: program of early active mobilization (active place-hold) [4]
This program was divided into four phases as follows:
Postoperative phase I: it was started 1 day postoperatively and continued till 4 weeks.
Active place-hold (we passively placed the digits into flexion and then instructed the patient to actively maintain the position with gentle muscle contraction).
Composite and straight fist exercise was performed.
Tenodesis exercises involved active digital extension with the wrist flexed. This is shown in Fig. 1.
FDS and FDP blocking exercises were performed for uninvolved digits. This is shown in Fig. 2.
Passive flexion and active extension to proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints till the limit of the splint.

Figure 1

Active tenodesis exercises. (a) Wrist flexion with finger extension. (b) Wrist extension with finger flexion.
Phase II 4–6 weeks: continue with DBS.
Continue passive flexion active extension to PIP and DIP joints.
Begin place and hold active hook fist exercises.
Active tenodesis exercises, with composite, straight, hook, and tabletop fists.
This is shown in Fig. 3.
Phase III 6–8 weeks: remove DBS.
Continue active tenodesis exercises.
Active tendon glide exercises were added (Fig. 3).
Gentle blocking exercises to FDS and FDP were started at 6 weeks for the involved digit.
Isometric pinch and grip exercises were performed.
Phase IV 8–12 weeks: active and resistive exercises were continued (hand grip and pinch against resistance).

Group II: program of early passive mobilization [6,7]
Elastic bands were attached at the tips of digits through a pulley to the palm and stretched till the distal forearm. These were used for passive flexion of the finger after the patient actively extended it. Passive flexion/active extension for the PIP and DIP joints for the first 6 weeks was performed. DBS was used for the first 6 weeks. From 6 to 8 weeks, patients started active flexion/active extension exercises for the PIP and DIP joints. From 8 to 12 weeks, patients started gentle resisted exercises, grip, and pinch exercises.

Follow-up examination was performed for all the patients and included measurement of the ROM of affected digits at 4, 8, and 12 weeks postoperatively using a finger goniometer. The angles of meta carpo phalangeal (MCP), PIP, and DIP joints (%) were measured in maximal possible active flexion and extension with the forearm and wrist in a neutral position. The ROM of the other side was used as a control to obtain the normal ROM of the patients. Total Active Motion (TAM) evaluation of the American Society for Surgery of the Hand was applied [2] as follows:

Excellent grade = 100% normal
Good grade = 75–99% normal
Fair grade = 50–74% normal
Poor grade = < 50% normal

\[
TAM = \frac{\text{total active flexion (MCP + PIP + DIP)} - \text{total extension deficit (MCP + PIP + DIP)}}{\text{TAM of injured finger/TAM of the contralateral finger.}}
\]

Grip strength was assessed at 8 weeks (as it is contraindicated to perform grip testing before 6 weeks...
postoperatively to avoid rupture tendon) using a pneumatic dynamometer with the shoulder held in adduction, elbow 90° flexion, and the forearm and wrist in a neutral position. The patient was instructed on how to hold the instrument and to push as hard as possible when asked to do so. Each hand was measured three times and the average strength was calculated in kilograms (the other hand used as a control) [3]. This is shown in Fig. 4.

**Statistical analysis**

Statistical package for the social sciences program was used. Continuous variables are expressed as mean ± SD or as median (interquartile range) in cases of skewed distributions. Categorical variables are expressed as frequencies and percents. Differences between independent groups were tested using the *t*-test or the Mann–Whitney *U*-test for continuous variables. In cases in which the samples were paired, the paired *t*-test was used. Categorical variables were compared using the Fisher exact test.

*P*-value: level of significance.

*P* > 0.05: nonsignificant.

*P* < 0.05: significant.

*P* < 0.01: highly significant.

**Results**

Descriptive data of group I included seven men (77.8%) and two women (22.2%); their ages ranged from 19 to 35 years, mean ± SD of (23.8 ± 5.7). Two patients had a right hand injury (22.2%) and seven (77.8%) had a left hand injury; among these, one thumb (11.1%), three index (33.3%), three middle (33.3%), one ring (11.1%), and one little (11.1%) digits were affected. After removal of sutures, there was an adherent scar in four (44.4%)
digits, whereas in five (55.6%) digits, the scar was not adherent.

Descriptive data of group II included nine men (100%); their ages ranged from 19 to 40 years, mean ± SD (28 ± 8.1). Four patients (44.4%) had right hand injury and five (55.5%) had left hand injury; among these, five index (41.7%), three middle (25%), two ring (16.7%), and two little (16.7%) digits were affected. After removal of sutures, there was an adherent scar in eight (66.7%) digits, whereas in four digits (33.3%), the scar was not adherent.

There was no statistical difference between the two groups in these data.

In group I, TAM at postoperative weeks at 4, 8, and 12 weeks was in the range of 16.6–63.6, 38.8–79.6, and 51.8–100°, respectively. Change in TAM ranged from 18.2 to 75.9°. Grip strength of the affected side ranged from 1.5 to 7.5 kg.

In group II, TAM at 4, 8, and 12 weeks had ranges of 12.9–66.6, 22.2–48.1, and 31.4–92.5°, respectively. Change in TAM ranged from 12.9 to 55.5°. Grip strength of the affected side ranged from 0 to 9 kg.

According to the American Society For Surgery of the Hand Score, better results were observed in the early active mobilization group than in the passive mobilization group (11.1% excellent grade compared with 0%, 33.3% good grade compared with 8.3%, 55.6% fair grade compared with 58.3%, 0% poor grade compared with 33.3%, respectively), but these results were not statistically significant (P>0.05) (Table 1).

There was a significant change in the TAM score between both groups in favor of the early active mobilization group (40.7 vs. 16.5°) (Fig. 5).

Comparison between TAM scores at 4, 8, and 12 weeks postoperatively to assess progress of recovery of ROM over time in the early active mobilization group showed a highly significant improvement (P<0.01), whereas only a significant improvement had occurred in the passive mobilization group between 4 and 12 weeks only (P<0.05) (Tables 2 and 3).

There were highly significant differences in grip strength between the normal and the affected side in both groups, but the mean average grip strength was higher among the patients in the early active mobilization group than in the passive mobilization group (4.05 and 3.3, respectively) (Tables 4 and 5).

**Discussion**

Early mobilization is considered as the most important element of rehabilitation in flexor tendon injuries.

**Table 1 Comparison between the two study groups in the Total Active Motion score at 4, 8, and 12 weeks postoperatively and grip strength**

<table>
<thead>
<tr>
<th>Program</th>
<th>Group I</th>
<th>Group II</th>
<th>P</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAM 4 (deg.)</td>
<td>30.9 ± 15.0</td>
<td>39.0 ± 16.5</td>
<td>0.262*</td>
<td>NS</td>
</tr>
<tr>
<td>TAM 8 (deg.)</td>
<td>52.9 ± 15.9</td>
<td>35.2 ± 18.3</td>
<td>0.194*</td>
<td>NS</td>
</tr>
<tr>
<td>TAM 12 (deg.)</td>
<td>71.6 ± 17.5</td>
<td>55.5 ± 18.1</td>
<td>0.055*</td>
<td>NS</td>
</tr>
<tr>
<td>TAM 12 grade [n (%)]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>0 ± 0.0</td>
<td>4 ± 3.3</td>
<td>0.105**</td>
<td>NS</td>
</tr>
<tr>
<td>Fair</td>
<td>5 ± 5.5</td>
<td>7 ± 58.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>3 ± 33.3</td>
<td>1 ± 8.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>1 ± 11.1</td>
<td>0 ± 0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAM change (TAM 12 – TAM 4) (deg.)</td>
<td>40.7 ± 21.2</td>
<td>16.5 ± 19.2</td>
<td>0.012***</td>
<td>S</td>
</tr>
<tr>
<td>Grip strength of affected side (kg)</td>
<td>4.1 ± 2.5</td>
<td>3.3 ± 3.9</td>
<td>0.406***</td>
<td>NS</td>
</tr>
</tbody>
</table>

S, significant; TAM, Total Active Motion score at postoperative weeks.

*Student t-test.

**Fisher’s exact test.

***Mann–Whitney U-test.
Maximal extension of the interphalangeal joints should be achieved to promote passive gliding of the flexor tendons [8]. When performed carefully, this can give rise to good clinical results, although there is a risk of rupturing the repair [9]. Wrist mobilization is another factor that has been explored to increase tendon gliding [10]. Tendon mobilization was performed in the rehabilitation program in the early active mobilization group. During flexion, the wrist tension in extensor tendons brings the digits into extension, whereas during extension of the wrist, tension in flexor tendons brings digits into flexion. Wrist flexion and extension can be carried out actively by the patient or assisted gently [2]. This mobilization helps to reduce edema and joint stiffness, and promote proximal gliding of flexor tendons [2].

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 [11]. The rupture rate can be reduced significantly when a stronger repair is used. Four, six, or eight strand repair will definitely provide a stronger repair that facilitates the early start of active movement and hence lead to better ROM and grip strength [12].

In our study, on comparing the early active mobilization group with the passive mobilization group, better results were found in the early active mobilization group than in the passive mobilization group (11.1% excellent grade compared with 0%, 33.3% good grade compared with 8.3%, 55.6% fair grade compared with 58.3%, and 0% poor grade compared with 33.3%, respectively), but these results were not statistically significant ($P > 0.05$).

There was a significant change in the TAM score between both groups in favor of the early active mobilization group (40.7 vs. 16.5%).

There were highly significant differences in grip strength between the normal and the affected side in both groups, but the mean average grip strength was higher among the patients in the early active mobilization group than in the passive mobilization group (4.05 and 3.3, respectively), indicating better grip strength in the early active mobilization group.

Libberecht et al. [3] and Hung et al. [2] found that the results of repair of zone II were inferior to the results of repair in other zones and a longer recovery time was required; our results were similar to those of Libberecht et al. [3], who studied 28 flexor tendon after repair and used postoperative passive Kleinert mobilization and found 0% excellent recovery in zone II, 50% good recovery, 50% fair recovery, and 0% poor recovery, whereas in our study, in the passive mobilization group, we found 0% excellent recovery, 8.3% good recovery, 58.3% fair recovery, and 33.3% poor recovery.

Tumble et al. [13] studied prospectively the ROM at 6, 12, 26, and 52 weeks following repair in 93 patients (106 injured digits) classified randomly into a group that received active place and hold mobilization and another group that received passive motion therapy. They found that at all time points, patients treated with the active motion program showed greater interphalangeal joint motion.

This is in agreement with our results as our early active mobilization group showed a significant increase in ROM between assessment at 4, 8, and 12 weeks, whereas the passive mobilization group showed significant improvement between 4 and 12 weeks, only indicating a faster improvement in the early active mobilization group.

Saini et al. [14] studied 25 cases with 75 digits involving 129 flexor tendons including eight flexor pollicis longus in zone II–V. The repair was performed using the modified Kessler core suture technique with locking epitendinous sutures with a knot inside the repair site using polypropylene 3-0/4-0 sutures. The rehabilitation program adopted was a modification of Kleinert’s regimen.
and the Silfverskiold regimen. The final assessment was carried out at 14 weeks after repair using the Louisville system of Lister et al. [15]; 63% (n = 47) of digits showed excellent results, whereas good results were observed in 19% (n = 14) of digits. Nine percent (n = 7) of digits showed fair and the same number showed poor results.

We found 11.1% excellent recovery, 33.3% good recovery, 55.6% fair recovery, and 0% poor recovery in our results. This could be because we included only zone II injuries, which show the worst outcome, whereas the study reported included all five injury zones. Also, this may be because of the smaller number of patients and shorter duration of follow-up in our study.

**Conclusion**

Early active mobilization of digits after flexor tendon repair in zone II is a better rehabilitation program for the total active ROM. Progressive improvement occurred earlier than in the passive mobilization program, although both programs were successful. The mean average grip strength was higher among the patients in the early active mobilization group. However, more studies with a larger number of patients and a longer follow-up period are needed.

**Acknowledgements**

**Conflicts of interest**

There are no conflicts of interest.

**References**