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Early Intervention of Ultrasound and Active Mobilization Post Surgical Repair of Hand Flexor Tendon Laceration

AHMED M. ZARRAA, M.Sc.*; MOHAMED M. KHALLAF, Ph.D.*; ASHRAF A. KHALIL, M.D.** and WALID A. ABOU EL-NAGA, Ph.D.*

The Departments of Physical Therapy for Surgery, Faculty of Physical Therapy and The Department of Plastic Surgery, Faculty of Medicine**, Cairo University*

Abstract

Background: Hand flexor tendon lacerations are very common and their surgical repair and postoperative rehabilitation, particularly in zone II, present a formidable challenge to hand surgeons and therapists.

Purpose: The current study was conducted to investigate the effect of an early intervention of ultrasound and active mobilization on Interphalangeal (IP) joints active Range of Motion (ROM) affected by peritendinous adhesions post surgical repair of hand flexor tendon laceration.

Subjects and Methods: 30 male patients who underwent zone II flexor tendon primary direct four-strand repair technique participated in this study. Their ages ranged from 20 to 35 years. They were selected from Cairo University Hospitals and divided randomly into three groups: Group (A) composed of 10 patients (15 operated digits) who received early Ultrasound (US) therapy, and at the 4th and 6th post-operative weeks, the 2nd and 3rd phases of Early Active Mobilization (EAM) program were added respectively to the US therapy, Group (B) composed of 10 patients (16 operated digits) who received EAM, and Group (C) composed of 10 patients (16 operated digits) who received early intervention of US therapy and active mobilization. Patients in each group received the treatment (3 sessions/week) from the 3rd day post-operative till the end of the 6th week post-operative. Post surgical medical care (medications including analgesics and antibiotics, and wound dressings) was provided for all patients in each group. Finger goniometer was used to measure the IP joints active ROM of the operated digits at end of 3rd and 6th post-operative weeks.

Results: Group A, B, and C showed significant improvement in the active ROM at end of 6th week post-operative compared with that at end of 3rd week post-operative. There was a significant improvement in the active ROM at end of 3rd and 6th week post-operative of Group B compared with Group A. Group C showed significant improvement in the active ROM at end of 3rd and 6th week post-operative when compared to Group A but no significant improvement when compared to Group B.

Conclusion: Early intervention of US and active mobilization can improve the IP joints active ROM post flexor tendon repair significantly more than early US therapy alone but not significantly more than EAM alone.

Key Words: *Ultrasound – Active mobilization – Flexor tendon laceration.*

Correspondence to: Dr. Ahmed M. Zarraa, The Department of Physical Therapy for Surgery, Faculty of Physical Therapy, Cairo University

Introduction

LACERATIONS of the long flexor tendons of the hand cause an immediate hand dysfunction [1]. The volar zone II of the hand "no-man's land" extends from the distal insertion of Flexor Digitorum Profundus (FDP) tendon to distal palmar crease. Because of the narrow space in which the tendons of the long flexors of the fingers lie and their limited vascularization in zone II, gliding-restricting adhesions are expected to develop after tendon injury and repair. Scar tissue formation during the healing process can limit tendon-excursion in the synovial sheath and significantly restrict the Range of Motion (ROM) of the operated digits [2].

Development of peritendinous adhesions after flexor tendon repair is a major complication in hand surgery. Several surgical, physical and pharmacological options have been introduced aiming to achieve better excursion of the digital tendons, by optimizing tendon healing and preventing peritendinous adhesions, without negatively affect the regeneration process [3].

The use of Ultrasound (US) in tendon healing may be accompanied by increases in the tendon initial tensile strength, increased motion, improved collagen alignment, and reduction in inflammatory infiltrate and scar tissue in tendons [4].

Ultrasound may interact with one or more elements of inflammation and results in earlier resolution of inflammatory phase. It also can lead to accelerated fibrinolysis, stimulation of macrophage-derived fibroblast mitogenic factors, heightened fibroblast production, accelerated angiogenesis, increased matrix formation, and increased tensile strength of the treated tissue **[3]**.

Early mobilization is the most common method of rehabilitation after flexor tendon repair. There are many various protocols and abundant research to support different approaches. Early Passive Mobilization (EPM) means passive flexion with either active or passive extension. Early Active Mobilization (EAM) means active flexion and extension of the involved digit(s). Place and hold therapy is a subcategory of EAM in which the operated digit is passively flexed and then actively hold by the patient **[5]**.

The primary feature that distinguishes an EAM from an EPM approach is the use of minimum-tension, active contractions of the repaired muscle-tendon units initiated during the acute stage of tissue healing, often by the 1^{st} to 3^{rd} day but not later than 5^{th} day post-operatively. It is hypothesized that gentle stresses placed on a repaired tendon by means of a very low-intensity static or dynamic muscle contraction, which "pulls" the repaired tendon through its sheath, is a more effective method of creating tendon excursion (gliding) than "pushing" the tendon with passive motion **[6]**.

Subjects and Methods

Thirty male patients who underwent zone II flexor tendon primary direct four-strand repair technique participated in this study. Their ages ranged from 20 to 35 years. The patients were selected from Cairo University Hospitals. The study conducted eight months from January 2017 to August 2017. The patients were randomly assigned into 3 groups:

Group A (early ultrasound therapy group): This group included 10 patients (15 operated digits) who received early ultrasound therapy. At the 4^{th} and 6^{th} post-operative weeks, the 2^{nd} and 3^{rd} phases of early active mobilization program were added respectively to the ultrasound therapy.

Group B (early active mobilization group): This group included 10 patients (16 operated digits) who received early active mobilization.

Group C (study group): This group included 10 patients (16 operated digits) who received early intervention of ultrasound therapy and active mobilization.

The treatment was conducted for 6 weeks (3 times/week) started at the 3^{rd} day post-operative till the end of 6^{th} week post-operative. Post surgical medical care (medications including analgesics and antibiotics, and wound dressings) was provided for all patients in each group.

The potential participants were excluded if they had associated vascular injuries requiring arterial repair, crush injuries and soft tissue loss, nerve injuries, tendon injuries of other zones, flexor pollicis longus repair, medical conditions inhibiting healing, preexisting problems such as arthritis limiting joint motion, isolated injuries to Flexor Digitorum Superficialis (FDS) tendon or FDP tendon, tendon injuries in both hands, diminished cognitive capacity, and history of previously failed repair.

Equipment and tools used:

- *Measurement tool:* Finger Goniometer (Baseline 12-1011 Finger Goniometer, Metal, 180 Degree-6" Deluxe).
- *Therapeutic equipment:* Therapeutic Ultrasound Device (Ultrasound Unit PULSON 200 GymnaUniphy N.V).

Procedures of the study:

- *Measurement procedures:* Measurements were taken at end of 3^{rd} and 6^{th} weeks post-operative. In each group, active Range of Motion (ROM) at Proximal Interphalangeal (PIP) and Distal Interphalangeal (DIP) joints of each involved digit was measured using finger goniometer **[7,8]**.
- *Treatment procedures:* A dorsal blocking cast was fabricated on the patient post surgery to immobilize wrist joint in 20-30º extension, Metacarpophalangeal (MCP) joints of 2^{nd} to 5^{th} digits in 40-50º flexion, and IP joints of 2^{nd} to 5^{th} digits in full but comfortable extension with free thumb **[9]**. The cast was fixed on the patient by a wrapped bandage.

A- *Procedures of early ultrasound therapy:* At the 3^{rd} day post-operative, with the cast in place, the bandage and the dressing on zone II were removed. The coupling gel medium was applied over the repaired area and a tap water-filled latex glove was placed over the gel. The coupling medium gel was applied on the US treatment head then it was placed on the tap water-filled latex glove **[10]**. The US parameters were adjusted to: 1MHz, $0.7W/cm^2$, 1:4 pulse ratio and the treatment duration was 5min **[11]**. The US treatment head was moved over the tap water-filled latex glove and care was taken not to cause undue movements of the repaired fingers. After the end of the therapy duration, the dressing and the bandage were carefully reapplied over zone II. The use of tap water-filled latex glove was discontinued after 3 weeks and direct application of US treatment head with only coupling gel medium was used. From the start of 4th week till the end of 6th week post-operative, the intensity of US therapy was increased to 1W/cm^2 **[11]**. Frequency of US therapy sessions was 3 times per week **[12]**.

B- Procedures of early active mobilization **[6,9, 13]**:

- *Phase (1):* From the 3rd day to the end of the 3rd week post-operative: With the cast in place, the bandage over the hand was removed and the following exercises were performed 15 times/2 waking hours; passive DIP joint flexion and extension, passive PIP joint flexion and extension, passive composite flexion and active extension to the limit of the cast, and active place and hold exercises which consisted of active wrist extension till the limit of the cast with simultaneous passive tolerable unrestricted composite flexion of the digits, then the patient was asked to maintain the attended digits flexion actively for 5 seconds, then the patient relaxed allowing the wrist and MCP joints to passively flex, and the IP joints to actively extend.
- *Phase (2):* From 4th to 6th week: In addition to the previous exercises, the cast was removed for phase (2) exercises. The following exercises were performed 15 times/2 waking hours; active IP joints flexion with MCP joints extension followed by full digital extension, and active tenodesis exercises which consisted of active wrist flexion with active digits extension, and active wrist extension with gentle active digits flexion in form of a straight fist, full fist, and hook fist alternatively.
- *Phase (3):* During the 6th week: The cast was discontinued. In addition to the previous exercises, the following exercises were performed 15 times/2 waking hours; active flexor tendon-gliding exercises which consisted of moving the fingers through the following five positions respectively (straight hand, hook fist, full fist, table-top position, and straight fist), and flexor tendon-blocking exercises for PIP flexion and DIP flexion.
- Frequency of sessions was 3 per week. In home, the patient was learned to perform the passive exercises and stabilization by his opposite hand.

Statistical procedures:

Paired *t*-test was conducted for comparison of active ROM between end of 3rd and 6th week post-operative in each group. Multivariate analysis of variance was conducted for comparison of active ROM at end of 3rd and 6th week post-operative between groups. All statistical measures were performed through the statistical package for social studies Version 19 **[14]**.

Results

Table (1) shows comparison of the mean values of active ROM at end of 3rd week and 6th week post-operative in Group A. There was a significant increase in the active ROM in Group A at end of 6th week compared with that at end of 3rd week post-operative (p=0.0001).

Table (2) shows comparison of the mean values of active ROM at end of 3rd week and 6th week post-operative in Group B. There was a significant increase in the active ROM in Group B at end of 6th week compared with that at end of 3rd week post-operative (p=0.0001).

Table (3) shows comparison of the mean values of active ROM at end of 3rd week and 6th week post-operative in Group C. There was a significant increase in the active ROM in Group C at end of 6th week compared with that at end of 3rd week post-operative (p=0.0001).

Table (4) and Fig. (1) show comparison of the mean values of active ROM at end of 3rd week post-operative between the three groups. There was a significant difference between the three groups in the mean value of active ROM at end of 3rd week post-operative (p=0.0001). There was a significant increase in the active ROM at end of 3rd week post-operative of Group B compared with Group A (p=0.0001). There was a significant increase in active ROM at end of 3rd week post-operative of Group C compared with Group A (p= 0.0001). There was no significant difference in active ROM at end of 3rd week post-operative between Group B and C (p=0.91).

Table (5) and Fig. (2) show comparison of the mean values of active ROM at end of 6th week post-operative between the three groups. There was a significant difference between the three groups in the mean value of active ROM at end of 6th week post-operative (p=0.0001). There was a significant increase in the active ROM at end of 6th week post-operative of Group B compared with

Group A (p=0.0001). There was a significant increase in active ROM at end of 6th week post-operative of Group C compared with Group A (p= 0.0001). There was no significant difference in active ROM at end of 6th week post-operative between Group B and C (p=0.96).

Table (1): Comparison of the mean values of active ROM at end of 3rd and 6th week post-operative in Group A.

	ROM (degrees) $\bar{X}$ ± SD	MD	% of improvement	t-value	p-value	Sig.
3rd week	55.86±22.79	–34.8	62.29	–35.8	0.0001	S
6th week	90.66±22.55					

$\bar{X}$: Mean. SD : Standard Deviation.
MD : Mean Difference. t-value : Paired t-value.
p-value : Probability value. S : Significant.

Table (2): Comparison of the mean values of active ROM at end of 3rd and 6th week post-operative in Group B.

	ROM (degrees) $\bar{X}$ ± SD	MD	% of improvement	t-value	p-value	Sig.
3rd week	108.87±18.74	–16.19	14.8	–8.83	0.0001	S
6th week	125.06±11.8					

Table (3): Comparison of the mean values of active ROM at end of 3rd and 6th week post-operative in Group C.

	ROM (degrees) $\bar{X}$ ± SD	MD	% of improvement	t-value	p-value	Sig.
3rd week	111.81±18.7	–19	16.99	–10.19	0.0001	S
6th week	130.81±12.41					

Table (4): Comparison of the mean values of active ROM at end of 3rd post-operative between the three Groups (A, B, and C).

ROM (degrees) $\bar{X}$ ± SD			F-value	p-value	Sig.
Group A	Group B	Group C			
55.86±22.79	108.87±18.74	111.81±18.7	37.55	0.0001	S

	Multiple comparison (Tukey)		
	MD	p-value	Sig.
Group A-Group B	–53.01	0.0001	S
Group A-Group C	–55.95	0.0001	S
Group B-Group C	–2.94	0.91	NS

$\bar{X}$: Mean. p-value : Probability value.
SD : Standard Deviation. S : Significant.
MD : Mean Difference. NS : Non Significant.

Table (5): Comparison of the mean values of active ROM at end of 6th week postoperative between the three Groups (A, B, and C).

ROM (degrees) $\bar{X}$ ± SD			F-value	p-value	Sig.
Group A	Group B	Group C			
90.66±22.55	125.06±11.8	130.81±12.41	27.57	0.0001	S

	Multiple comparison (Tukey)		
	MD	p-value	Sig.
Group A-Group B	–34.4	0.0001	S
Group A-Group C	–40.15	0.0001	S
Group B-Group C	–5.75	0.96	NS

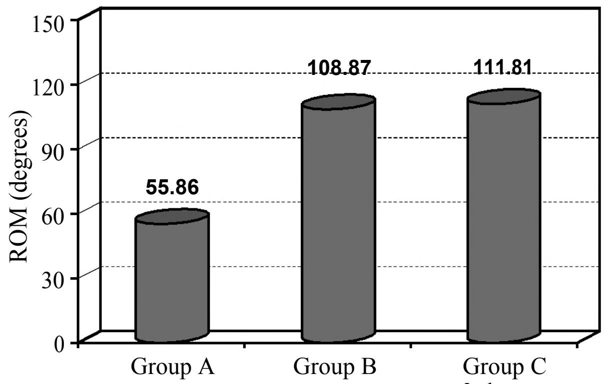

Fig. (1): Mean values of active ROM at end of 3rd week post-operative of Group A, B, and C.

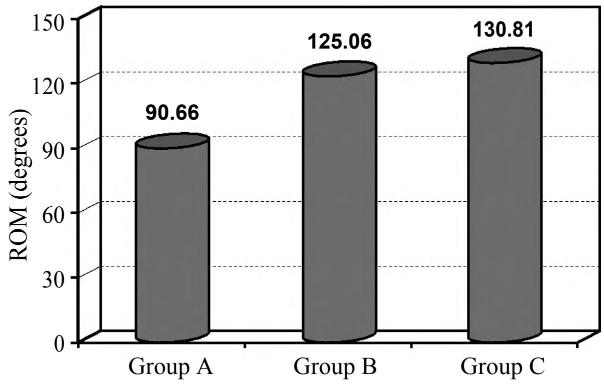

Fig. (2): Mean values of active ROM at end of 6th week post-operative of Group A, B, and C.

Discussion

The present study was designed to investigate the effect of an early intervention of ultrasound and active mobilization on IP joints active ROM affected by peritendinous adhesions post surgical repair of hand flexor tendon laceration.

The main purposes of flexor tendon repair are to facilitate the tendon healing intrinsically and reduce the scar tissue extrinsically in order to enhance tendon excursion and ROM. Despite great evolution in the techniques used in flexor tendon repair and rehabilitation, postoperative complications continue to occur, regardless skills and experience of both surgeons and therapists. Adhesion formation is the most common postsurgical complication which significantly limits the operated fingers active ROM **[15]**.

Postsurgical rehabilitation greatly affects the flexor tendon repair outcome. Many published postsurgical rehabilitation protocols have been introduced, but no particular therapy protocol has been proven to be optimal. The EAM protocols seems to have satisfying outcome which includes improved active ROM with accepted low rupture rates **[16]**.

Clinically, US therapy has been used to facilitate tissue healing and repair, enhance protein formation and blood flow, improve mobility of joints, and increase extensibility of high collagenous tissues like tendons. Animal studies provide strong evidence about the stimulatory effects of therapeutic US on tendon regeneration and healing **[17,18]**.

Regarding the results of Group A in the current study, the mean ± SD active ROM at end of 3 rd week post-operative was 55.86±22.79 degrees and that at end of 6 th week post-operative was 90.66± 22.55 degrees. There was a significant increase in the active ROM in the Group A at end of 6 th week compared with that at end of 3 rd week post-operative (p=0.0001).

In the present study, early US therapy showed improvement in the active ROM in compare to the results of post-operative immobilization in the study done by Geetha et al., **[11]**.

Geetha et al., reported that the active ROM of 75% of the operated digits was >90º by the end of 12th week post flexor tendon repair in the patients kept in complete immobilization for 3 weeks post-operatively **[11]**. While in the present study, the mean ± SD active ROM in Group A was 90.66º± 22.55º only by the end of 6th week post-operatively.

This could be interpreted by the effect of US on optimizing tendon healing, prevention of post-operative tendon adhesions **[3]**, and therefore improve the active ROM of the operated digits, while it has been proven that prolonged post-operative immobilization leads to increased disability period, insufficient tensile strength, decreased functional capabilities, and joint stiffness and deformity **[19]**.

In contrast, Robertson and Baker disagreed with the effectiveness of US on facilitation of soft tissue healing **[20]**.

Robertson and Baker in their systematic review about the effectiveness of therapeutic US, found only the results of 2 Randomized Controlled Trials (RCTs) from 10 RCTs (matched their criteria in selection) suggested that therapeutic US is more effective in treating some clinical problems (carpal tunnel syndrome and calcific tendinitis of the shoulder) than placebo US, and the results of the remaining 8 trials (post surgical extraction third molar, perineal trauma, breast engorgement, osteoarthritis of knee, shoulder pain, and pressure ulcers) suggested that it is not. Robertson and Baker concluded that there was no sufficient evidence about the effectiveness of therapeutic US on facilitation of soft tissue healing **[20]**.

The contrast between the Roberston and Baker finding and the present study finding, regarding the effectiveness of US therapy, could be due to the dependency of the US effect on the nature of the treated tissue, as high collagenous structures like tendons (in carpal tunnel, shoulder or zone II in the hand) can absorb US efficiently while others with low collagen content cannot. Also, calculation of US treatment dose, which differs from one to another study, affects greatly the outcome **[21]**.

Regarding the results of Group B in the present study, the mean ± SD active ROM at end of 3 rd week post-operative was 108.87 ±18.74 degrees and that at end of 6th week post-operative was 125.06±11.8 degrees. There was a significant increase in the active ROM in the Group B at end of 6th week compared with that at end of 3 rd week post-operative (p=0.0001).

These results could be compared by the results found in the study of Trumble et al., **[22]**.

In the RCT done by Trumble et al., they compared the results of patients treated with EAM and those treated with EPM following zone II 4-strand flexor tendon repair. 103 patients (119 digits) were randomized to either EAM or EPM group and the treatment was started at the 3 rd post-operative day. They found that the mean active ROM (122º±16º by the end of 6th post-operative week) of IP joints in the EAM group (52 patients, 61 operated digits, 20 digits had digital nerve injury) was significantly higher than the mean active ROM (82º±14º by the end of 6th post-operative week) in the EPM group (51 patients, 58 operated digits, 18 digits had digital nerve injury) (p<0.05). It was concluded that EAM provides greater active ROM than EPM after zone II flexor tendon repair and poorer outcomes are associated with patients who have concomitant nerve injuries **[22]**.

The similarity between the results of Trumble et al., and the results of Group B in the present study could prove the effectiveness of EAM on enhancement of the outcomes post flexor tendon repair. The slight increase in the mean active ROM in Group B at end of the 6th post-operative week in the current study (125.06º±11.8º) in compare to the mean active ROM in EAM group in the Trumble et al., study (122º±16º) might be due to exclusion of patients with associated nerve injuries in the present study.

In the present study, there was a significant increase in the active ROM at end of 3rd and 6th week post-operative of Group B compared with Group A (p=0.0001).

The superiority of Group B results over Group A results might be due to two possible causes. Firstly, the complete immobilization of the digits in Group A for 3 weeks could results in 47% loss of concentric, eccentric, and isometric strength of the long flexors. This is what was concluded in the study of Hortobagyi et al., about the effect of 3 weeks of immobilization on the muscle strength [23]. As the muscles are the movers of the joints, so significant weakness in the muscles will directly decrease the active ROM of the joints working on them. While in contrast, active muscle contraction promotes recovery of muscle tone and strength [24] and that what occurred in Group B, as keeping or improving muscles strength would be reflected on increasing the joints active ROM.

Secondly, both motion and tension which are associated with EAM improve the tendons response to injury and that which was concluded by Kubato et al., who studied the effects of motion and tension on the healing response of injured flexor profundus tendons in chickens. They found that the greatest cellular activity occurred in the group received early both motion and tension post-operatively and the least cellular activity in the group deprived from both motion and tension for 4 weeks post-operatively [25].

In addition, Pettengill concluded that good tendon function requires the adhesions not to be only prevented but also should be stressed to maintain some tissue extensibility. The evidence shows that early mobilization both limits the amount of adherence and helps ensure that any adhesions are stressed to be elastic enough to allow functional gliding. Early mobilization also increases the rate of revascularization and healing of the repair, increases repair strength, improves tendon excursion and helps remodel the gliding surface of the tendon itself [5].

So, in the present study, as EAM in Group B accompanied by early motion, tension, and stresses on the repaired tendon, which were not provided early with US in Group A, this could make the significant differences in favor of Group B.

The superiority of EAM over early US therapy, found in the present study, was disagreed by Ng et al., [26].

Ng et al., compared the effects of therapeutic US to exercises on Achilles tendon healing in 49 rats. The medial Achilles tendon of the right leg was transected and the rats were divided into 5 groups: 1- Control (n=9), 2- 1W/cm^2 US (n=9), 3- 2W/cm^2 US (n=10), 4- Running (n=11) and 5- Swimming (n=10). All animals were treated daily, starting from postsurgical day 5, according to their group assignment, except for group 1 control. On day 30, the Achilles tendons were biomechanically tested. Results revealed that groups 3 and 4 had higher tensile strength than the controls (p=0.037, p=0.034 respectively) but without significant difference between group 3 and 4, but groups 2 and 5 were not different from the controls. These findings suggest that therapeutic US at 2W/cm^2 and running exercise improve the strength of repairing Achilles tendon [26].

The differences between the results found by Ng et al., and the results found in the present study, regarding the superiority of EAM over early US therapy, might be due to the intensity of US which was increased by Ng et al., to 2W/cm^2 while kept at 0.7 to 1W/cm^2 in the present study.

Regarding the results of Group C, The mean ± SD active ROM at end of 3rd week post-operative was 111.81±18.7 degrees and that at end of 6th week post-operative was 130.81±12.41 degrees. There was a significant increase in the ROM in the Group C at end of 6th week compared with that at end of 3rd week post-operative (p=0.0001).

These results of Group C could be interpreted by the previously mentioned effects of both early US therapy (discussed in Group A results) and EAM (discussed in Group B results) on the repaired tendons.

The comparison between the results of Group C and A showed that there was a significant increase in the active ROM at end of 3rd and 6th week post-operative of Group C compared with Group A (p= 0.0001).

The superiority of combined early US therapy and EAM over early US therapy alone could be clearly attributed to the effects of EAM in Group C because, as it was shown, EAM alone in Group B had significant superiority over Group A.

Although the mean ± SD active ROM at end of 3rd and 6th week post-operative of Group C (111.81º± 18.7º and 130.81º± 12.41º respectively) was higher than the mean ± SD active ROM at end of 3rd and 6th week post-operative of Group B (108.87º± 18.74º and 125.06º± 11.8º respectively), there was no statistical significant difference in active ROM at end of 3rd and 6th week post-operative between Group C and B (p=0.91, p=0.96 respectively).

The slight improvement in active ROM in favor of Group C when compared to Group B may be attributed to the combined effects of early US therapy and EAM in optimizing tendon healing through inflammatory, proliferative and remodeling stages, prevention of adhesions, and direct (by EAM) and indirect (by US) increase of the tendon excursion and active ROM of the operated digits. But this improvement failed to produce statistical significant difference between Group C and B.

The non-superiority of combined electrophysical agent and therapeutic exercises over therapeutic exercises alone, which found in the present study, has been confirmed by some studies like ones done by (Thiruvasagar [27], Goren et al. [28], Özkan et al. [29] and Gam et al. [30]).

Thiruvasagar studied the effectiveness of US therapy in combination with manual therapy and shoulder exercises for Subacromial Impingement Syndrome (SIS). 26 participants were randomly divided into 2 groups, control group (13 participants) received manual therapy and shoulder exercises and study group (13 participants) received the same in addition to US therapy (Pulsed, 1 MHz, 1W/cm^2, 5 minutes). Shoulder pain intensity using Visual Analogue Scale (VAS), shoulder disability using the shoulder disability index and shoulder ROM were evaluated at baseline and at the end of 1st, 2nd and 3rd weeks of treatment. Both groups showed improvement regarding pain, disability and ROM but without significant difference between them (p<0.05, p<0.01 and p<0.001). It was concluded that US therapy has no additional benefit when combined with manual therapy and shoulder exercises in the treatment of patients with SIS to reduce pain, disability and to improve ROM [27].

Goren et al., evaluated the effectiveness of therapeutic exercises alone and in combination with US in patients with lumbar spinal stenosis. 45 patients were assigned to one of 3 groups: US plus exercise (group 1, n=15), sham US plus exercise (group 2, n=15) and no exercise-no treatment (control group, n=15). The US was applied with 1MHz, 1.5W/cm^2 intensity and in continuous mode on the back muscle for 10 minutes in Group 1. Before and after a 3-week period, all subjects were evaluated by pain and disability. Leg pain and disability decreased in Group 1 and Group 2 compared with the control group (p>0.05) but without any statistically significant difference between Groups 1 and 2 (p<0.05). It was concluded that combined US and therapeutic exercises don't produce significant better results, regarding pain and disability, than therapeutic exercises alone in patients with lumbar canal stenosis [28].

Özkan et al., investigated the effect of laser photostimulation to therapeutic exercises in rehabilitation of human digital flexor tendons. 25 patients with 41 digital flexor tendon injuries participated in this study. In Group I (21 digits in 13 patients), infrared GaAs diode laser with a frequency of 100Hz was applied between the 8th and 21st days post-operatively and all patients were given the Washington rehabilitation program until the end of the 12th week. In Group II (20 digits in 12 patients), the same treatment protocol was given but the laser instrument was switched off during applications. There was no significant difference between the two groups for functional evaluation performed according to Strickland and Buck-Gramcko systems using total active motion and fingertip to distal palmar crease distance parameters (p>0.05) [29].

In a RCT done by Gam et al., they studied the effect of treatment with US, massage and exercises versus massage and exercises alone on Myofascial Trigger-Points (MTrP) in the neck and shoulder. 58 patients were randomized to 3 groups; Group A (20 patients) was treated with US, massage and exercise, Group B (18 patients) was treated with sham-US, massage and exercise, while Group C (18 patients) was a control group. The duration of the study was 6 weeks. The outcome measures were pain at rest and on daily function tested by VAS, analgesic usage, global preference and index of MTrP. A significant reduction in index were found between treatment Groups (A and B) and control Group (C), but no difference between group A and B. VAS scores, analgesic usage or global preference showed no difference between Group A, B or C. It was concluded that US has no additional effect when combined with massage and exercises in reduction of the number and intensity of MTrP [30].

In contrast, Ucar et al., [31] and Huang et al., [32] confirmed the superiority of combined electro-physical agent and therapeutic exercises over therapeutic exercises alone.

Ucar et al., compared the effectiveness of home exercise alone versus home exercise combined with US for patients with temporomandibular joint disorders. 23 female and 15 male patients were divided randomly into 2 groups. The home exercise group performed a home exercise program consisting of an exercise program and patient education, and the home exercise combined with US group received US therapy (5 sessions per week, 0.8 to 1W/cm^2 for 3 minutes) in addition to the home exercise program. Pain intensity was evaluated using a VAS. Pain free maximum mouth opening was evaluated at baseline and 2 weeks after the treatment. After the treatment, the VAS decreased and pain free maximum mouth opening scores improved significantly in each group. Additionally, both values were higher in the home exercise combined with US group than in the home exercise group ($p<0.05$) [31].

The difference between the results of Ucar et al., and the present study results regarding the comparison between "combined US therapy and therapeutic exercises" and "therapeutic exercises alone" might be due to increased number of US therapy sessions (5 sessions per week) in the study of Ucar et al., in compare to only 3 US therapy sessions per week in the present study.

Huang et al., tested the use of US to increase effectiveness of isokinetic exercise for knee Osteoarthritis (OA). 120 subjects with bilateral knee OA were randomized sequentially into 1 of 4 groups. Group I received isokinetic muscular strengthening exercises, Group II received isokinetic exercise and continuous US (1MHz, 1.5 W/cm^2, for 20 minutes, 3 times/week), Group III received isokinetic exercise and pulsed US (1MHz, 2.5W/cm^2, for 20 minutes, 3 times/week), and Group IV was the control group. Changes in ambulation speed, lequesne index, knee ROM, VAS for pain, and muscle peak torques during knee flexion and extension were evaluated and compared. Patients in Group III showed the greatest increase in walking speed, increase in muscular strength gains with 180 degrees/s angular velocity peak torques, and decrease in disability after treatment and follow-up ($p>0.05$). It was concluded that pulsed US is the best to significantly increase the effectiveness of isokinetic exercise for functional improvement of knee OA [32].

The difference between the results of Huang et al., and the present study results regarding the comparison between "combined pulsed US therapy and therapeutic exercises" and "therapeutic exercises alone" might be due to the increased intensity (2.5W/cm^2) and treatment duration (20 minutes) of pulsed US therapy in the study of Huang et al., in compare to an intensity of 0.7 to 1 W/cm^2 and a treatment duration of 5 minutes in the current study.

Limitations of the present study were the differences between surgeons who participated in this study in skills and experience, physical and psychological conditions of the patients during the period of treatment, individual differences in patients and their response to the treatment, possible human errors, patients co-operation, patients nutrition, patients culture and life styles, and patients commitment to routine home exercises.

Conclusion:

Early intervention of US and active mobilization can improve the IP joints active ROM post flexor tendon repair significantly more than early US therapy alone but not significantly more than EAM alone.

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التدخل المبكر للموجات فوق الصوتية والتحريك الإيجابى بعد العملية الجراحية لإصلاح تمزق الوتر القابض لليد

أجريت هذه الدراسة لفحص تأثير التدخل المبكر للموجات فوق الصوتية والتحريك الإيجابى على المدى الإيجابى لحركة مفاصل ما بين السلاميات المتأثر بالإلتصا قات المحيطة بالوتر بعد الإصلاح الجراحى لتمزق الوتر القابض لليد. إشترك فى هذه الدراسة ٣٠ مريضا (أعمارهم بين ٢٠ و٣٥ عاما) من الذين خضعوا للإصلاح الجراحى الإبتدائى المباشر للوتر القابض بالمنطقة الثانية بإستخدام تقنية الأربع جدائل. تم تقسيم المرضى عشوائيا إلى ٣ مجموعات: المجموعة (أ) (١٠ مرضى) تلقوا العلاج المبكر بالموجحات فوق الصوتية، وتم إضافة المرحلة ٢ و٣ من برنامج التحريك الإيجابى المبكر عند الإسبوع ٤ و٦ بعد الجراحة بالترتيب والمجموعة (ب) (١٠ مرضى) تلقوا التحريك الإيجابى المبكر والمجموعة (ج) (١٠ مرضى) تلقوا تدخل مبكر بالموجات فوق الصوتية والتحريك الإيجابى. تلقى المرضى فى كل مجموعة العلاج (٣ جلسات/أسبوع) بداية من اليوم ٣ بعد الجراحة وحتى نهاية الإسبوع ٦ بعد الجراحة. إستخدم منقل مقياس الزوايا الأصبعى لقياس المدى الإيجابى لحركة مفاصل ما بين السلاميات للأصابع المصابة عند نهاية الإسبوع ٣ و٦ بعد الجراحة. ومن نتائج الدراسة تم إستنتاج أن التدخل المبكر للموجات فوق الصوتية والتحريك الإيجابى يستطيع أن يحسن من المدى الإيجابى لحركة مفاصل ما بين السلاميات بعد الإصلاح الجراحى للوتر القابض وذلك بدلالة إحصائية زائدة عن العلاج المبكر المنفرد بالموجات فوق الصوتية ولكن بدون دلالة إحصائية زائدة عن التحريك الإيجابى المبكر المنفرد.