Original Research Article

Evaluation of rehabilitation of surgically repaired flexor hand tendons and ultrasonographic follow up of their healing

Running Head: Rehabilitation and ultrasound evaluation of repaird flexor tendons

Abstract:

Objectives: To evaluate the role of early rehabilitation of surgically repaired flexor hand tendons in improvement of clinical outcome and the role of musculoskeletal ultrasound in follow up of their healing.

Patients and methods: Thirty patients with 31 repaired flexor tendons. Assessment was done after 2^{nd}, 4^{th},8^{th} and 12^{th} weeks of rehabilitation by visual analogue scale (VAS), total active motion of injured fingers (TAM), grip strength, hand assessment tool (HAT) score and ultrasound (US).

Results*:*There was significant improvement in pain assessed by VAS, TAM, grip strength and HAT score of the affected hand ($p<0.001$). Ultrasonographic assessment of healing flexor tendons showed significant improvement in defect size, thickness, vascularity, echogenicity and margination. There was positive correlation between margination of healing flexor tendon with VAS, hand grip and HAT score.

Conclusions: Application of proper rehabilitation programs has a great impact on improving the functional outcome after surgical repair of flexor hand tendons. High-frequency ultrasound is used to follow up tendon healing after surgical repair and to evaluate tendon healing status in relation to clinical outcome.

Key words: musculoskeletal ultrasound**,** hand assessment tool**,**rehabilitation of repaired flexor hand tendons

Introduction:

The hand is a very complex organ with multiple joints, different types of ligaments, tendons and nerves.Next to the brain, the hand is the most fascinating and complex human organ we have. No other creature in the world has hands that can grasp, hold, move, and manipulate objects like human hands. Any injury to the underlying structures of the hand carries the potential for serious handicap.(1)

Hand injuries are common and account for 20% of all injuries treated. The most common mechanisms of open hand injury are road traffic accidents, blunt trauma (e.g. crush injury, contusions) and assault (2). Tendon injuries are the second most common injury seen in the hand. If they not repaired, this can result in severe functional loss.(3)

Early application of well selected rehabilitation programme after surgical repair of flexor hand tendons improves the gliding function of the healing tendons, increases tensile strength, improves tendon excursion and stimulates morphological restoration of the injured tendons. This improves functional outcome and decrease the time needed by the patient to return to work.(4)

Follow up of tendon healing is required for evaluation of tendon healing status in relation to clinical outcomes. Musculoskeletal ultrasound is a non-invasive imaging modality that can be used to investigate real-time tendon healing in vivo in the human hand.(5)

Patients and methods:

This study was carried out on 30 patients with 31 repaired flexor hand tendons two weeks after operation. They were collected from the out-patient clinic of the Physical Medicine, Rheumatology and Rehabilitation Department, Tanta University Hospitals. We exclude patients with collagen disease, congenital hand deformities, bone fractures, nerve injuries, fingertip injuries, burn injuries, or thumb tendon repair from the study. Written informed consent was obtained from all participants. The research was conducted in line with the ethical principles of the Declaration of Helsinki. The study was accepted by Tanta University's Faculty of Medicine's Local Research Ethics Committee.

Patients underwent a modified Duran protocol of rehabilitation. A custom fabricated dorsal protective splint was usedto put wrist in 20^{o} flexion, metacarpophalangeal (MCPs) in 40^{o}-50^{o} flexion, and proximal interphalangeal joint(PIPs) in neutral position.(6) All patients received pulsed electro-magnetic field therapy (PEMF) for one hour, 3 times/week over the site of injury. The treatment started 1-2 days after repair and continued for 4 weeks(7). Some physical modalities such as paraffin wax bath and ultrasound therapywere added to prevent complications like joint stiffness and adhesive scars.(8)

A full history was taken from all patients. Visual analogue scale (VAS) was used to assess pain at 2^{nd},4^{th},8^{th},12^{th}weeks of rehabilitation program. The scale was represented at 10 cm line. Its ends means the extreme pain from zero to maximum

pain at 10, each patient was asked to make point on this scale representing his /her degree of pain intensity(9). Total active motion (TAM) of the injured fingers was evaluated by goniometer at the 8th and 12th weeks according to Strickland's Classification using the following equation:

$$\frac{\text{(PIP + DIP) flexion – (PIP + DIP) extension deficit}}{175} \times 100 = \%\ \text{of normal active PIP+DIP motion.}$$ (10)

Grip strength of the affected hands was evaluated at the 8th and 12th weeks using a modified sphygmomanometer technique. Percentage decrease of hand grip compared to the normal hand was calculated (11). Hand Assessment Tool (HAT) score was evaluated at the 8th, 12th weeks. Seven factors were assessed by 14 questions firm grip, fine hand skills, pain, extension, neuritic symptoms, gross grip, and aesthetics. Each question answered was scored and a total score was obtained using the equation [(sum of n responses)/n) - 1] x 25, n is the number of items (12).

All patients underwent ultrasonographic evaluation at the 4th,8th and 12th weeks at the ultrasound unit of the Physical Medicine, Rheumatology and Rehabilitation Department of Tanta University Educational Hospital using SAMSUNG MEDISON (UGEOH60) using linear array transducers with frequencies ranging between 9-13 HZ.

Technique: The patients were seated facing the examiner. The transducer was placed directly on the patient’s skin with gel. The site of the tendon repair was determined by scanning in the transverse and longitudinal planes. Care was taken to avoid the effect of anisotropy artifact by keeping the transducer perpendicular to the tendon. The corresponding location was identified on the contralateral uninjured digit using bony landmarks.

Ultrasound measurement definitions(13):

Defect size:it was defined as the distance (mm) between the discernible borders of the hypo-echoic region of healing tendon and the adjacent normo-echoic tendon.

Tendon thickness**:** Linear measurement (mm) was taken in the transverse view at midpoint of tendon repair on the injured digit and also at corresponding site on the uninjured hand.

Vascularity:it was assessed using the Power Doppler (PD) mode in the transverse plane. The PD signals were scored as follows: grade 0 = no detectable PD signal, grade 1 = mild vascularity ≤30% of transverse area, grade 2 = moderate vascularity ≤60%, grade 3 = severe vascularity >60%.

Echogenicity: it was rated according to the following scale: grade 0 = normal tendon, grade 1 = reduced reflectivity up to 25%, grade 2 = reduced reflectivity 25% 50%, grade 3 = reduced reflectivity 50%–75%, grade 4 = reduced reflectivity 75%–100% of the transverse area.

Margination: The definition of tissue margins was scored according to the following scale: grade 1 = margins well defined, grade 2 = slightly less definition between borders, grade 3 = margins irregular, grade 4 =borders blend.

Statistical analysis: Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp) Qualitative data were described using number and percent.Comparisonsbetween different periods of follow upwere performed using ANOVA test and Wilcoxon signed ranks test. Pearson and Spearman coefficient were used to correlate between quantitative variables.Statistical significance was defined as a P value of <0.05.

Results:

In our study, 21 patients were males (70%) and 9 patients were females (30%). The patients' age ranged from 16-48 years.19 patients (63.3%) had right side injury and 11 patients (36.6%) had left side injury. The little finger was the most injured finger (36.6%).

There was significant improvement in pain assessed by VAS after the 4th, 8th and 12th weeks of the rehabilitation program when compared with the 2nd week, and after the 8th and 12th weeks when compared with the 4th week ($p<0.001$).

There was a significant improvement in TAM of injured fingers, grip strength, and HAT score of the affected hand after the 12th week of the rehabilitation program when compared with the 8th week ($p<0.001$).

Ultrasonographic assessment:

There was a significant decrease in defect size after the 8th and 12th weeks of the rehabilitation program when compared with the 4th week, and after the 12th week when compared with the 8th week.

There was a significant decrease in thickness after the 8th and 12th weeks of the rehabilitation program when compared with the 4th week, and after the 12th week when compared with the 8th week. Also, there was a significant increase in thickness of healing tendons after the 4th, 8th and 12th weeks of the rehabilitation program when compared to the normal hand.

There was a significant decrease in vascularity after the 8th and 12th weeks of the rehabilitation program when compared with the 4th week. There was significant improvement in echogenicity after the 8th and 12th weeks of the rehabilitation

program when compared with the 4th week, and after the 12th week when compared with the 8th week.

There was significant improvement in margination after the 8th and 12th weeks of the rehabilitation program when compared with the 4th week.

There was a positive correlation between margination of the healing tendon assessed by ultrasound and VAS. In addition, there was a positive correlation between margination of the healing flexor tendon assessed by ultrasound with hand grip and HAT score.

Discussion:

The hand is involved in almost every physical activity and hence exposed to injury from a number of different etiologies including mechanical trauma, accidents and burn injuries. Hand trauma is defined as any closed or open injury to the wrist and /or the hand, involving skin, muscle, tendon, bone and joint, nerve and /or vessels. Hand injuries are among the most frequent injuries that occur in the body. They constitute between 6.6% and 28.6% of all injuries; and 28% of injuries of the musculoskeletal system.(14)

Early physical therapy and splinting after tendon repair is very important to improve tendon healing, increase tensile strength, decrease adhesion formation andminimises any possible complications.(15)

Ultrasound is a non-invasive and easily accessible imaging modality with potential for use in follow up of tendon healing.(16)

This study included 30 patients after surgical repair of flexor hand tendons. As regard clinical manifestations**,** pain was assessed by VAS.Our study showed that there was

significant improvement in pain assessed by VAS after the 4th,8th and 12th weeks of the rehabilitation program when compared with the 2nd week, and after the 8th and 12th weeks when compared with the 4th week. This is explained by applying early motion protocols that decrease the possibility of stiffness and adhesions and by using pulsed electro-magnetic field therapy (PEMF) which helped to resolve edema and enhance tendon repair, thus decreasing postoperative pain. Also, some physical modalities were added, such as a paraffin wax bath and ultrasound therapy, which helped to decrease pain, joint stiffness, and adhesive scars.

We found that total active motion (TAM) of the injured finger improved after the 12th week when compared with the 8th week. This is in agreement with the results of Rrecaj et al(17) who used Strickland classification to assess the range of motion of injured flexor tendons after using a Duran rehabilitation protocol. They found that there was improvement of range of motion of the injured flexor tendons after the 12th week of the rehabilitation program in comparison to the 8th week. This is explained by an improvement in pain assessed by VAS and the application of more advanced exercises in the rehabilitation protocol which results in improved total active motion of the injured fingers.

Grip strength of the affected hand significantly improved after the 12th week when compared with the 8th week. This is explained by application of strengthening and resisted exercises which lead to improved grip strength in the affected hand.

Kitis et al (18) reported that the mean grip strength of the injured hand was 81% of that of normal hand after 12 weeks in patients who used a controlled passive movement rehabilitation protocol for flexor tendons. Grip strength was measured using a Jamar dynamometer. Many studies that assessed grip strength after 6 months

or one year reported thatit improved for the first 6 months and then reached a steady state at one year, as described by Libberecht et al (19).

On evaluating the functional outcome of the patients using HAT score, our results showed that HAT score significantly decreased after the 12th week when compared with the 8th week. This can be explained by the improved TAM of the injured finger, grip strength of the affected hand, and pain assessed by VAS which lead to improvement of hand functions and thus a decreased HAT score.

With regard to ultrasound assessment, our results showed that defect size of the healing tendon was significantly decreased after the 12th week when compared with the 4th and 8th weeks. This is explained by the natural healing process that consists of 3 stages; inflammatory, proliferative, and remodeling.(20)

Thickness of the healing tendons was significantly increased when compared with the normal hand. This is in line with the findings of Bűhler et al(13) who reported that the tendon thickness values in the surgically repaired tendon at mid-repair site ranged from 94% to 369% of those of the uninjured contralateral tendons. Furthermore, there was a significant decrease in tendon thickness after the 12th week when compared with the 4th and 8th weeks. These results can be explained by the healing process; in the proliferative stage there is rapid proliferation of fibroblasts resulting in synthesis of collagen, proteoglycans, and other components of the extracellular matrix. High cellularity and formation of vascular network in a healing tendon make its thickness higher than normal tendon thickness, then in the remodeling stage which begins 6-8 weeks after injury there is a decrease in cellularity and reduced matrix synthesis and this decreases tendon thickness.(21)

We found that vascularity of healing flexor tendons was significantly decreased after the 12th week when compared with the 4th week. This is can be explained by the natural healing process because in proliferative stage, an extensive blood vessel network is present. Then the remodeling stage starts 6-8 weeks after injury, during the latter half of this stage, tenocyte metabolism and tendon vascularity decline.(22)

Echogenicity of the healing flexor tendon was significantly improved after the 12th week when compared with the 4th and 8th weeks. This is in agreement with the results of Puippe et al (23) who found that echogenicity changes during the healing course toward more hyperechogenic structures within the suture site. They explained their results by phases of tendon healing; in the early inflammatory and proliferative phases, tendons appeared predominantly hypoechogenic, which can be explained by the high content of blood vessels and edema, but in the remodeling phase, the increase of organised collagen fibers lead to a higher echogenicity within the tendon.

We found that margination of the healing flexor tendon was significantly improved after the 12th week when compared with the 4th week. This can be explained by phases of tendon healing similar to echogenicity. In the early inflammatory and proliferative phases, tendons appeared predominantly hypoechogenic with ill-defined edges, which can be explained by the high content of blood vessels and edema. While in the remodeling phase, the increase of organised collagen fibers lead to a higher echogenicity within the tendon and also well-defined tendon margins.

Regarding the correlation data, there was a positive correlation between margination of the healing flexor tendon assessed by ultrasound with VAS, hand grip and HAT score. Our findings can be explained by the well-defined tendon margins that may indicate good healing process which results in good clinical and functional outcome.

Conclusion: Application of proper rehabilitation programs has a great impact on improving the functional outcome after surgical repair of flexor hand tendons. High-frequency ultrasound is used to follow up tendon healing after surgical repair and to evaluate tendon healing status in relation to clinical outcome.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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zone II by high-frequency ultrasound: preliminary experience. AJR Am J Roentgenol. 2011;197(6):W1110-7.

Table (1): Distribution of the studied cases according to demographic data, side of injury and injured finger

	No.	%
Gender	**(n=30)**	
Male	21	70
Female	9	30
Occupation	**(n=30)**	
Student	6	20
Manual worker	14	46.6
Housewife	10	33.3
Side of injury	**(n=30)**	
Right	19	63.3
Left	11	36.6
Injured finger	**(n=31)**	
Little	11	36.6
Ring	8	25.8
Middle	7	22.5
Index	5	16.1

Table (2): Correlation between visual analogue scale (VAS), total active motion (TAM), Hand grip,hand assessment tool (HAT) score with ultrasound (US) findings.

Change in US findings	Change in VAS (4 to 12 weeks)		Change in TAM (8 to 12 w)		Change in Hand grip (8 to 12 w)		Change in HAT score (8 to 12 w)	
	r_s	p	r	p	r	p	r_s	p
Decrease in defect size	0.236	0.368	0.456	0.096	0.106	0.706	0.453	0.371
Decrease in thickness in mm	-0.372	0.348	-0.023	0.565	0.062	0.825	0.067	0.792
Change in vascularity	0.267	0.326	-0.467	0.089	0.100	0.722	-0.126	0.564
Decrease in echogenicity	0.162	0.268	0.367	0.187	0.296	0.285	-0.078	0.778
Decrease in margination	0.710*	0.019*	0.192	0.569	0.593*	0.046*	0.826*	<0.001*

r_s: Spearman coefficient **r: Pearson coefficient**

*: Statistically significant at $p \leq 0.05$

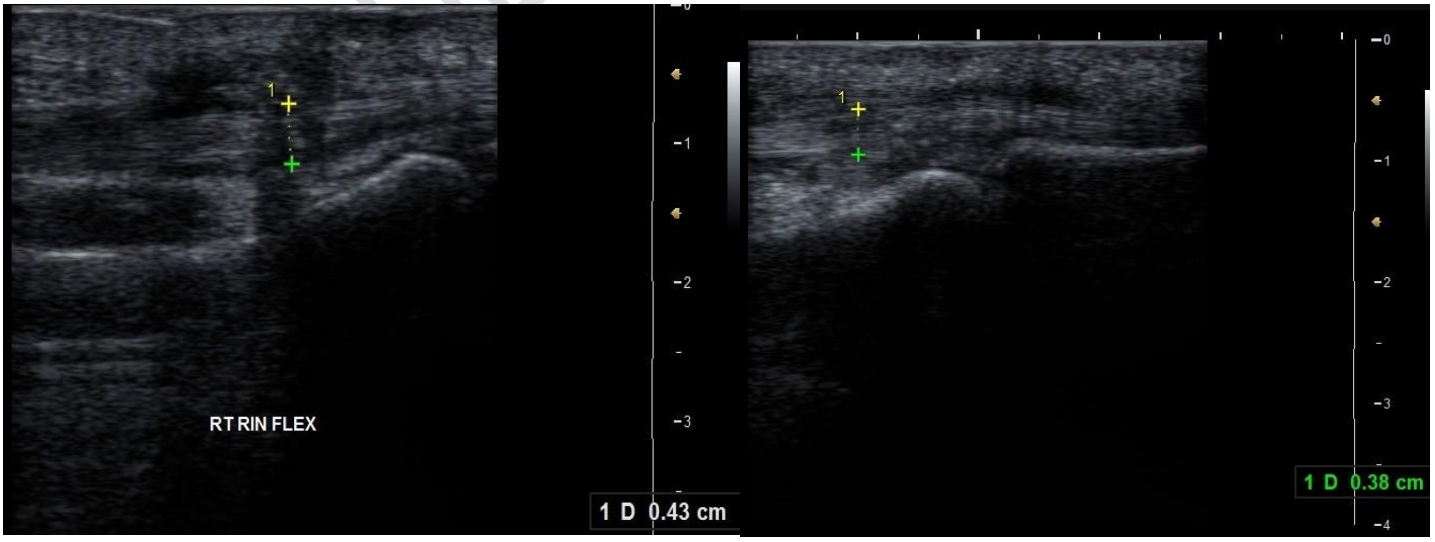

Image 1: Thickness of cut FDP in right ring finger after 4th and 12th weeks of surgical repair respectively.

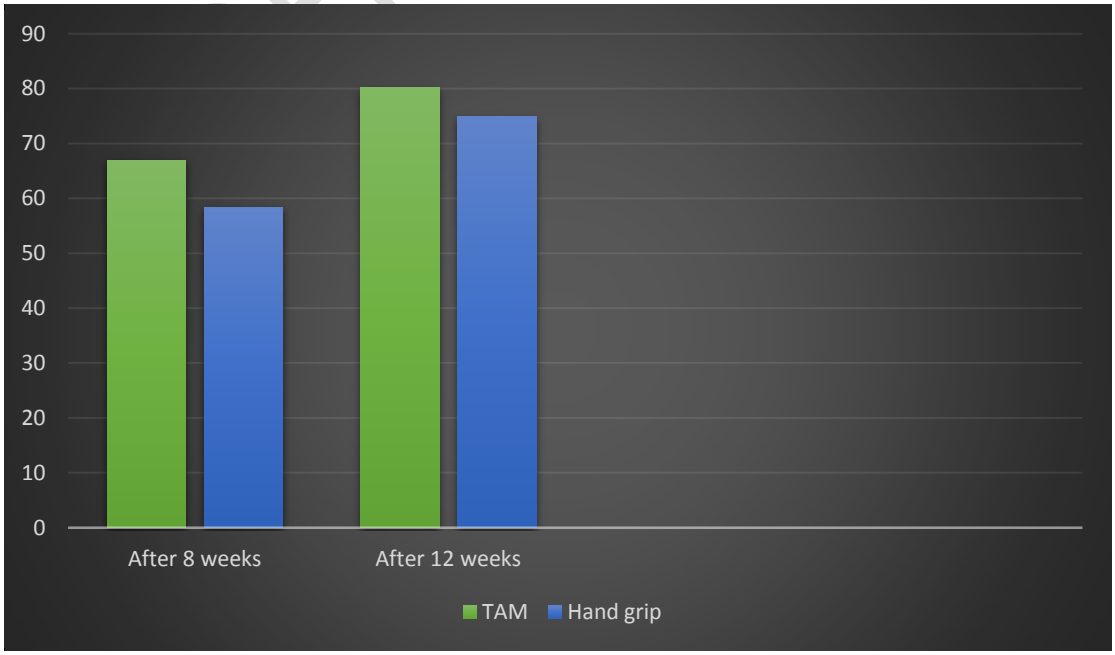

Figure 1: Assessment of total active motion (TAM)and grip strength of the affected hand (%of normal side) after 8th and 12thweeks of rehabilitation program.

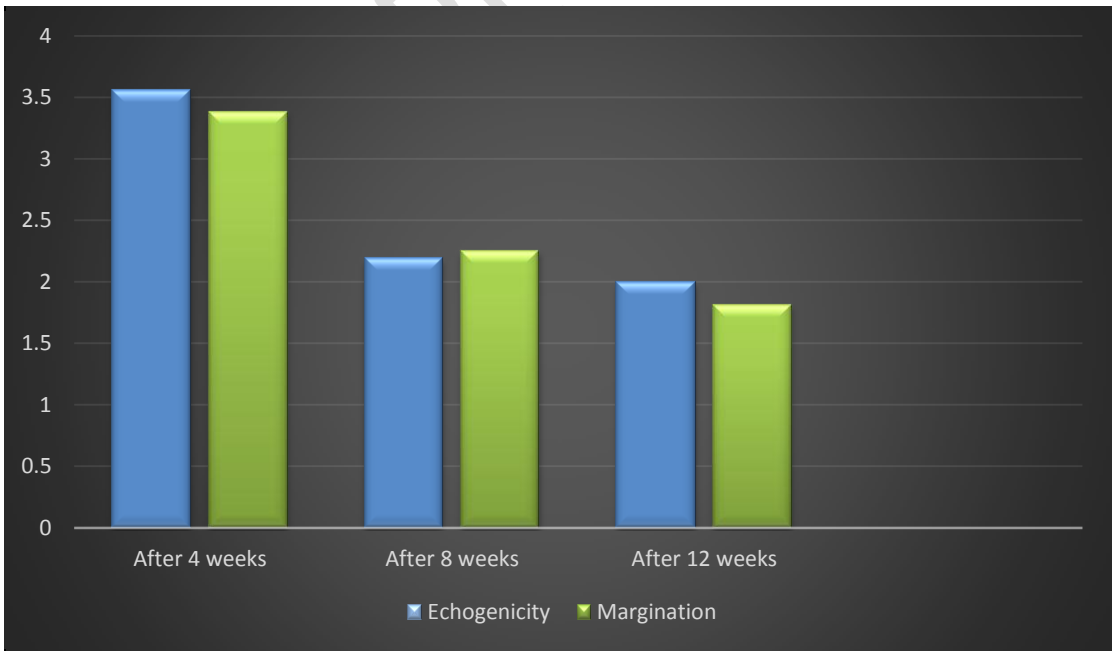

Figure 2: Assessment of echogenicity and margination of healing flexor tendon by ultrasound after 4th, 8th and 12th weeks of rehabilitation program.