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Functional outcome of zone 5 to zone 8 extensor tendon injuries of hand managed with early active mobilization following repair using a static splint: an observational study

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ABSTRACT

Background: Injuries to extensor tendons of the hand are underrepresented in the literature compared to flexor tendons. The concept of early mobilization following extensor tendon repair emerged as previous strategies of static immobilization lead to frequent adhesions and poor outcome. In our study we assessed the functional outcome of early active mobilization after extensor tendon repair using a static splint.
Methods: In this observational study 42 patients with 48 extensor tendon severances of the hand from zone 5 to 8 were selected. Following repair, early active mobilization with a static splint was done and the functional outcomes were assessed using the Dargan criteria.
Results: After mobilizing for 4 weeks, out of total 48 patients, 18 (43%) had good outcomes, 19 (45%) had fair and 5 patients (12%) had poor outcome. After 6 weeks 14 patients (33.3%) had excellent, 20 patients (48%) had good and 6 patients (14%) had fair outcomes whereas only one patient (2.4%) had poor outcome. This result was statistically significant with a p value of 0.000.
Conclusions: Early active mobilization following extensor tendon repair from zone 5 to 8 prevents adhesion around the repair site, leads to better post-operative outcome and faster recovery. Using a static splint along with a patient friendly, easily comprehensible rehabilitation protocol offers results comparable to the use of dynamic splints and requires fewer post-operative follow ups. The static splints being cheap, easy to construct are financially beneficial to the patients.

Keywords: Extensor tendon injury, Early active mobilization, Static splinting

INTRODUCTION

Injuries to the extremities are commonly encountered in the Emergency department and hand injuries account for a large chunk. Almost 10% of all the cases are due to hand injuries among which soft tissue injuries comprise of almost 80%.[1] In 90% cases where a deep injury is suspected tendon injury of the hand is likely and extensor tendon injuries are much more commonly encountered than flexor tendon injuries due to their superficial location and less soft tissue coverage.[2-4] This also makes the extensor tendons a target of complex injuries such as crush injuries or tendon loss and more prone to sustain a concomitant injury with trauma to the bone or the joint capsule due to their close proximity.[5] Still the extensor tendon injuries are less represented in the literature compared to flexor tendon injuries.[6] As both flexor and extensor tendons together contribute to a balanced limb, their optimal repair is of utmost importance.[7] The traditional protocol of treating such injuries is to maintain a clean wound with thorough debridement of the infected tissue and end to end repair under strict sterile conditions

followed by static immobilization for 3 to 4 weeks.[8,9] The affected hand after repair is splinted in functional position which renders least amount of stress to the repaired tendon.[10] The main goal of rehabilitation after surgery is to allow maximum possible mobility, with keeping the 'repair' intact.[11] But rehabilitation strategies with static immobilization tends to produce adhesions and tendon mobility gets impaired.[12-14] In this scenario the early mobilization strategy after repair of an extensor tendon holds a considerable advantage as it allows tendon gliding to restore mobility, it also promotes tendon healing by proper alignment of collagen fibrils and DNA synthesis with improvement of vascularity at the site of injury.[15-17] Clinical studies suggest early mobilization post repair enables faster healing and improved range of movements.[18,19] Initially, dynamic splints with early passive motion were used while mobilizing.[20] Some authors however pointed out that dynamic splints though provide with a better result but are more expensive to the patient and far more complicated to construct compared to static ones and the patients need frequent revisits due to complex rehabilitation programs. This effects the patient's compliance and motivation.[21-26] Whereas, the static splints are cheaper, easier to make and with a simple but effective mobilization plan produce results as good as dynamic splinting.[27-29] Our study is focused on assessing the functional outcome of extensor tendon injuries of the hand following repair which are subjected to early active motion with a static splint applied. Using the statistical tools this study also attempts to find the significance of early active mobilization with a static splint following hand extensor tendon repair.

METHODS

This prospective study was carried out in the Department of Orthopedics, Little Flower Hospital And Research Centre, Angamaly, Kerala from October 2018 to December 2019. Brief history was taken from patients presenting with injury to the dorsum of the hand in the emergency department or in the outpatient department. The wounds were examined under local anesthesia (2% lignocaine solution). Patients belonging to the age range of 15 to 65 years sustaining injury to one or multiple finger extensor tendons from zone 5 to zone 8 causing complete disruption of tendon continuity who are willing to participate in the study were included. Patients having associated fractures of metacarpals and phalanges, tendon losses and injury to the thumb extensors were excluded from the study. After thorough washing and dressing of the wound written informed consent was taken from the patients and they were posted for the surgical repair and subsequent mobilization protocol. Taking an anticipated proportion of the extensor tendon injuries as 42% with 95% confidence interval and 15% allowable error the minimum sample size was calculated to be 42.[27] The patients were positioned supine in the operating table with the effected limb rested on the side arm support. The limb to be operated on was anaesthetized with brachial block anesthesia; in cases where brachial block was difficult to achieve or had failed general anesthesia was used. The skin was prepared by washing and scrubbing of the parts by povidone iodine scrub and normal saline followed by thorough painting with 10% Povidone Iodine solution.

Then the involved upper limb was draped using sterile towels. The injured tendon was properly exposed by meticulous soft tissue dissection and the severed ends were held with non-toothed forceps or if needed by percutaneous fixation with a 24G needle. Then the tendon was repaired using 3-0 polypropylene (prolene) sutures by putting core sutures using modified Kessler technique. After putting the core sutures the tendon ends were further approximated with circumferential simple sutures using the same material (Figure 1).

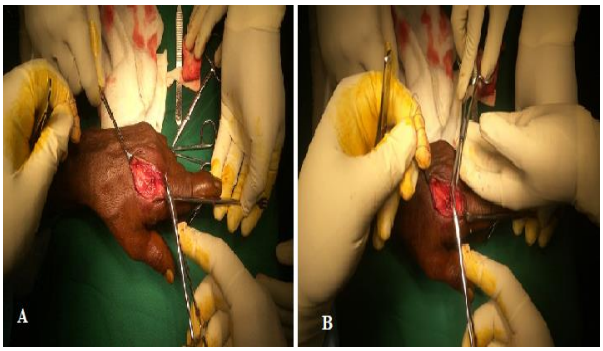

Figure 1: A) extensor indicis proprius tendon to left index finger being repaired with core sutures B) during application of circumferential sutures.

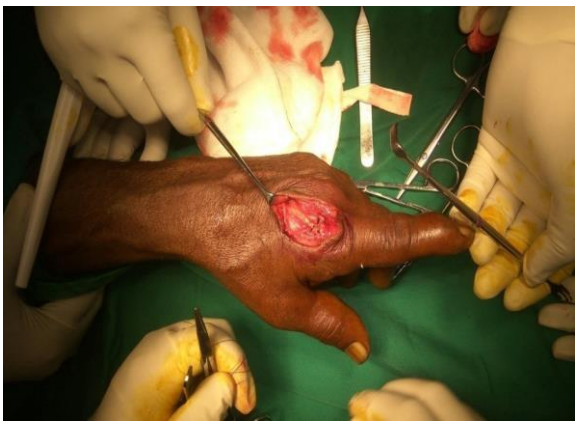

Figure 2: Repaired extensor indicis proprius tendon left (zone 5).

The tendon continuity post repair was assessed and after thorough saline wash the skin was closed with 3-0 polyamide (ethilon) sutures (Figure 2). Sterile dressings applied and a volar below elbow slab made with plaster of Paris was put with the wrist at 45° of extension, metacarpophalangeal (MP) joints at 50° of flexion and interphalangeal (IP) joints in full extension reaching distally up to the distal phalanx. The thumb was kept free (Figure 3). On the second postoperative day the operative wound over the dorsum of the hand was dressed by making

an opening through the bandages of the splint up to the metacarpal bases. At the same setting the patients were explained about the mobilization protocol and the rehabilitation was started. The patients were asked to do the following two exercises: a) active extension of metacarpophalangeal (MCP) joints keeping interphalangeal (IP) joints fully extended 4 times in each set, 4 sets a day for 4 weeks; b) active flexion of IP joints with the MCP joints held in full extension by the opposite hand 4 times in a set, 4 sets a day for 4 weeks.

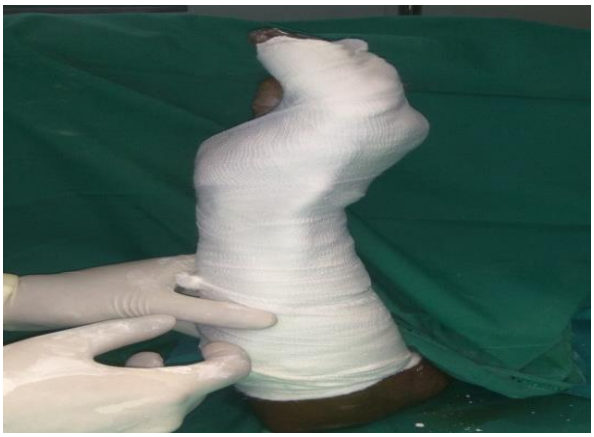

Figure 3: Volar below elbow plaster of Paris splint application.

Figure 4: (A and B) Assessment of functional outcome of repaired EIP tendon left at 4th week.

The patients were trained in the rehabilitation process till 4th post-operative day during their stay at hospital. On 4th post-operative day the patients were discharged. They were asked to continue exercises as demonstrated, at home without removing the splint. On 10th post-operative day the patients were asked to visit the OPD for suture removal and afterwards were advised to continue the rehabilitation in home up to 4 weeks following repair (Figure 4) By 4th week the patients were assessed for the tendon mobility using Dargan criteria by the same orthopedic surgeon (Table 1).[30]

In cases where there was no complication like tendon re-rupture the rehabilitation protocol was modified and continued regardless of the outcome according to Dargan's criteria. The modifications of the rehabilitation were: a) gentle MCP joint flexion beyond 50°, holding the IP joints fully extended. b) continuing IP joint flexion keeping the MCP joint fully extended using the other hand. The patients were asked to continue these exercises in the same frequency for next 2 weeks. During this 2 weeks' time the splint was discarded at day time and was used only at night time during sleep. The patients were asked to pay a second visit on 6th week after repair and during this visit the functional outcome was reassessed using Dargan's criteria (Figure 5).

Figure 5: (A and B) Assessment of functional outcome of repaired EIP tendon left at 6th week.

Table 1: Dargan's criteria.

Results	Extension Lag		Flexion Range
Excellent	No extension with	lag.	Flexion palm of pulps to mid
Good	Extensor lag with,	$<15^0$	Flexion of pulps to mid- palm
Fair	Extensor lag $16\text{-}45^0$	OR,	Pulp to mid-palm distance <2 cm
Poor	Extensor lag $>45^0$	OR,	Pulp to palm distance >2 cm

Irrespective of the final outcome the splint was discarded after 6th week and active fist making exercise was started. Descriptive statistics was used to assess the baseline characteristics of the data. All quantitative variables were presented as mean and standard deviation and qualitative variables in frequency and percentages. Diagrams or graphs were used accordingly. Wilcoxon signed rank test and Chi square tests were used to assess the significance of change in the functional outcome. A 'p value' of less than 0.05 was considered statistical significance. All the data was entered in Microsoft excel and analyzed using SPSS Version 20.00.

RESULTS

This observational longitudinal study was conducted among 42 patients who had extensor tendon injuries of the hand from zone 5 to zone 8 to assess the functional

outcome of early mobilization following tendon repair using a static splint. All the patients were treated by the same surgeon. Till the 4th post-operative day the patients were kept admitted in the hospital and then they were discharged. They were followed up for 3 subsequent visits, one at 10th day for stitch removal, the next one at 4th week and another at 6th week post repair.

Table 2: Distribution of tendon zones amongst study population.

Zone	Frequency	Percentage
Zone-5	21	50.0
Zone-6	16	38.1
Zone-7	3	7.1
Zone-8	2	4.8
Total	42	100.0

Table 3: Distribution of functional outcome among the study population.

Functional outcome	4 weeks		6 weeks	
	Frequency	%	Frequency	%
Excellent	0	0	14	33.3
Good	18	42.9	20	47.6
Fair	19	45.2	6	14.3
Poor	5	11.9	1	2.4
N/A	0	0.0	1	2.4
Total	42	100.0	42	100.0

Table 4: Comparison of functional outcome of 4 weeks to 6 week's assessments.

Outcome	4 weeks	6 weeks	Z statistic*	P Value
Excellent	0	14	-5.333	0.000
Fair	18	20		
Good	19	6		
Poor	5	1		
N/A	0	1		

*Wilcoxon signed rank test, p<0.05 considered as statistically significant

The parameters we considered were age, gender, involvement of the dominant or non-dominant hand, involvement of fingers, tendons, extensor tendon zones, co-morbidities and complications. The age of the patients in our study ranged from 16 to 65 years with the average age of involvement being 42.5 years. There were 32 male patients and 10 female patients. All patients were right handed, with dominant side involvement in 19 (45%) and non-dominant side involvement in 23 (55%).The most common single digit affected was the middle finger (MF) (31%) followed by index finger (IF) (29%). Among 48 tendon severances of the hand EDC (extensor digitorum communis) was involved in 62% cases followed by EIP (Extensor indicis proprius) in 23% and EDM (Extensor digiti minimi) in 5% cases. The most common extensor tendon zones involved in our study was zone 5(50%) followed by zone 6 (38%) (Table 2).

Table 5: Comparison of functional outcome in 6 weeks amongst age groups.

Age in years	6 weeks					χ^2	P value
	Excellent	Good	Fair	Poor	N/A		
16-25	5	1	0	0	0	30.981[a]	0.014
26-35	7	2	0	0	0		
36-45	2	4	1	0	0		
46-55	0	7	2	0	1		
56-65	0	6	3	1	0		
Total	14	20	6	1	1		

*Wilcoxon signed rank test, p<0.05 considered as statistically significant, X2: Chi Square test

Table 6: Comparison of functional outcome in 6 weeks according to zone of injury.

Zone	6 weeks					x^2	P value
	Excellent	Good	Fair	Poor	N/A		
Zone 5	7	9	4	1	0	29.258[a]	0.004
Zone 6	7	8	1	0	0		
Zone 7	0	3	0	0	0		
Zone 8	0	0	1	0	1		
Total	14	20	6	1	1		

*Wilcoxon signed rank test, p<0.05 considered as statistically significant, X2: Chi Square test

Out of 42 patients 28 (67%) had no co-morbidities,11 (26%) had diabetes, 2 (5%) had hypertension and only one patient (2%) had both diabetes and hypertension. After 4 weeks of mobilization using our protocol, 18 patients (43%) had good outcomes, 19 (45%) had fair outcomes and 5 patients (12%) had poor outcome based on the Dargan criteria 64. But after 6 weeks of mobilization 14 patients (33.3%) had excellent and 20 patients (48%) had

good outcomes while 6 patients (14%) had fair outcomes and only one patient (2.4%) had poor outcome (Table 3). This change was found to be statistically significant (Table 4).

Correlation was observed in between the functional outcome, age of the patients and zone of involvement (Table 5, 6). Only one patient (2.4%) had a complication of tendon rerupture after 4 weeks of mobilization.

DISCUSSION

Extensor tendon injuries are much more common than flexor tendon injuries.[2] But these injuries are neglected in literature as it is assumed that the results following their repair are better than flexor tendon severances. Initial strategy of static immobilization following extensor tendon repair lead to frequent adhesions and poor results.[5,12] Gradually early passive mobilization strategies with dynamic splinting emerged and showed good results.[20,31] However, high cost and complicated nature of the dynamic splints paved the way for use of static splints and early active mobilization which produced results as good as the dynamic splinting.[24,28] We assessed 42 patients having 48 tendon severances over a period of 1 year. Clean tendon injuries over the dorsum of hand from extensor zone 5 to extensor zone 8 with no other associated injuries were included in the study. In our study population males (76%) predominated over females (24%). Most of the patients were within the age group of 46 to 65 years with the average age of the patients being 42.5 years.

In a study by de Jong et al. 84% males and 16% females were affected with an average age of 36.9 years.[2] Studies conducted by Saini et al. showed a gender distribution of 73% male and 27% female.[27] In another study by Browne and Ribik the average age of patients was 36.[6] Hence the results regarding gender distribution in our study almost matches all the previous studies. However, the average age of involvement in our study matches with the average age in the studies of de Jong et al and Browne and Ribik.[2,6] Most of the cases were due to road traffic accidents and worksite injuries, this lead to dominant representation of working age males in the result. In our study 55% patients sustained injury to the dominant hand and 45% to non-dominant hand. Dominant to non-dominant ratio in the study done by de Jong et al. was 86% and 14% respectively.[2] Saini et al. on the other hand observed 62% dominant and 38% non-dominant side involvement.[27] Whereas according to the study by Crosby et al 40% dominant and 60% non-dominant sides were involved.[20] So in most of the studies dominant hand was affected more than the nondominant hand and our findings match with these studies.

No statistically significant correlation was noted in between side of injury and functional outcomes. The most common single digit which was affected in our study was the middle finger (31%) followed by index finger (29%), little finger (14%) and ring finger (7%). Study conducted by Newport et al showed 38% middle finger, 28% index finger, 18% ring finger and 16% little finger involvement.[5] The study conducted by Khandwala et al showed 35% middle finger, 20% index finger, 25% ring finger and 20% little finger involvement.[22] Most of the studies showed greater proportions of middle finger involvement amongst the medial four digits of the hand which was similar to our finding. However, no statistically significant association between the digits affected and the functional outcome was found. We observed that EDC was involved in 62% cases followed by EIP (23% cases) and EDM (5% cases). Study conducted by de Jong et al. showed 23% EDC, 4% EIP and 2% EDM involvements while Saini et al observed that EDC was involved in 81% cases.[2,27] So to conclude, in most of the studies EDC was involved most commonly and these findings correlate with our study.

The extensor tendon zone most commonly involved in our study was zone 5(50%) followed by zone 6 (38%), zone 7 (7%) and zone 8 (5%); de Jong et al in his study observed that 5.6% patients hand zone 1 involvement, 7.4% had zone 2, 12.6% zone 3, 6.3% zone 4, 10.4% zone5, 5.2% zone 6, 1.1% had zone 7 and 2% had zone 8 involvements.[2] In a study conducted by Crosby et al 36% zone 5, 12% zone 6 and 18% zone 7 involvements were shown.[20] When the proximal extensor tendon zones are considered, most of the studies showed similar tendon zone involvements with zone 5 and zone 6 getting injured much more frequently than zone 7 and zone 8, which correlates with our study. This is attributed to prominent MCP joints (knuckles) and exposed dorsum in the hand extensor surface. Out of the 42 patients 67% had no co-morbidities, 26% had diabetes, 5% had hypertension and 2% had both diabetes and hypertension.

Functional outcome of our rehabilitation technique was assessed clinically using Dargan criteria.[30] After 4 weeks of early active mobilization, 42.9% patients had good outcomes, 45.2% had fair outcomes and 11.9% had poor outcomes but none had excellent outcome. The poor outcomes were attributed to the inability of the patient to flex the and IP joints of the involved fingers due to scar tenderness, resulting a pulp to palm distance of more than 2 cm.[30] But after 6 weeks there was considerable improvement as 33.3% patients had excellent results; 47.6% patients had good outcome, 14.3% had fair and 2.4% had poor outcomes. 80% patients in total had good or excellent outcomes after 6 weeks. This shows that the patients gained significant range of movement after 6 weeks of early active mobilization. This result was highly statistically significant (p=0.000) and it shows the effectiveness of our mobilization technique. Similar study by Ip et al where early mobilization was done using dynamic splint showed 92% good or excellent results.[31] Sylaidis et al conducted a study where 92% patients achieved such results, he also used Dargan's criteria as a clinical assessment tool.[28] Similar outcome was recorded in a study conducted by Saini et al.[27]

Our study used almost the same rehabilitation protocol as in the studies conducted by Sylaidis et al and Saini et al because the patients could easily comprehend and follow the rehabilitation regimen.[27,28] We advised active MCP extension keeping IP joints fully extended and active IP flexion keeping MCP joints fully extended passively by contralateral hand. Each exercise was to be repeated 4 times in one set, 4 sets a day for 4 weeks. For the patient this 4×4×4 regimen was easy to memorize. A volar below elbow splint was constructed keeping MCP at 50° flexion and wrist at 45° extension extending up to distal phalanx using plaster of Paris. Yet our study had significant differences as Sylaidis et al included zone 5 to zone 7 extensor tendon injuries only but in our study we included extensor zone 8 as well.[28]

In our study we used a single repair technique for all patients, whereas Saini et al. used modified Kessler technique for zone 5 and zone 6 tendon severances and double right angle sutures for zone 7 and zone 8 tendon injuries with no use of peripheral suture application; his study included complex tendon injuries with soft tissue loss and metacarpal fractures, such patients were excluded in our study because these associated injuries might have affected the rehabilitation.[27] Sylaidis et al discarded the volar slab and replaced it with a thermoplastic slab the next day after surgery; Saini et al discarded the initial splint as well, he used another plaster of Paris slab for rehabilitation.[27,28] In our study we used the same slab applied immediately after surgery throughout the entire span of rehabilitation (6 weeks).

This reduced the financial burden over the patient. There were statistically significant correlations between age of the patients and outcome after 6 weeks of mobilization. The younger age group of 16-35 years achieved most of the excellent results, however the majority of the study population within the age group of 36-65 years had good outcomes by the same period (p=0.014). Statistically significant correlations were observed between affected zone of tendon and functional outcome after 6 weeks of mobilization. Better results were seen in zone 5 and zone 6 injuries; no injuries involving zone 7 and zone 8 had excellent outcomes (p=0.004).

But the fact that majority of tendon severances (88%) we encountered in our study were within zone 5 and zone 6 there is room for further research. Statistically significant correlations were noted between the presence or absence of co-morbidities in the patients and functional outcome after 6 weeks of mobilization following surgery. Excellent results were recorded only in those patients who had no co-morbidities. As in our study majority of the patients had no co- morbidities (67%) there is a room for further study. Only one patient had a complication of tendon re-rupture, detected during her follow up at 4th week which can be attributed to DM2, multiple digits involvement and increased age. This patient was taken out of the study, re-ruptured tendon was repaired using the same suturing techniques and suture materials and the hand was immobilized for 4 weeks in a volar splint. Rehabilitation was started after 4 weeks and the patient gained good results as per Dargan criteria no patients were lost in follow up.[30]

CONCLUSION

Early active mobilization following hand extensor tendon repair from zone 5 to zone 8 prevents adhesion formation around the repair site and enhances tendon healing leading to better post-operative outcomes by 6th week following repair and faster recovery. Using static splint in such early mobilization techniques, combined with a patient friendly and easily comprehensible but effective rehabilitation protocol offers favorable results comparable to the use of dynamic splints. Simple rehabilitation protocols require fewer post-operative follow ups and the construction of static splints being very simple and cheap becomes financially beneficial to the patients. However, the patients undergoing such rehabilitation protocol must be cautioned about the chance of tendon re-rupture as a potential complication.

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