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Immobilization versus early active mobilization after surgical repair of injured extensor tendon of hand and forearm

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Abstract
Background: Extensor tendon injuries are very common injuries in hand & forearm, which inappropriately treated can cause severe lasting impairment of hand function of the patient. After the extensor tendons repair whether to immobilization or to early active mobilization is debatable.
Objectives: Compare the two common protocols, immobilization vs. early active mobilization by using a simple static splint after surgical repair of extensor tendon.
Method: This prospective randomized study was conducted in the Department of Orthopaedic Surgery, BSMMU, Dhaka for duration of January 2014 to December 2017. Forty (40) patients of extensor tendon injuries in zone V-VIII were selected. The patients were divided into two groups by sealed envelope technique, Group A-immobilization group & Group B-early active mobilization group. Extensor tendon was repaired by Doyle proposed technique. Mayo Wrist Score and Dargan criteria were used for evaluation of final result at 12th months.
Results: Most of the patients were in 3rd decade. Male and right hand injury were predominant in both groups. More than one third, (35.0%) patients were factory worker in immobilization group and 8(40.0%) in EAM group. Majority 17(85%) patients had glass cut injury in both groups. Nine (45.0%) patients had Zone VI injury in immobilization group and 10(50.0%) in EAM group. In immobilization group out of 72 tendon injury EDC injury was 37(51.38%) and in EAM group out of 69 tendon injury EDC injury was 37(53.62%). Complications developed 6(30.0%) in immobilization group and 4(20.0%) in EAM group. Satisfactory outcome was 85% in immobilization group and 95% in EAM group at 12th months. Assessment at 12th weeks and 6th months were statistically significant (p<0.05) but not at 12th months between two groups.
Conclusion: EAM by using simple static splint following extensor tendon repair shown faster recovery, gain complete range of motion and improved grip strength at early post-operative period.

Keywords: Extensor tendon, repair, immobilization, early active mobilization

Introduction
The hand is the medium of introduction to the outside world. It is important for prehensile movements, grasp, pinch and hook-action. Hand is not only as a sophisticated tool, but it is also an organ of communication. So we are more aware of our hands than of any other part of the body [1]. Tendon injuries are the second most common injuries of the hand and therefore an important topic in trauma and orthopedic patients [2]. Extensor tendon injuries are more frequent than flexor tendon injuries of hand [3], as they are not protected as well as the flexor tendons due to their superficial location and overlying subcutaneous tissue [4]. Despite their frequency, extensor tendon injuries do not receive a proportionate amount of attention in the scientific literature [5]. Inappropriately treated can cause severe lasting impairment of hand function of the patient [6]. So proper treatment need to gain optimum hand function and early return to work [7].
Kleinert and Verdan wrote a classification system for extensor tendon lacerations according to the eight zones of the hand, wrist and forearm which has been widely accepted. Verdan defined eight zones-four odd numbered zones overlying each of the joints and four even numbered zones overlying the intervening tendon segments, increasing from distal to proximal [8].

Extensor tendon injuries were most frequent in Verdan's zone 1 followed by zone VI. Less frequent were tendon injuries in zones III and V. Complex injuries were more frequent in zones III and VI [8, 9].

The long disputed issue of rehabilitation of extensor tendon repairs in zones V–VIII has been concerned with either complete immobilization of these repairs or early active mobilization. During their study time twenty-two patients with 58 injured tendons were included in group A (static splinting), while 23 patients with 61 injured tendons were included in group B (EAM). There was significant difference between group A and group B with respect to TAM of at 4, 6, 8 and 12 weeks ($P < 0.01$), indicating that patients with early motion had superior results. This advantage was, however, not maintained at 6 months [7]. If repaired extensor tendons are immobilized postoperatively in static splints for several weeks and when the splints are removed, extensor lag may occur at the metacarpophalangeal (MP) or interphalangeal (IP) joints, and composite IP and MP flexion is often impossible because of tendon adhesions [6, 9, 10].

Stuart [11] study showed good or excellent results were found in 79% if the fingers were splinted for ten days, in 73% if splinted for three weeks, and in 60% if *splinted for one* day. But tendon rupture was more in case where immobilization was less than 3 weeks. Recently in Saini *et al*. (2008) study they continued splinting upto 6 weeks with EAM and showed 92% excellent result at the end of one year follow up [8, 10, 12].

The early mobilization of repaired extensor tendon, prevents formation of adhesions as compared to rigid immobilization and the use of dynamic splint was cumbersome and limited to centers having adequate facilities to manufacture the splint. The static splint besides being easy to prepare and apply gives equally good results as the dynamic splints. The patient compliance with this easy-to-follow rehabilitation plan was very good. At the end of one year of follow-up 92% showed excellent results. The patients return to work early, thus reducing the amount of work day lost [12]. Dynamic versus static splinting outcome for zone V and zone VI are different. Functional outcomes at 4, 6 and 8 weeks were improved after dynamic compared to static splinting. However unfortunately the outcomes were not improved after 6 months of tendon repair [13].

Materials and Methods

This prospective randomized study was conducted in the Department of Orthopaedic Surgery, BSMMU, Dhaka for duration of January 2014 to December 2017. Forty (40) patients of extensor tendon injury in zone V-VIII was selected as per inclusion and exclusion criteria after taking informed consent. Inclusion criteria were age 11 to 60 years of both sexes, extensor tendon injury in zone V-VIII of hand (Figure 1) and forearm but thumb zone III-VI correspond to hand zone V-VIII.

Fig 1: Preoperative deformity and extensor tendon injury of the hand at Zone VI

Duration of extensor tendon injury was less than 6 weeks. No evidence of motor involvement of median, redial & ulnar nerve injury. Stiff joint, associated hand bone fracture, infection, medical problem like epilepsy, paralyzed hands were also excluded from this study. The patient was divided into two groups by sealed envelope technique, Group A-immobilization group & Group B-early active mobilization group. Extensor tendon (zone V-VIII) was repaired by Doyle proposed technique [15]. Modified Kessler suture of 4-0 synthetic material in the thickest portion of the tendon and 5-0 cross-stitch/epitendinious running suture around the entire circumference of the tendon was used to repair the tendon (Figure 2) Post-operatively a split was applied. The objective of this study was to compare the clinical outcome between immobilization and early active mobilization group. In addition, we evaluated and compared the range of fingers and wrist movement and also assessed the grip strength as well as complications between two groups. For statistical analysis, Dargan criteria [16] & Mayo wrist score[17] system was used for the overall functional assessment of repaired tendon at 12 weeks, 6 months and 12 months and the outcome was considered as excellent, good, fair and poor categories.

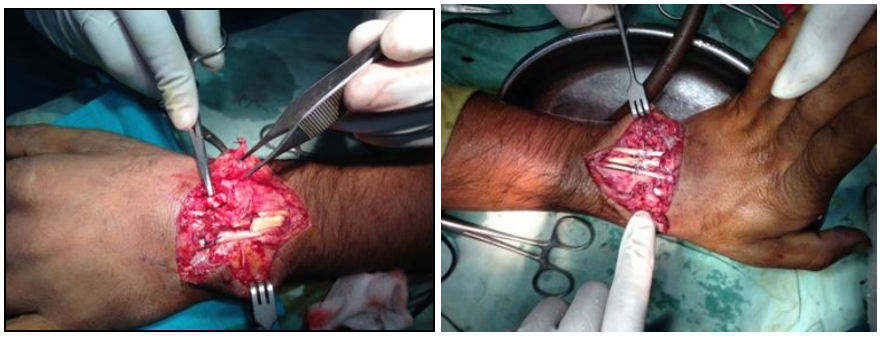

Fig 2: Peroperative picture of extensor tendon injury (A), after repair of injured tendon (B).

Results

This prospective study was observed that majority of patients belonged to age 21-30 years in both groups. The mean age was found 29.5±11.8 years in immobilization group and 28.3±12.6 years in EAM group. Male were predominant in both groups which was 15(75.0%) in immobilization group and 13(65.0%) in EAM group. Majority patients were factory worker in both groups, which was 7(35.0%) in immobilization group and 8(40.0%) in EAM group. Right hand dominance was found in all patients in both groups. Mean age, sex, occupational status was not statistically significant (p>0.05) between two groups.

Table 1: Distribution of the study patients by mode of injury (n=40)

Mode of injury	Immobilization group (n=20)		EAM group (n=20)		P value
	n	%	n	%	
Glass cut	8	40.0	9	45.0	
Sharp Weapon	6	30.0	4	20.0	0.851[ns]
Machinery injury	5	25.0	5	25.0	
Road traffic injury	1	5.0	2	10.0	

Table 1 shown, Majority of patients had glass cut injury in both groups, which was 8(40.0%) in immobilization group and 9(45.0%) in EAM group. Right hand injury was found 13(65.0%) in immobilization group and 14(70.0%) in EAM group.

Table 2: Distribution of the study patients by zone of injury (n=40)

Zone of injury	Immobilization group (n=20)		EAM group (n=20)		P value
	n	%	n	%	
Zone V	5	25.0	4	20.0	
Zone VI	9	45.0	10	50.0	0.129[ns]
Zone VII	4	20.0	3	15.0	
Zone VIII	2	10.0	3	15.0	

Table 2 shown majority patients had Zone VI injury in both groups, which was 9(45.0%) in immobilization group and 10(50.0%) in EAM group. The difference was not statistically significant (p>0.05) between two groups. Time interval between injury and operation was found 2-14 days in both group.

Table 3: Distribution of the study patients by per-operative findings of tendon injuries (n=40)

Per-operative findings	Immobilization group			EAM group
		(n=20)	%	(n=20) %
Thumb	EPL	08	40	09 45
	AbPL	06	30	05 25
	EPB	05	25	05 25
Index	EIP	11	55	11 5 5
	EDC of Index	11	55	12 60
Middle finger	EDC	12	60	13 65
Ring finger	EDC	10	50	09 45
Little finger	EDC	05	25	06 30
	EDM	05	25	05 25
Wrist	ECRL	06	30	05 25
	ECRB	06	30	05 25
	ECU	04	20	03 15

Table-3 shown, EPL was injured 8(40.0%) and 9(45.0%) in immobilization group and EAM group respectively. AbPB was injured 6(30%) and 5(25%) respectively on the other hand EPB was injured 5(25%) in both group. Cut EDC for middle finger was found 12(60.0%) in immobilization group and 13(65.0%) in EAM group. Cut EIP was found 11(55.0%) in immobilization group and 11(55.0%) in EAM group. EDC for index was cut 11(55.0%) in immobilization group and 12(60.0%) in EAM group. EDC of ring finger was injured 10(50.0%) and 9(45.0%) in immobilization group and EAM group respectively. Cut EDC for little finger was 5(25.0%) in immobilization group and 6(30.0%) in EAM group. Cut EDM was 5(25.0%) and 5(25.0%) in immobilization group and EAM group respectively. ECRL and ECRB were injured 6 (30%) and 5 (25%) in immobilization group and EAM group respectively. ECU was injured 4(20.0%) in immobilization group and 3(15.0%) in EAM group.

Table 4: Distribution of the study patients according to complications (n=40)

Complications	Immobilization group (n=20)		EAM group (n=20)	
	n	%	n	%
Superficial skin infection	02	10.0	01	5.0
Hypertrophic scars	01	05.0	02	10.0
Rupture tendon	00	00	01	5.0
Tendon adhesion	03	15.0	00	0.0

Table 4 shown, Superficial skin infection was found 2(10.0%) in immobilization group and 1(5.0%) in EAM group. Hypertrophic was 1(5.0%) and 2(10.0%) in immobilization and EAM group respectively. Rupture tendon was 1(5.0%) in EAM group. Tendon adhesion was found 3(15.0%) in immobilization group.

Table 5: Assessment by Dargan criteria (Dargan, 1969)[16] (n=40).

Assessment by Dargan criteria	Immobilization group (n=20)		EAM group (n=20)		P value
	n	%	n	%	
Assessment at 12th weeks					
Excellent	2	10.0	7	35.0	
Good	4	20.0	8	40.0	0.031[s]
Fair	11	55.0	4	20.0	
Poor	3	15.0	1	5.0	
Assessment at 6th months					
Excellent	5	25.0	13	65.0	0.042[s]

Good	6	30.0	5	25.0	
Fair	7	35.0	2	5.0	
Poor	2	10.0	0	0.0	
Assessment at 12th months					
Excellent	11	55.0	15	75.0	0.369ns
Good	6	30.0	4	20.0	
Fair	2	10.0	1	5.0	
Poor	1	5.0	0	0.0	

Table 5 shown assessment by Dargan criteria. Assessment at 12th weeks, 6(30.0%) of patients were excellent to good and majority 14(70%) of patients were fair to poor in immobilization group but 15(75.0%) of patients were excellent to good in EAM group. At 6th months 11(55.0%) patients were excellent to good in immobilization group and 18(90.0%) in EAM group but at 12 months it was 85% and 95% respectively. Assessment at 12th weeks and 6th months were statistically significant (p<0.05) between two groups.

Table 6: Final assessment by Dargan criteria (Dargan, 1969)[16] (n=40).

Final assessment by Dargan criteria	Immobilization group (n=20)		EAM group (n=20)		P value
	n	%	n	%	
Assessment at 12th weeks					
Satisfactory	6	30.0	15	75.0	0.006s
Unsatisfactory	14	70.0	5	25.0	
Assessment at 6th months					
Satisfactory	11	55.0	18	90.0	0.013s
Unsatisfactory	9	45.0	2	10.0	
Assessment at 12th months					
Satisfactory	17	85.0	19	95.00	0.297ns
Unsatisfactory	3	15.0	1	5.0	

Final assessment by Dargan criteria, it was observed that at 12th weeks, satisfactory was found 6(30.0%) patients in immobilization group and 15(75.0%) in EAM group. At 6 months satisfactory was found 11(55.0%) patients in immobilization group and 18(90.0%) in EAM group. At 12th months satisfactory was found 17(85.0%) and 19(95.0%) patients in immobilization group and EAM group respectively. At 12th weeks and at 6th months were statistically significant (p<0.05) difference between two groups.

Table 7: Assessment by Mayo Wrist Score[17].

Assessment by Mayo Wrist Score	Immobilization group (n=20)		EAM group (n=20)		P value
	n	%	n	%	
Assessment at 12th weeks					
Excellent	1	5.0	6	30.0	
Good	3	15.0	8	40.0	0.013s
Fair	13	65.0	6	30.0	
Poor	3	15.0	0	0.0	
Assessment at 6th months					
Excellent	2	10.0	14	70.0	
Good	8	40.0	4	20.0	0.001s
Fair	9	45.0	2	10.0	
Poor	1	5.0	0	0.0	
Assessment at 12th months					
Excellent	11	55.0	17	85.00	0.119ns
Good	6	30.0	2	10.0	
Fair	2	10.0	1	5.0	
Poor	1	5.0	0	0.0	

Table VII shown assessment by Mayo Wrist Score. At 12th weeks majority 13(65.0%) of patients were fair in immobilization group but 14(70.0%) of patients were excellent to good in EAM group. At 6th months 10(50.0%) patients were excellent to good in immobilization group on the other hand 18(90.0%) patients were excellent to good in EAM group but at 12 months 85% and 95% was the result respectively. Assessment at 12th weeks and 6th months were statistically significant (p<0.05) between two groups.

Table 8: Final assessment by Mayo Wrist Score [17].

Final assessment by Mayo Wrist Score	Immobilization group (n=20)		EAM group (n=20)		P value
	n	%	n	%	
Assessment at 12th weeks					
Satisfactory	4	20.0	14	70.0	0.002s
Unsatisfactory	16	80.0	6	30.0	

Assessment at 6th months					
Satisfactory	10	50.0	18	90.0	0.005[s]
Unsatisfactory	10	50.0	2	10.0	
Assessment at 12th months					
Satisfactory	17	85.0	19	95.0	0.297[ns]
Unsatisfactory	3	15.0	1	5.0	

Final assessment was done by Mayo Wrist Score. At 12th weeks, satisfactory outcome was found 4(20.0%) patients in immobilization group and 14(70.0%) in EAM group. At 6 months satisfactory was found 10(50.0%) patients in immobilization group and 18(90.0%) in EAM group. At 12th months satisfactory was found 17(85.0%) and 19(95.0%) patients in immobilization group and EAM group respectively. At 12th weeks and at 6th months results were statistically significant (p<0.05) between two groups.

Discussion

After extensor tendon repair, a period of immobilization would logically lead to the formation of a strong fibrous union at the repair site, which has less chance of breakage. But has the potential disadvantage of causing adhesions around the repair site, leading to limitation of flexion. On the other hand, early mobilization can potentially result in less adhesions and better range of flexion, but with the risk of weakening the tendon repair leading to possible rupture or scar stretch and extension lag. There have been case series using either of these techniques in the past [18, 19] but very few randomized controlled trials have been reported [7, 13, 20].

In this present study it was observed that majority patients belonged to age 21-30 years in both groups. Male female ratio was 7:3 in both groups. Majority patients were factory worker in both groups, which was 7(35.0%) in immobilization group and 8(40.0%) in EAM group as because male are more work in factory. Right hand dominance was found in all patients in both groups. Similar result was found in study of Saini *et al*. [7], in their series 77% (n = 20) of the patients were < 30 years of age. Males were more often affected than females with M: F = 19:7. These findings are consistent with a ratio of 13:2 in Crosby and Wehbé [4]. 27(67%) were dominant hand injury in our study, similarly study of Saini *et al*. (2008) was also found the dominant hand was involved in 62% (n = 16) cases [7]

Out of 40 patients, majority had sharp cutting injury 67.5% (27/40) out of that glass cut injury 42.5% (n=17/40) in both groups. In study of Saini *et al*. [7] the most common nature of injury was sharp cut in 81% patients, with crush injury seen in only 19% cases but Pandey and Goyal [21] revealed that the causative agent has varied in various series depending upon the predominant occupation in the area and location of the hospital. Stuart reported a study of 130 patients in whom the injury to the extensor tendon was located over the metacarpal heads; his patients were workers in gold mines and injury was due to sharp edges of quartz crystals [11].

On our study postoperatively the splint prepared with Plaster of Paris bandage, was based on Norwich regimen. Saini *et al*. and Sylaidis *et al*. (1997) also used post operative splint on the basis on Norwich regimen in their study. Splint designs used in previous studies have been variable. Evans and Brukhalter (1986) have suggested that around 38° of finger MCPJ flexion is enough to produce this excursion in repaired extensor tendons [22].

Majority patients had Zone VI injury in both groups, which was 9(45.0%) in immobilization group and 10(50.0%) in EAM group. Compared with the study of Saini *et al*. (2008) they reported that most common site of injury was extensor Zone VI, 42% [7]. In study of Howell, *et al*. (2005) showed the most common zone of injury was in zone V (80%), followed by zone IV (10%), zone VI (6.42%) [23]. In Carl *et al*. (2007) study extensor tendon injuries were most frequent in Verdan's zone I (distal interphalangeal joint) (n=90; 44%), followed by zone VI (metacarpus) (n=46; 23%) [9].

In current study showed most of the time interval between injury and operation was found 2-14 days in both groups. Similar result was found in study of Howell *et al*. (2005) showed average days from injury to tendon repair were 2.3 (range 0–21) days [23]. Another study by Saini *et al*. (2008) showed out of 26 patients primary repair of extensor tendons in Zone V to VIII was done within 6-12 hours (n = 14), whereas delayed primary repair was done in the rest. But this series showed that delay in treatment is not the cause of poor results [7, 23]. Our study was also shown the similar result.

In immobilization group out of 72 tendon injury EDC injury was 37(51.38%) next common EIP, ECRL and ECRB which were 11(15.27%), 6(8.3%) and 6(8.3%) respectively and in EAM group out 69 tendon injury EDC injury was 37(53.62%) next common were EIP, ECRL and ECRB which were 11(15.94%), 5(7.24%) and 7(7.24%) respectively. In compare with the study of Saini *et al*. (2008) showed amongst the tendons affected, EDC (81%) (n =21) was most commonly affected in their series, EI (46%) (n = 12), and EPL (31%) (n = 8) were the next commonest [7].

It was observed that superficial skin infection was found 2(10.0%) in immobilization group and 1(5.0%) in EAM group. Hypertrophic was 1(5.0%) and 2(10.0%) in immobilization and EAM group respectively. Rupture tendon was 1(5.0%) in EAM group. Tendon adhesion was found 3(15.0%) in immobilization group. Only three cases of tendon re-ruptures were reported in one study with 100 subjects (3%) (Khandwala *et al*., 2000). Two were in the EAM group and one in dynamic splinting [20]. In the Saini *et al*. (2008) series three (11.5%) cases developed superficial infection, this improved after antibiotics and regular dressings. This did not affect the final outcome [7].

In this study observed at 12th weeks majority 8(40.0%) had mild occasional pain in immobilization group and 15(75.0%) patients were no pain in EAM group. At 6th months 13(65.0%) patients were no pain in immobilization group and 18(90.0%) in EAM group (Figure 3A & B). At 12th months 17(85.0%) and 19(85.0%) patients were no pain in immobilization group and EAM group respectively. Pain intensity at 12 weeks and 6th months were statistically significant (p<0.05) between two groups. Patil and Koul (2012) study reported that patients in group A (immobilization group) complained about pain. From the fifth week onwards, however, many of them had severe pain that required pain medicines. Many of them complained of not being able to do mobilization for the scheduled time (10min). Most of these patients had pain up to 12 weeks (regular follow-up) and it gradually settled. Patients in group B (EAM) complained about pain up to 2 weeks. From the fourth week onwards, they had significantly less pain[7].

A B

Fig 3: Assessment at 12 weeks and 6 months and improvement of hand functions.

In this study within 12 weeks, 100% patients are able to work in EAM group, on the other hand 70% patients able to work in immobilization group (Figure 3 A). Limited data are available on average time to return to work after extensor tendon repair. Sylaidis *et al*. (1997) reported an average return to work at 6 weeks with the Norwich regimen. Bruner *et al*. (2003) reported return to work at 10 weeks, and Browne and Ribik (1989) reported a range of 8 to 11 weeks with DES. However, Patil and Koul (2012) study observed the patients in immobilization group returned to full work after an average of 77.47 days (SD=14.79), while those in EAM group needed an average of 70.58 days (SD=11.51) [7].

In this series observed that grip strength was significant difference between two groups at 12th weeks and 6th months, means EAM group has better grip strength than immobilization group, but no significant difference at 12 months (Figure 4) There are three studies reported grip strength (Bulstrode *et al*., 2005; Hall *et al*., 2010; Mowlawi *et al*., 2005). In Mowlawi *et al*. (2005) study, they reported dynamic splinting group was found to have better grip strength than static immobilisation at 8 weeks but not at 6 months. Bulstrode *et al*. (2005) study also supported our results they showed their results at 12 weeks postoperatively, in the static immobilization group the repaired hand was significantly weaker than the uninjured hand. However, such difference was not demonstrated in the EAM group. But Hall *et al*. (2010) found no significant difference in grip strength at 12 weeks among the three regimens studied[7, 12, 13].

Fig 4: Assessment of grip strength and improvement of hand function at 12 months.

It was observed that according to Dargan criteria, assessment at 12th weeks, satisfactory was found 7(35.0%) patients in immobilization group and 16(80.0%) in EAM group. At 6 months satisfactory was found 11(55.0%) patients in immobilization group and 18(90.0%) in EAM group. On the other hand, according to Mayo wrist score assessment at 12th weeks, satisfactory was found 4(20.0%) patients in immobilization group and 14(70.0%) in EAM group. At 6 months satisfactory was found 10(50.0%) patients in immobilization group and 18(90.0%) in EAM group and finally at 12th months satisfactory was found 17(85.0%) and 19(95.0%) patients in immobilization group and EAM group respectively. In this study on the basis of both criteria EAM group was significantly better at 12th weeks and 6th months than immobilization group (p<0.05) but long term follows up at 12th months there was no significant difference between two groups. In Mowlavi *et al*. (2005) conducted a prospective randomized trial comparing dynamic extension splinting (DES) to static splinting and found significantly better total active motion (TAM) and grip strength in the DES group at 8 weeks. However, by 6 months, no differences were seen between groups [13]. Chow *et al*. (1989) also experienced disappointing results, they found markedly better results with the DES protocol based on Dargan's criteria, 100% of patients treated with DES achieved excellent results by 6 weeks, whereas only 40% achieved excellent results with static splinting at a mean follow-up of 13 weeks [10]. Our results are also comparable with Patil and Koul (2012) they showed overall hand function of patients in group B undergoing early motion up to 12 weeks was significantly better when compared to that in patients of group A undergoing immobilization (P < 0.01). This advantage again was not maintained over long term[7]. Sylaidis *et al*. (1997) prospectively followed up 24 simple extensor tendon repairs in zones 4 to 7 treated by early active mobilization with volar splint on the basis of Norwich regimen. They found 92% excellent or good results at 6 weeks based on Dargan's criteria[24]. Today, the majority of studies that use dynamic extension assist or static splints with controlled motion report at least 90% excellent/good results.

Conclusion

EAM by using simple static splint following extensor tendon repair shown faster recovery, gain complete range of motion and improved grip strength at early post-operative period. So that the early return to work was also facilitated.

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