Early Active Short Arc Motion for the Repaired Central Slip

Roslyn B. Evans, BS, Vero Beach, FL

This study compared the functional results in patients with open and repaired central slip injuries treated by two different postoperative management methods. The groups were similar in number of patients and amount of complex injuries. The comparisons made were proximal interphalangeal joint extensor lag, flexion at distal interphalangeal and proximal interphalangeal joints, total active motion, and length of treatment required. Patients in group 1 were treated with 3–6 weeks of continuous immobilization followed by a vigorous standard rehabilitation program. Patients in group 2 were treated by early active short arc motion initiated between the second day and the eleventh day after repair. By all criteria evaluated, patients in group 2 demonstrated better results at discharge compared to patients in group 1. (J Hand Surg 1994; 19A:991–997.)

Injuries to the extensor mechanism in zones III and IV[1] are difficult to treat because of intimate relationship of tendon to bone and intrinsic to extrinsic extensor systems.[2,3] Injuries in this area are often complex.[4–6] Injuries to this tendon mechanism have received much attention,[7–18] but little has been paid to the final results[4] and there has been slight change in the details of rehabilitation over the past 50 years.[19–21]

Poor final results have moved some clinicians to recommend early passive motion for zone III and IV injuries,[22–26] but this has not been widely accepted because the majority assume that early motion will lead to attenuation if not rupture of the central slip.

On the basis of theoretical work[27] standard rehabilitation methods were compared with an approach of carefully defined early active short arc motion (SAM). The criteria selected to compare the two methods were (1) proximal interphalangeal joint (PIP) extensor tendon lag; (2) PIP and distal interphalangeal (DIP) joint flexion; (3) total active motion (TAM) as calculated by the Strickland-Glogovac formula;[28] and (4) treatment time.

Materials and Methods

A chart review was taken from patients with central slip injuries treated over a period of 7 years. Sixty-four digits in 55 patients with central slip repairs were reviewed in detail. The patients were referred by 23 plastic or orthopedic surgeons from a five-county geographic area.

The patients were divided into group 1 (30 patients), who were treated with 3–6 weeks (mean, 33 days) of continuous immobilization before any PIP motion was initiated, and group 2 (25 patients), who started the SAM protocol between 2 and 11 postoperative days (mean, 5 days). Group 1 patients treated during the first 2 years reviewed were evaluated retrospectively. All patients treated during the last 5 years reviewed (some from Group 1, all of Group 2) were evaluated prospectively.

Each patient in both groups was categorized as a simple or complex injury. A simple injury was classified by skin and tendon only, with repair to the tendon with or without inclusion of the lateral band(s). Complex injuries were simple injuries with associated injury to cartilage, ligament, bone or DIP joint. Insufficient follow up data or concomitant

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Reprint requests: Roslyn B. Evans, BS, Indian River Hand Rehabilitation, Inc., 777 37th Street, Suite D-101, Vero Beach, FL 32960.

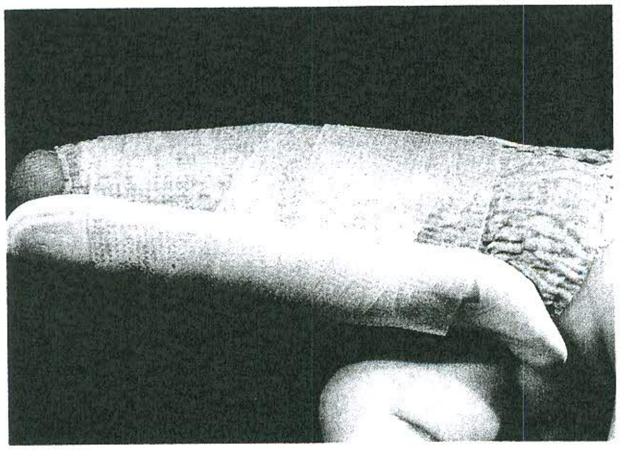

Figure 1. The involved digit is splinted in an anterior static thermoplastic splint immobilizing the PIP and DIP joints at 0°.

flexor tendon injury was reason for exclusion from the study.

For each patient, age, sex, digit, type of injury, treating surgeon, postoperative management technique, postoperative day motion was initiated, day of discharge from therapy, PIP joint extension lag, and PIP joint and DIP joint flexion (at various time intervals) were recorded. The patients were predominantly males of working age and the majority had complex injuries.

Seven of the 30 group 1 patients were referred to therapy early and treated with finger casts, while 23 were referred following an immobilization phase initiated by the surgeon.

Short Arc Motion Protocol

Except during exercise, the PIP and DIP joints of the involved digit were immobilized in a palmar static thermoplastic splint (Fig. 1) held by tape directly over the two joints to ensure rest at 0° extension. Two exercise splints were used by the patient during exercise sessions to control stress application and excursion of the repaired central slip. Template splint 1 (Fig. 2A) for PIP joint motion is a palmar static splint with a 30° PIP joint flexion angle and a 20°–25° flexion angle for the DIP joint. Template splint 2 (Fig. 3A) for DIP joint flexion is an anterior static extension splint for proximal and middle phalanges with the PIP joint at 0° extension and DIP joint free.

Patients were instructed to remove the immobilization splint (Fig. 1) on the hour for 20 repetitions of PIP joint and DIP joint exercise with the wrist at 30° flexion and the metacarpophalangeal (MP) joint at or near 0° extension. The patients manually supported the MP joint with template splint 1, which allows the PIP joint to flex to 30° and the unrestrained DIP joint to 20°–25°. Active flexion/extension of the PIP joint through this 30° range was then performed 20 times (Fig. 2). Each exercise was performed slowly and sustained briefly in full extension. Template splint 2 was then applied with manual pressure to stabilize the PIP joint at 0°, and the DIP joint was fully flexed and extended (if no lateral band repair) or flexed 30°–45° and then fully extended (if lateral band repair was performed) (Fig. 3).

The patients were instructed in a technique of "minimal active tension"[27,29] with the active extension phase. The active phase must be performed in the prescribed position with repetitions performed slowly and frequently.[27]

The immobilization splint must be applied precisely to keep the two interphalangeal joints at 0°.[27] Two weeks after the program started, template splint 1 was altered to allow 40° flexion at the PIP

Figure 2. (A) Template splint 1 allows 30° flexion at the PIP joint and 20°–25° at the DIP joint, preventing the patient from stretching the repair site by allowing only precalculated excursion of the central slip. The wrist is positioned in 30° flexion, the MP joint at 0°, the digit is supported at the proximal phalanx by the contralateral hand. (B) The PIP joint is actively flexed and extended in a controlled range.

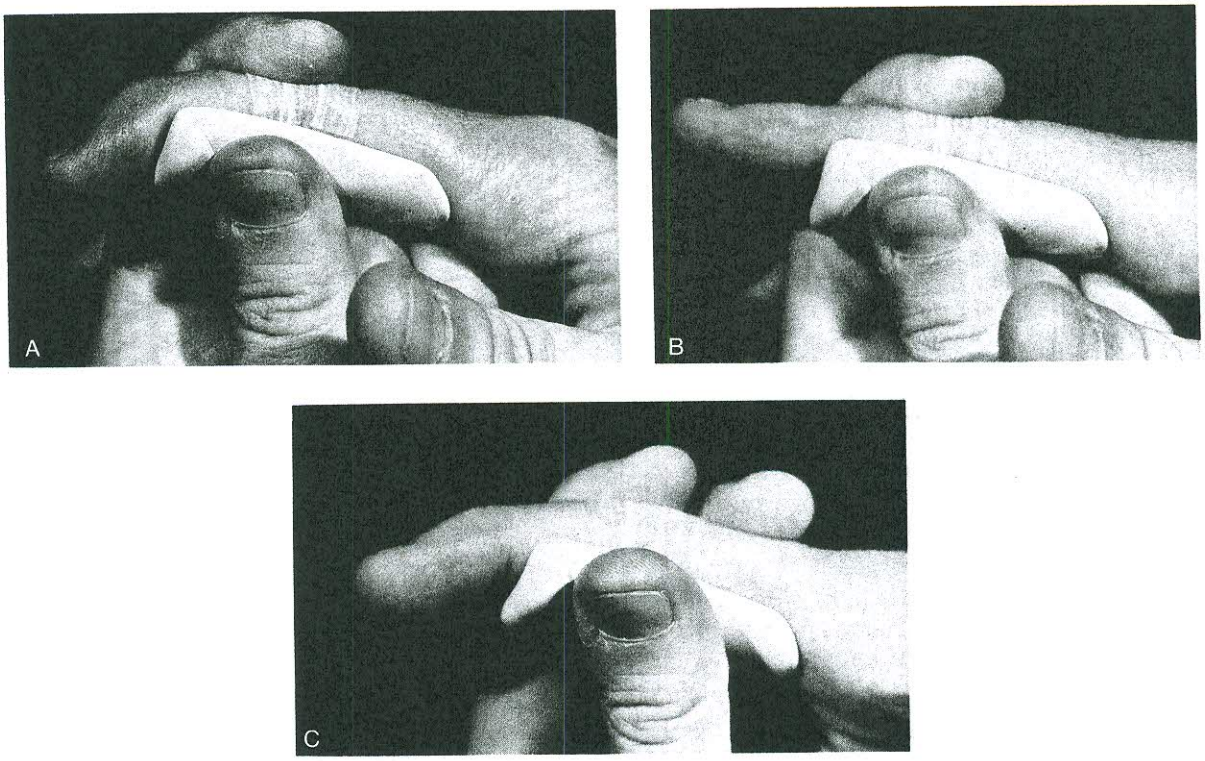

Figure 3. Template splint 2 immobilizes the PIP joint allowing isolated distal joint motion to create gliding of the lateral bands. (A, B) If the lateral bands are not repaired, the distal joint is fully flexed and extended. (C) If the lateral bands are repaired, the DIP joint is flexed only to 30°–35°.

joint and 50° at 3 weeks if no extensor lag had developed.

The MP joint, the wrist joint, and the uninvolved digits were free to move through a normal range of motion, with just the affected PIP and DIP joints immobilized (Fig. 4). The usual antiedema measures (Coban wraps, retrograde massage, ice, and elevation) were followed. Controlled mobilization and intermittent splinting at 4 weeks provided protection for the healing tendon as PIP joint flexion was gradually increased.[16,30]

Results

Group 1 digits were compared group 2 digits, with each category considered separately for statistical analysis. No significant difference was noted between groups 1 and 2 as regards age, sex, or com-

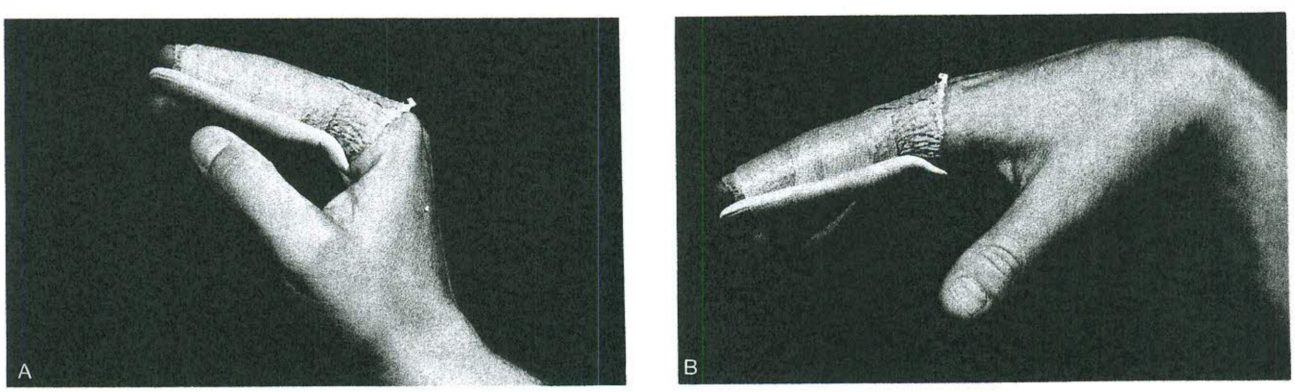

Figure 4. The wrist, MP joints, and the uninvolved digits are free to move through all available ranges of motion. (A) The natural tenodesis action of wrist extension and finger flexion as well as wrist flexion and finger extension will create proximal and distal migration of the sagittal bands but place minimal stress on the repair site, which is protected by the position of PIP joint extension (B).

Table 1. Final Results and Statistical Analysis

	Group 1 (Immobilization)	*Group 2 (Short Arc Motion)*	t-*Test p*	*Chi Square Test p*
Number of digits	38	26		
Mean age (years)	40	42	NS	
% male	87%	81%		NS
% complex injury	76%	77%		NS
Mean day motion initiated	33	5	<.001	
Mean day injury to discharge	76	51	<.001	
Proximal interphalangeal extension lag on first motion day	13°	3°	<.01	
Proximal interphalangeal extension lag on discharge	8°	3°	<0.1	
Proximal interphalangeal motion at 6 weeks	44°	88°	<.001	
Proximal interphalangeal motion at discharge	72°	88°	<0.1	
Total active motion (Proximal interphalangeal & Distal interphalangeal) at discharge	111°	132°	<.01	
Distal interphalangeal motion at discharge	38°	45°	<.01	

plexity of injury. The mean day for initiation of motion, day of discharge from therapy, TAM, and PIP joint extensor lag were all highly significant ($p < .01$).

Extensor lag was significantly greater in group 1 than group 2 on the first day of motion ($p < .01$). Extensor lag on the day of discharge had improved in group 1 but was unchanged in group 2. Six group 1 patients demonstrated increased extensor lag following treatment, presumably from tendon bone adhesions in zone IV that would increase stress at the zone III repair site when flexion was initiated.

Flexion for group 2 patients was the same at 6 weeks and at discharge because formal therapy for most of these patients was concluded by that time.

Table 2. Classification[38] of Results (Strickland-Glogovac formula)[28]

	Group 1 (Immobilization)	*Group 2 (Early Active Short Arc Motion)*
Excellent 85–100% ≥150°	5	5
Good 70–84% 125°–149°	11	12
Fair 50–69% 90°–124°	12	7
Poor 0–49% <90°	10	2
Total digits	38	26

Simple injuries when evaluated separately showed overall better results. Nine group 1 digits in this category had an average TAM of 139°, an average discharge time of 67 days, and an average extensor lag at 6 weeks of 8°. Six simple injury digits in group 2 had an average TAM of 147°, an average discharge day of 47, and a 6-week extensor lag of 1°. Even in the cases of simple injury, extensor lag was less in group 2 patients and in this early motion group PIP joint motion (PIP joint flexion minus extensor lag) was 62° by 4 weeks, the point at which group 1 digits were just starting motion (Table 1).

The results for each digit were calculated as a percent of normal (excluding the predictably normal MP joint) according to the formula[28]

$$\frac{(\text{Sum active pip joint} + \text{dip joint flexion}) - \text{extensor lag}}{175} \times 100$$
$$= \%\ \text{normal combined PIP joint/DIP joint flexion}$$

Results from group 1 averaged 63% of normal, group 2 75%. These results must be considered in light of the high percentage of complex injuries in both groups (76% in group 1 and 77% in group 2).

Finally, results were classified as suggested by Gelberman et al.[31] Compared to group 1, group 2 had a higher percentage of excellent and good results (Table 2).

No group 2 patient developed a boutonnière deformity, and there were no tendon ruptures. The patients in this group had an average extensor lag of 3° with a maximum of 10°.

A long term followup survey was attempted but did not contribute much information to the study. Approximately one quarter of (15 of 55) patients responded to a mail survey or came for a follow-up visit. Two of these patients lost PIP joint motion (one group 1 patient lost 35°, one group 2 patient lost 25°, both had complex injuries), but the other patients surveyed maintained or improved PIP joint motion. Two group 1 patients had poor DIP joint motion at discharge, which did not improve.

Discussion

Newport et al.,[4] Kelly,[5] Hauge,[6] and Allieu et al.[23] have all confirmed that results are poor when central slip injury is associated with fractures. The incidence of complex injury combined with traditional treatment (4–6 weeks of immobilization) may be as much a factor in poor results as the nature of the extensor mechanism gliding requirements. Tendon to bone adherence in zone IV elevates tension at a zone III repair site when flexion is initiated late (4 weeks or more).[2,27] The immobilized repair, devoid of the benefits of intrinsic strengthening associated with early motion programs, may gap or elongate with resultant extensor lag as PIP flexion is gained. The effects of stress deprivation to connective tissue have been well defined in terms of biomechanical and biochemical changes.[27,31–49] Immobilization may result in functional limitation not only of tendon but of ligament and cartilage with loss of both PIP joint and DIP joint motion. Age, lengthy immobilization, or associated osteoarthritis may turn a simple injury into a complex one.[50] Imprecise splinting technique in the immobilization phase (i.e., PIP joint at less than 0°) may result in extensor lag and is often a problem.[27]

The concept of early passive motion for the repaired extensor tendon is not new. Reports of early motion in zones V, VI, and VII have been favorable, and this postoperative management technique has gained popularity in the last decade.[22–24,51–55] Early controlled motion for the more distal extensor injury has been described by a few authors,[23–26] but most reports are for simple tendon injury, and all protocols have problems with the position of splint immobilization,[23,24,26] timing of the application of stress,[25] or parameters for PIP joint motion.[23,24,26]

Allieu et al.[23] described an early motion program for extensor lesions in all zones with a wrist extension splint and digital dynamic extension traction. Electromyographic analysis of the extensors demonstrated electrical silence, leading them to the conclusion that tendon glide was passive.[23] Their technique does not define the resting PIP joint extensor position or the PIP joint and DIP joint motion allowed. They do not explain why they splint the wrist and MP joint for injury in zone III.[27] It is not necessary to splint the wrist or MP joint with this injury, and indeed it may be contraindicated because controlled physiologic motion is necessary to maintain glide in zones III and IV.[27]

O'Dwyer and Quinton[25] used a spring coil dynamic splint for treatment starting at 10–14 days after injury. Twenty-five of 65 injuries were incomplete and all were simple injuries; they were reported as 70% excellent or good results and therefore not outstanding. This is a difficult type of splint to apply and hold successfully. Gelberman et al.[56] and others[38,42,46,49] have shown that dense adhesion may form by 10 days and immediate motion may enhance the biochemical and biomechanical events at the repair site. Hung et al.[24] described a splint that holds the wrist in extension, MP joint at 70°–90° flexion, and dynamic traction distal to the PIP joint. They do not define the limits of PIP joint motion, and their results at this level are not impressive. Splinting the MP in full flexion causes the sagittal bands to glide distally, decreasing tension transmitted to the central slip.[10,57] In this position, PIP joint extension, if passive, is obtained by the dynamic splint, if active is affected by the intrinsic musculature.[58–60] The repair site may not migrate proximally with this technique, and without set limitations for flexion, excessive distal excursion may occur.

Saldana et al.[26] have described a technique for "micromotion" of the repaired central slip, but close analysis of their work indicates that the PIP joint is not worked until the fourth week.

The SAM protocol described in this study creates approximately 4 mm of extensor tendon excursion through zones III and IV at 0° to 30° active flexion (as calculated by radians).[27] Forced application or applied resistance at the repair site with that range of active motion with the wrist flexed to reduce resistance of the flexor system calculates at 291 g,[27] 200 g less than the lowest tensile strength measured for extensor tendon repairs through the healing process that would create a 2 mm repair site gap.[61] The prescribed distal joint motion addresses the problem of lateral band adherence. The technique has proven itself to be safe, simple, effective, comfortable, and inexpensive.

Statistical analysis was performed by Isadore Enger, MA, MS, statistician, Department of Orthopaedics and Rehabilitation, University of Miami, School of Medicine.

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