DYNAMIC SPLINTING AFTER EXTENSOR TENDON REPAIR IN ZONES V TO VII

S. BRÜNER, M. WITTEMANN, A. JESTER, K. BLUMENTHAL and G. GERMANN

From the Department for Hand, Plastic and Reconstructive Surgery, Burn Centre, Plastic and Hand Surgery University of Heidelberg, BG – Trauma Centre, Ludwigshafen, Germany and the Department of Occupational Therapy, BG—Trauma Centre, Ludwigshafen, Germany

This retrospective study evaluates a dynamic active motion protocol for extensor tendon repairs in zones V to VII. Fifty-eight patients with 87 extensor tendon injuries were examined. Using Geldmacher's and Kleinert and Verdan's evaluation systems, the results were graded as "excellent" and "good" in more than 94%, and as "satisfactory" in the remainder. The need for secondary tenolysis was low (6%), and no other surgical complication occurred.
Journal of Hand Surgery (British and European Volume, 2003) 28B: 3: 224–227

INTRODUCTION

The outcome of flexor tendon injuries was poor until special suture techniques were used in combination with active or passive motion rehabilitation techniques (Chow et al., 1989; Evans, 1995; Kleinert et al., 1967, 1973; Slater and Bynum, 1997; Verdan, 1966). Chow combined the essential parts of the Kleinert and the Duran and Houser protocols to produce a dynamic protocol frequently called the "Washington protocol" (Chow et al., 1987; Duran et al., 1976).

In contrast to flexor tendon injuries, extensor tendon lacerations are still frequently considered as simple injuries which are easy to treat. Consequently they have not been given the same clinical and scientific attention (Doyle, 1992; Elliott, 1970; Entin, 1960) and are often treated by younger or less experienced staff (Evans et al., 1995; Ip and Chow, 1997). Postoperative protocols traditionally consist of static immobilization in a forearm splint for 3–4 weeks, which frequently results in significant loss of flexion and extension lags of the metacarpophalangeal and interphalangeal joints, caused by tendon adhesions and joint capsule contractures (Blair and Steyers, 1992; Chow et al., 1989; Couch, 1939; Lee, 1984; Mason and Allen, 1941; Miller, 1942). Based on the excellent results in flexor tendon repair and supporting experimental data (Amiel et al. 1982, 1991; Becker and Diegelmann, 1984; Evans, 1986, 1995; Evans and Burkhalter, 1986; Evans and Thompson, 1992; Freehan and Beauchene, 1990; Gelbermann et al., 1980–1983, 1985, 1991; Gelbermann and Manske, 1985; Hitchcock et al., 1987; Rothkopf et al., 1991; Woo et al., 1980, 1981a,b, 1982), Evans and Chow introduced dynamic active range of motion protocols for extensor tendon repairs (Chow et al, 1989; Duran and Houser, 1975; Evans, 1995; Gelbermann et al., 1986; Ip and Chow, 1997). Little data has been published on the efficacy of these "reversed Washington" protocols.

PATIENTS AND METHODS

Eighty-five patients with simple extensor tendon injuries in Verdan's zones V to VII and no severe associated injuries were treated from 1995 until 1999. Fifty-eight of these 85 patients with a total of 87 injured digits (68% of the patient population) had complete follow-up data. The remaining 27 patients were excluded from the study because of poor compliance with therapy, or incomplete data. All the tendons were repaired with a modified Kirchmayr–Kessler suture or a horizontal mattress suture (Geldmacher and Köckerling, 1991; Newport and Williams, 1992).

Dynamic rehabilitation programme

The dynamic rehabilitation programme (Table 1) started on the second postoperative day, when a thermoplastic dorsal forearm splint (Fig. 1) was formed which held the wrist in 30° extension and the finger metacarpophalangeal joints in 10° hyperextension. Active flexion of the metacarpophalangeal joints to 15 or 30° was permitted in this splint depending on the intraoperative tension of the tendon repair. The permitted range of active flexion was constantly increased, in defined weekly steps, to 90° within 5 weeks. Active extension of the distal interphalangeal and proximal interphalangeal joints was commenced in the fourth week, and the splint was removed after 5 weeks.

The mean length of follow-up was 21 (range, 5–39) months, and outcome was then assessed by measuring the active ranges of motion (AROM) of all finger joints and the wrist, the pulp to palm distance, power grip (Jamar Dynamometer™), pinch grip (Pinchmeter™) and pain (Visual Analogue Scale). Patients' subjective perception of their outcome was also assessed using a grading scale (excellent, good, fair and poor). The functional results were evaluated with Geldmacher's (1991), Kleinert and Verdan's (1983) and Miller's (1942) systems, and graded into four categories: excellent,

Table 1—Rehabilitation program for extensor tendons in Verdan zones V to VII

Day	*Rehabilitation program*
Day 0	Extensor tendon repair
Day 3	*Forearm-based dorsal splint* Wrist: 30° extension MPJ: 10° hyperextension PIP/DIPJ: free *Exercise programme: (10 timeslh)* Active flexion of MPJ to 30° (15°)
Week 2	Active flexion of MPJ to 45° (30°)
Week 3	Active flexion of MPJ to 60° (45°)
Week 4	Active flexion of MPJ to 90° (60°) Active extension of PIP/DIPJ Fist (if possible)
Week 5	Active flexion of MPJ to 90°
Week 6	*Splint removed* Physical therapy against resistance
Week 7–12	Physical therapy against increased resistance

MPJ – metacarpophalangeal joint; PIPJ – proximal interphalangeal joint; DIPJ – distal interphalangeal joint.

good, fair and poor. The results for our patients were then compared with a historical group of patients treated with static immobilization (Geldmacher et al., 1986; Kleinert and Verdan, 1983; Miller, 1942).

RESULTS

Only five patients (9%) were women, and the mean age of the group was 37 years (range, 12–67 years). Forty-one (71%) of the 58 sustained a right hand injury, and 29 patients (50%) had an injury to the middle finger. Nineteen hands (33%) with 48 digits had more than one (two to four) extensor tendon lacerations. One patient required split-thickness skin graft to cover a soft tissue defect on the dorsum of the hand. Thirty-one of the 58 injuries (53%) were occupational injuries. Patients returned to their previous work status after a mean of 10 weeks (range, 5–30 weeks), and no patient had a residual impairment that interfered with his/her activities of daily life. Five (6%) digits in four patients required tenolysis because of tendon adhesions. The split-thickness skin graft that was performed in one case had no effect on finger function. The mean total active range of motion (TAM) of the 87 digits was 237° (range, 155–330°), representing 94% of the uninjured hand. The total extension lag of the fingers was 6° (range, 0–50°), with 62 of the injured fingers having no extension lag. The mean total active ranges of motion of the proximal and distal interphalangeal joints were 94° (range, 50–145°) and 63° (range, 0–100°), respectively. A mean loss of metacarpophalangeal joint flexion of 8° (range, 0–55°) occurred. One patient with more than one injured extensor tendon had a loss of 55° flexion in one metacarpophalangeal joint. The mean metacarpophalangeal extension lag was only 2° (range, 0–20°). Forty-seven patients (81%) were able to make a full fist; and the mean pulp to palm distance was 0.2 cm (range, 0–3.5 cm). Only three patients had a pulp to palm distance of greater than 2 cm. A mean 5% (range, 0–50 %) loss of wrist extension and a 6% (range, 0–40%) loss of flexion, in comparison to the uninjured hand, was noted. Grip strength averaged 91% (range, 50–116%) of the unaffected hand, with 17 patients (29%) regaining their pre-injury grip strength (Table 2). All patients who sustained injuries to up to three extensor tendons regained more than 80% of the grip strength of the unaffected hand. Pinch grip strength ranged from 25% to 140% (mean, 78%) of the uninjured hand and the

Table 2—Mean (range) functional results

Total active motion	*236°*	*(range 155–330°)*
Extension lag of all joints	6.°	(range 0–50°)
Flexion lag of all joints	3°	(range 0–50°)
Range of motion MPJ	78°	(range 30–120°)
Extension lag MPJ	3°	(range 0–20°)
Flexion lag MPJ	8°	(range 0–55°)
Range of active motion PIPJ	94°	(range 50–145°)
Extension lag PIPJ	3°	(range 0–50°)
Flexion lag PIPJ	4°	(range 0–40°)
Range of active motion DIPJ	63°	(range 0–100°)
Extension lag DIPJJ	1°	(range 0–25°)
Flexion lag DIPJ	5°	(range 0–45°)
Extension lag wrist	5°	(range 0–40°)
Flexion lag wrist	6°	(range 0–80°)
Pulp to pulm distance	0.2 cm	(range 0–3.5)
Grip strength	91% of uninjured hand	(range 50–116%)
Pinch grip strength	78% of uninjured hand	(range 25–140%)
Pain (VAS 1–10)	0.2	(range 0–5)

Table 3—Different grading systems

	Geldmacher	*Miller*	*Kleinert*
Excellent	61 (70%)	11 (13%)	24 (28%)
Good	21 (24%)	38 (44%)	58 (67%)
Fair	5 (6%)	32 (37%)	5 (6%)
Poor	0	6 (7%)	0

mean pain value on the Visual Analogue Scale (VAS 1–10) was 0.2 (range, 0–5). Only four patients reported increased pain at work and subjective patient satisfaction was high. Forty-three (74%) of the patients graded their results as excellent, 12 as good and only five as fair. One patient rated the result as fair although the measured function of the digit was excellent. None of the patients were dissatisfied with the result. The outcomes according to the various grading systems are shown in Table 3.

DISCUSSION

Although early active motion protocols are considered the gold standard for flexor tendon injuries, they have not gained widespread acceptance for extensor tendon injury rehabilitation. The purpose of this study was to evaluate the efficacy of a dynamic active motion protocol following extensor tendon repairs in zones V to VII in a clearly defined group of patients. The main weakness of this study is the lack of a control group. The study was commenced as a pilot project in 1994, but the preliminary results were so convincing that it was not considered ethical to treat a group of patients with tendon repair and immobilization. Thomas et al. (1996) reported on 88 injured extensor tendons in zones V to VII in a homogenous patient group after early dynamic mobilization and found that 61% had regained a full range of motion after 1 year. Ip and Chow (1997) reported on zones IV to VIII injuries treated with dynamic splintage and observed a total active range of motion (TAM) of 242°, which represented a loss of 23° of active finger motion compared to a normal Chinese population. Our data compare favourably with these results with 66 percent of all digits recovering more than 90% of the TAM of the unaffected side. Only few studies compare the results of immobilization and active motion protocols (Chow et al., 1989; Evans, 1989, 1995; Purcell et al., 2000). Evans (1989) had to perform tenolyses in 30% of the treated digits and Chow et al. (1989) in 17% after immobilization and Kelly (1959) reported 20% poor results following 4 weeks of immobilization. Geldmacher and Köckerling (1991) found that only 76% of 145 extensor tendon repairs achieved good or excellent results: 24% were rated as fair to poor.

Grip strength in our patients was 91% of the contralateral hand. The loss of active range of motion and grip strength following treatment with early motion protocols is low and should only slightly impair the patient's activities of daily living (Chow et al., 1989). Eighty-one per cent of our patients could make a full fist and they considered that as important as grip strength.

Associated injuries significantly worsen the results of extensor tendon repair (Hauge, 1954; Ip and Chow, 1997; Kelly, 1959; Newport et al., 1990) which is why patients with associated injuries were excluded from this study. Newport demonstrated an average range of motion of 89% of the healthy hand after mostly static splinting for 3–4 weeks. This series also included injuries in zones I to IV and there were sometimes associated digital injuries, so that it is not comparable with our study (Newport et al., 1990). However, even the comparison of the functional outcomes of simple injuries remains difficult, since authors use different evaluation systems that yield different outcome results (Browne and Ribik, 1989; Elliott, 1970, Evans, 1995; Ip and Chow, 1997; Newport et al., 1990; Newport and Shukla, 1992; Slater and Bynum, 1997; Sylaidis et al., 1997; Thomas et al., 1996). Almost 94% of our patients rated their results as excellent (74%) or good (20%) and thought that the rehabilitation programme was easy to learn. Intensive individual care by the therapists, and the ability to return to their pre-injury occupation probably account for the high satisfaction level. The surgeon factor is apparently not so crucial with these types of follow-up protocol as, although the extensor tendon repairs were performed by numerous surgeons with different operative experiences, our data were comparable to those of groups where only small numbers of surgeons were involved (Evans, 1995; Kerr and Burczak, 1989). Dynamic rehabilitation protocols are expensive and labour intensive (Crosby and Wehbe, 1996, Purcell et al., 2000) and require individually tailored splints for each patient. In addition the patient has to be seen on a regular basis by a competent hand therapist. Thus, although beneficial, these therapeutic protocols may have to be confined to hand surgery units that are able to provide the necessary infrastructure (Evans, 1995). Our data suggest that better results are achieved with active motion protocols than with immobilization treatment regimes. We consider that active early motion protocols should be considered as the standard for extensor tendon repairs in zones V to VII.

References

Amiel D, Gelbermann R, Harwood F (1991). Fibronectin in healing flexor tendons subjected to immobilization or early controlled passive motion. Matrix, II: 184–189.

Amiel D, Woo S, Harwood FL (1982). The effect of immobilization on collagen turnover in connective tissue. A biochemical–biomechanical correlation. Acta Orthopaedica Scandinavica, 53: 325–332.

Becker H, Diegelmann RF (1984). The influence of tension on intrinsic tendon fibroplasia. Orthopaedic Review, 13: 65–71.

Blair WF, Steyers CM (1992). Extensor tendon injuries. Orthopedic Clinics of North America, 23: 141–148.

Browne EZ, Ribik CA (1989). Early dynamic splinting for extensor tendon injuries. Journal of Hand Surgery, 14: 72–76.
Chow J, Thomes L, Dovelle S, Milnor WH, Seyfer AE, Smith AC (1987). A combined regimen of controlled motion following flexor tendon repairs in ‘‘no man’s land’’. Plastic and Reconstructive Surgery, 79: 447–453.
Chow JA, Dovelle S, Thomes LJ, Ho PK, Saldana J (1989). A comparison of results of extensor tendon repair followed by early controlled mobilization versus static immobilization. Journal of Hand Surgery, 14: 18–20.
Chow SP, Stephens MM, Ngai WK, So YC, Pun WK, Chu M, Crosby C (1990). A splint for controlled active motion after flexor tendon repair: design, mechanical testing, and preliminary clinical results. Journal of Hand Surgery, 15: 645–651.
Couch JH (1939). Principles of tendon sutures in the hand. Canadian Medical Journal, 199: 27–30.
Crosby CA, Wehbe MA (1996). Early motion after extensor tendon surgery. Hand Clinics, 12: 57–64.
Doyle JR. Extensor tendons – acute injuries. In: Green D, (Ed.) *Operative hand surgery*. New York, Churchill Livingstone, 1992: 1925–1954.
Duran RJ, Houser RG (1975). Controlled passive motion following flexor tendon repair in zones II and III. In: The American Academy of Orthopedic Surgeons: Symposium on Tendon Surgery in the Hand. St Louis, CV Mosby, 1975: 105.
Duran RJ, Houser RG, Coleman CR et al. (1976). A preliminary report in the use of controlled passive motion following flexor tendon repair in zones II and III. Journal of Hand Surgery, 1: 79–85.
Elliott RA (1970). Injuries to the extensor mechanism of the hand. Orthopedic Clinics of North America, 1: 335–354.
Entin MA (1960). Repair of the extensor mechanism of the hand. Surgical Clinics of North America, 40: 275–285.
Evans JD, Wignakumar V, Davis TRC, Dove A (1995). Results of extensor tendon repair performed by junior accident and emergency staff. Injury, 26: 107–109.
Evans RB (1986). Therapeutic management of extensor tendon injuries. Hand Clinics, 2: 157–169.
Evans RB (1989). Clinical application of controlled stress to the healing extensor tendon: a review of 112 cases. Physical Therapy 69: 1041–1049.
Evans RB (1995). Immediate active short arc motion following extensor tendon repair. Hand Clinics, 11: 483–512.
Evans RB, Burkhalter WE (1986). A study of the dynamic anatomy of extensor tendons and implications for treatment. Journal of Hand Surgery, 11: 774–779.
Evans RB, Thompson DE (1992). The application of stress to the healing tendon. Journal of Hand Therapy, 5: 187–201.
Freehan LM, Beauchene JG (1990). Early tensile properties of healing chicken flexor tendons: Early controlled passive motion versus postoperative immobilization. Journal of Hand Surgery, 15: 63–68.
Gelberman RH, Amiel D, Gonsalves M, Woo S, Akeson WH (1981). The influence of protected passive mobilization on the healing of flexor tendons: a biomechanical and microangiographic study. Hand Clinics, 13: 120–128.
Gelberman RH, Botte MJ, Spiegelman JJ, Akeson WH (1986). The excursion and deformation of repaired flexor tendons treated with protected early motion. Journal of Hand Surgery, 11: 106–110.
Gelberman RH, Manske PR (1985). Factors influencing flexor tendon adhesions. Hand Clinics, 1: 35–42.
Gelberman RH, Menon J, Gonsalves M, Akenon WH (1980). The effects of mobilization on the vascularization of healing flexor tendons in dogs. Clinical Orthopaedics and Related Research, 153: 283–289.
Gelberman RH, Steinberg D, Amiel D, Akeson WH (1991). Fibroblast chemotaxis after repair. Journal of Hand Surgery, 16: 686–693.
Gelberman RH, Vande Berg JS, Lundborg GN, Akeson WH (1983). Flexor tendon healing and restoration of the gliding surface. Journal of Bone and Joint Surgery 65: 70–80.
Gelberman RH, Vande Berg JS, Manske PR (1985). The early stages of flexor tendon healing: a Morphologic study of the first 14 days. Journal of Hand Surgery, 10: 776–784.
Gelberman RH, Woo SL, Lothringer K, Akeson WH, Amiel D (1982). Effects of early intermittent passive mobilisation on healing canine flexor tendons. Journal of Hand Surgery, 7: 170–175.
Geldmacher J, Köckerling F. In: *Urban und Schwarzenberg: Sehnenchirurgie*. München, Wien, Baltimore, 1991: 114–115, 239–240.
Geldmacher J, Plank K, Treuheit D (1986). Die Bedeutung der präoperativen Ausgangssituation bei der Beurteilung der Rekonstruktionsergebnisse an Strecksehnen. Handchirurgie, 18: 23–29.
Hauge MF (1954). The results of tendon suture hands; a review of 500 patients. Acta Orthopaedica Scandinavica, 24: 258–270.
Hitchcock TF, Light TR, Bunch WH, Knight GW, Sartori MJ, Patwardhan AG, Hollyfield RL (1987). The effect of immediate constrained digital motion on the strength of flexor tendon repairs in chickens. Journal of Hand Surgery, 12: 590–595.
Hung Lk, Chan A, Chang J, Tsang A, Leung PC (1990). Early controlled active mobilization with dynamic splintage for treatment of extensor tendon injuries. Journal of Hand Surgery, 15: 251–257.
Ip WY, Chow SP (1997). Results of dynamic splintage following extensor tendon repair. Journal of Hand Surgery, 22: 283–287.
Kelly AP (1959). Primary tendon repairs. A study of 789 consecutive tendon severances. Journal of Bone and Joint Surgery, 41A: 581–598.
Kerr CD, Burczak JR (1989). Dynamic traction after extensor tendon repair in zones 6, 7, and 8: a retrospective study. Journal of Hand Surgery, 14: 21–22.
Khandwala AR, Webb J, Harris SB, Foster SJ, Elliot D (2000). A Comparison of dynamic extension splinting and controlled active mobilization of complete divisions of extensor tendons in zones 5 and 6. Journal of Hand Surgery, 25: 140–146.
Kleinert HE, Kutz JE, Ashbell TS (1967). Primary repair of lacerated flexor tendons in ‘‘no man’s land’’. Journal of Bone and Joint Surgery, 49: 577.
Kleinert HE, Kutz JE, Atasoy E, Stormo A (1973). Primary repair of flexor tendons. Orthopedic Clinics of North America, 4: 865–876.
Kleinert HE, Verdan C (1983). Report of the committee on tendon injuries. Journal of Hand Surgery, 8: 794–798.
Lee VH (1984). In: Hunter J.M. (Ed.) *Rehabilitation of the hand* 2nd edn, St Louis, CV Mosby, 1984: 365.
Mason ML, Allen HS. (1941). The rate of healing tendons: an experimental study of tensile strength. Annals of Surgery, 113: 424–459.
Miller H. (1942). Repair of severed tendons of the hand and wrist: statistical analysis of 300 cases. Surgery, Gynecology and Obstetrics, 75: 693–698.
Newport ML, Blair WF, Steyers CM (1990). Long-term results of extensor tendon repair. Journal of Hand Surgery, 15: 961.
Newport ML, Shukla A (1992). Electrophysiologic basis of dynamic extensor splinting. Journal of Hand Surgery, 17: 272–277.
Newport ML, Williams C (1992). Biomechanical characteristics of extensor tendon suture techniques. Journal of Hand Surgery, 17: 1117.
Purcell T, Eadie PA, Murugan S, O’Donnell M, Lawless M (2000). Static splinting of extensor tendon repairs. Journal of Hand Surgery, 25: 180–182.
Rothkopf DM, Webb S, Szabo RM, Gelberman RH, May JW (1991). An experimental model for the canine flexor tendons adhesions. Journal of Hand Surgery, 16: 694–700.
Slater RR, Bynum DK (1997). Simplified functional splinting after extensor tenorrhaphy. Journal of Hand Surgery, 22: 445–451.
Strickland JW, Glogovac SV (1980). Digital function following flexor tendon repair in zone II: a comparison of immobilization and controlled passive motion techniques. Journal of Hand Surgery, 5: 537–543.
Sylaidis P, Youatt M, Logan A (1997). Early active mobilization for extensor tendons injuries. The Norwich Regime. Journal of Hand Surgery, 22: 594–596.
Thomas D, Moutet F, Guinard D (1996). Postoperative management of extensor tendon repairs in zones V, VI, and VII. Journal of Hand Therapy, 9: 309–314.
Verdan C.Primary,secondary repair of flexor and extensor tendon injuries. In: Flynn JE (Ed.) *Hand surgery*. Baltimore, Williams & Wilkins, 1966: 220–275.
Woo SL, Gelberman RH, Cobb NG (1981a). The importance of controlled passive mobilization on flexor tendon healing: a biomechanical study. Acta Orthopaedica Scandinavica, 52: 615–622.
Woo SL, Gomez MA, Woo Y (1982). Mechanical properties of tendons and ligaments: II. The relationships of immobilization and exercise on tissue remodeling. Biorheology, 19: 397–408.
Woo SL, Gomez MA, Amiel D (1981b). The effects of excercise on the biomechanical and biochemical properties of swine digital flexor tendons. Journal Biomechanics, 103: 51–56.
Woo SL, Ritter MA, Amiel D (1980). The biomechanical and biochemical properties of swine tendons: long term effects of exercise on the digital extensors. Connective Tissue Research, 7: 177–183.

Dr S Brüner, Am Kreuzteich 9, 38104 Braunschweig, Germany. Tel.: 0049-172-6975619; fax: 0049-621-6810211; E-mail: sbruener@yahoo.com

doi:10.1016/S0266-7681(03)00014-7/jhsb.2003.0914, available online at http://www.sciencedirect.com