Complications of extensor tendon repairs at the extensor retinaculum

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Abstract

Literature describing surgical, post-operative management and outcomes following EDC repairs in close proximity to or within the extensor retinaculum is limited. This complex injury can result in decreased wrist and digital motion as well as loss of independent motion of the digits. This paper reviews complications following such injuries observed clinically as well as experimental simulation performed on cadaveric specimens. Our observations have direct implications to hand therapy practice and outcomes used following such injuries.

Keywords Extensor tendon repair · Extensor retinaculum · Complications · Therapeutic management · Outcomes

Introduction

Digital extrinsic extensor tendon injury near or within the extensor retinaculum is a complex injury which often results in loss of tendon excursion due to adhesions among tendons, sheaths, retinaculum, and bone [1]. It has been reported that adhesions to the extensor digitorum communis (EDC) distal to the extensor retinaculum can restrict combined wrist and finger extension. Conversely, adhesions proximal to the extensor retinaculum can restrict combined wrist and finger flexion [2]. This reduced tendon excursion around the extensor retinaculum can have significant effect to combined use of the wrist and hand.

Literature describing surgical, post-operative management, and outcomes of extrinsic extensor tendon repairs in close proximity to or within the extensor retinaculum is limited. Traditionally, repaired extensor tendons have been immobilized in a cast or static splint for several weeks [3–6] but this may result in tendon adhesions, loss of digital flexion, extensor lag, joint contracture, and prolonged rehabilitation [5, 6]. These complications have led to the development of various early mobilization regimes. Retrospective studies and prospective observations of dynamic splinting following extensor tendon repair has consistently reported greater than 90 percent excellent and good range of motion (ROM) with no significant incidence of tendon rupture, extensor lag, or tenolysis [6–14]. Early active mobilization in conjunction with protective static splinting has also been found to produce greater than 85% excellent and good ROM [15, 16]. Only three prospective randomized controlled clinical trials [17–19] have been conducted to compare the outcome of dynamic and variations of static splinting for simple extensor tendon injuries in zones V–VII. Based on these studies no evidence was found for the superiority of either early controlled mobilization or early active mobilization in the rehabilitation of extensor tendon injuries at final follow-up.

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This paper will review critical anatomical considerations, complications of such injuries, simulate tendon adhesions and identify these complications on cadaveric models. Based on clinical and cadaveric observations we propose new techniques and outcome considerations for management of these complex injuries.

Anatomical considerations

Klienert and Verdan [20] and Verdan [21] proposed a system of classifying extensor tendon lacerations according to eight zones in the hand, wrist, and forearm. Doyle [22] suggested adding a ninth zone to characterize injuries to the extensor muscles of the mid and proximal forearm. At the level of the wrist the extensor tendons pass through six fibrous compartments as they enter the hand. These compartments are each separated by septa. The extensor tendons are synovial only at this level [23–25]. The synovial sheaths and extensor retinaculum act as pulleys which maintain the relationship of the tendon with changes in wrist and digital positions.

The extensor tendons of the metacarpophalangeal joints are the EDC, the extensor indicis proprius (EIP), and the extensor digiti quinti (EDQ). The EDC and the EIP enter the hand beneath the extensor retinaculum in the fourth dorsal compartment. The EDC lies superficial to the EIP [26]. The EDC tendon to the index, long, and ring fingers are substantial in size, however, the slip to the small finger is variable in size [2]. The EDQ enters the hand through the fifth dorsal compartment. The EIP and EDQ have independent muscles that allow independent function, thus, extension of the index and small fingers is easily performed irrespective of the position of the other fingers.

Tendon gliding

Cadaveric studies of EDC excursion has been described in the literature (please see table 1) [27]. It has been postulated that 3–5 mm of tendon mobilization is necessary to maintain functional glide and prevent dense adhesion formation [28]. Evans and Burkhalter [29] measured EDC excursion intraoperatively and found that 30 degrees of metacarpophalangeal motion effected 5 mm of EDC glide in zones V, VI, and VI. These authors suggest a simple equation be used to calculate the necessary amount of MCP joint flexion required to equate 5 mm of EDC excursion in zones V–VI. The equation is: joint motion divided by tendon excursion for that particular joint is equal to the number of degrees of motion required to effect 1 mm of tendon glide [29].

The cadaveric work of Minamikawa et al. [30] found if the wrist is extended 21 degrees or greater the EDC tendon

glides with little or no tension in zones V and VI throughout full simulated grip to passive extension. Based on this study the authors suggest full composite active flexion with passive digital extension can be performed post-operatively as this will not place any tension to a repaired EDC tendon if the wrist is extended 21 degrees or greater. However, these investigators found redundant tendon buckling occurred in zones VII and VIII if the wrist was not positioned in less than 21 degrees of extension for any tendon excursion to take [30]. Therefore, allowing increased digital motion while protecting the repair with adequate wrist extension may provide sufficient tendon excursion to prevent certain complications such as loss of digital flexion and loss of composite wrist and digital flexion in zones VII and VIII.

Extensor tendon laceration

Extensor tendon injuries are quite common and occur more frequently than flexor tendon injuries. However, rehabilitation after repair of extensor tendon injury has been less addressed in the literature than that of flexor tendons [(1, 31, 32].

Verdan [33] reported that zone VI EDC lacerations proximal to the juncturae tendinum will retract upon laceration and may require exposure of the fourth dorsal compartment for successful tendon repair. Post-operative management of acute extensor tendon injuries has evolved within the past two decades. Traditionally, management of extensor tendon repairs in zones VI–VII consisted of static splinting for three to four weeks followed by gradual mobilization [34]. However, with increasing amounts of evidence, early controlled mobilization by the use of dynamic splinting has become the preferred method of rehabilitation of zone VI–VIII injuries [5, 6, 13, 14, 34, 35].

The consequences of immobilization programs following extensor tendon injuries has been documented in the literature [36] leading many to advocate the benefits of implementing a controlled mobilization program. However, controlled mobilization using dynamic splinting which fails to mobilize the EDC tendon adequately at or within the retinacular level may not regain complete excursion. If the level of the tendon repair is in the vicinity of the extensor retinaculum, either just proximal or distal, and optimal tendon gliding is not achieved early in the rehabilitation program, there may be limitations with combined wrist and digital movements.

We have observed this in our clinical practice, however, the literature fails to identify these complications following zone VI–VIII injuries. We believe that the various outcome measures used in the literature are not sensitive to limitations in combined wrist and digital motion.

Table 1. Excursion of the extensor Digitorum communis tendon as reported by Bunnell (1970)

	Excursion of the EDC as reported by Bunnell (1970)				
	Total (mm)	Wrist (mm)	MCP (mm)	PIP (mm)	DIP
Index	54	38	15	2	0
Long	55	41	16	3	0
Ring	55	39	11	3	0
Small	35	20	12	2	0

Fig. 1 Loss of digital flexion along with extension of the wrist, due to intertendinous adhesion in zone VI, may contribute to limited function of the hand **Fig. 2** Combined wrist and digital extension is affected in Zone VI, due to the scarring of the tendons. Gliding amplitude of the tendons through the fibro-osseous sheath is reduced

Complications observed clinically following post-operative management of extensor tendon injuries in zone VI–VIII

Having treated a number of extensor tendon injuries at the level of the extensor retinaculum following protocols published in the literature, certain complications were identified. Our clinical observations are based on eight patients (3 in zone VI; 3 in zone VII; 2 in zone VIII) which followed either immobilization or early controlled mobilization using a dynamic splint which mobilized the digits only as described by Crosby and Wehbe [9]. All of the tendons in zone VI–VIII were repaired using a modified Kessler stitch with a Silfverskiöld epitendinous stitch. We found that these post-operative treatment methods produced variable complications which were dependant on the zone of injury.

Zone VI injuries resulted in intertendinous adhesions and adhesions surrounding the tendons which caused loss of digital flexion with simultaneous wrist extension (Figure 1), loss of combined extension of the wrist and digits (Figures 2 and 3c), and loss of wrist extension with fingers flexed (Figure 3a). Furthermore, loss of independent extension of each digit was observed (Fig. 4). These limitations were due to the restraining adhesions having difficulty gliding beneath the fibroosseous sheath (Figs 3b and d). Composite flexion of the wrist and the digits, how-

ever, demonstrated no limitations since the tendons were able to move distal to the fibroosseous sheath. Subcutaneous adhesions (if present) gradually remodel with therapy as the flexors produce greater strain on the adhesions when flexion is performed.

Zone VII injuries resulted in reduced gliding amplitude of the extensor proximally as well as distally as the tendons were tethered in the fibroosseous sheath. This contributed to limitations of digital and wrist motion in both flexion and extension. Gaining wrist and digital flexion, however, was less challenging because of the muscle strength and its capacity for sustained tension stimulating remodelling of the scar tissue. On the contrary, regaining extension of the digits presented challenges due to the strength of the extensor muscle and excursion of the tendons in this particular zone (Fig. 5).

Zone VIII injuries resulted in loss of combined wrist and digital flexion due to intertendinous as well as peritendinous adhesions. Independent digital flexion was also diminished as these adhesions experienced difficulty gliding through the fibroosseous sheath during flexion. Combined extension of the wrist and digits, however, was unrestricted since the tendons glided proximally. Upon flexion of the wrist the digits were strongly pulled into extension demonstrating a strong “extensor-plus”. Extensor-plus is a condition which shortens the excursion of

Fig. 3 Zone-VI injury patient demonstrates limitation in the wrist extension and extension with fingers flexed or extended **A** and **C**. This limitation is due to the restricted proximal gliding of the extensor tendons. Whereas, the wrist extension and flexion is full irrespective of digital position (**B** and **D**) since the extensors are gliding distally

Fig. 4 Patient demonstrates loss of independent extension of the finger (**A**, **B** and **C**) irrespective of the position of the wrist suggesting adhesions of the tendons to the adjacent EDC tendons

the extensor hood mechanism over the metacarpophalangeal joint and proximal phalanx. This causes strong extension tendency of the fingers when the wrist is flexed (Fig. 8) [37]. Variable wrist positions also produced an altered grip pattern. Sustained grip with the wrist in flexion became significantly impossible (Figs. 6–8).

The wrist and digital extensor tendon must glide beneath the retinaculum freely for full digital and wrist mobility. Due to the anatomical structures at this level of the wrist, immobilization or traditional dynamic splinting following extensor tendon repair may result in complications and inadequate outcomes. The description of our observed complications following extensor tendon repairs

Fig. 5 In zone VII – Extensor lag at the digits is likely to be a common complication caused by extensor tendon adhesions in fibro-osseous sheath. Flexion of the digits often improves because of the flexor strength as compared to the strength of the extensors

in zone VI–VIII ignited a desire to further understand the causes of these complications by performing anatomical dissections on fresh cadaveric specimens.

Anatomical cadaveric trials

In order to simulate adhesions proximal and distal to the extensor retinaculum two fresh cadavers were dissected (Fig. 9). The entire dorsal skin and fascia were reflected to expose the extensor retinaculum. The extensor tendons and their compartments were identified and labelled. Extensor tendon adhesions were simulated by suturing the tendons distal and proximal to the extensor retinacu-

lum (Figs. 10–12). The tendons were pulled and the joints were moved in different directions to study the effect of tendon adhesion in various regions of the retinaculum.

The first phase of this experiment consisted of simulated tendon adhesion by suturing the tendons to the surrounding structures distal to the extensor retinaculum in zone VI and moving the wrist in flexion and extension while holding the digits in composite flexion and extension. Combined wrist and digital extension demonstrated restricted composite extension of the digits due to the tendons having difficulty gliding beneath the extensor retinaculum (Figs. 13–14), whereas, no restriction in digital extension was noted with the wrist held in flexion. Furthermore, passive wrist and digital flexion demonstrated no limitations in tendon gliding and full wrist and digital flexion was attainable.

Fig. 6 The extensor tendons demonstrating difficulty gliding beneath the extensor retinaculum in zone VIII, causing limitation in combined flexion of the wrist and digits

Fig. 7 Intertendinous tendon adhesion at the extensor retinaculum is likely to limit independent digital mobility in zones VI–VIII

The second phase of the experiment consisted of simulating EDC tendon adhesions by suturing the tendons to the surrounding structures proximal to the extensor retinaculum in zone VIII and moving the wrist in flexion and extension while holding the fingers in composite flexion and extension. Passive wrist flexion with the digits held in flexion demonstrated restricted combined motion of the wrist and digits as the simulated adhesions had difficulty gliding beneath the extensor retinaculum (Figs. 15 and 16). Extension of the wrist and the digits demonstrated no limitation.

Since the extensor tendons were tethered to each other in proximal zone VI and distal zone VIII, independent

Fig. 8 Demonstrating limitation of digital flexion with flexion of the wrist in zone VIII. Increased flexion of the wrist produces a strong extensor plus tendency at the digits since the extensors tendons have gliding difficulty beneath the extensor retinaculum

Fig. 9 Orientation of extensor tendons of the 4th extensor compartment in proximal zone VI

motion of the fingers was also limited. Due to the adhesion formation between the tendons, loss of differential tendon motion between the digits caused limitation in

Fig. 10 Simulation of extensor tendon adhesion distal to extensor retinaculum and the sheath

Fig. 11 Simulation of extensor tendon adhesions in zone VIII

Fig. 12 Simulation of extensor tendon adhesion distal to extensor retinaculum and fibroosseous sheath (marked with an arrow)

extension of one digit while the other digits were flexed. This simulation however, was not possible on cadaver experimentation since a flexor force on the adjacent digits while an extensor pull on a particular digit could not be attained due to the lack of proper instrumentation.

Clinical implications to hand therapy practice

This cadaveric experiment simulated EDC adhesions just proximal and distal to the extensor retinaculum which produced limitations in combined wrist and digital movements. This experiment reproduced what we have observed clinically when treating these injuries using controlled mobilization utilizing traditional dynamic splinting which involves controlled mobilization of the digits only.

Therefore, based on this cadaveric observation, clinical experience, and current knowledge regarding EDC gliding it is our opinion that EDC repairs within or in close

Fig. 13 In zone VI, composite extension of the wrist and fingers are restricted since the simulated tendon adhesions demonstrated limited gliding beneath the extensor retinaculum

Fig. 14 In zone VI, tendons demonstrated no limitations when combined flexion of the wrist and fingers was attempted

vicinity to the extensor retinaculum be managed post-operatively using a controlled active and passive mobilization program. This can be achieved by utilizing traditional dynamic splinting, incorporating wrist tenodesis, and differential tendon gliding exercises. This treatment approach will maximize EDC excursion, minimize gliding resistance, provide differential tendon excursion, place minimal tension at the repair site, and prevent post-operative complications.

Wrist tenodesis exercises and differential tendon gliding

Wrist tenodesis following zones VI–VIII tendon repair is not a new concept [38–40]. Two papers have addressed

Fig. 15 Upon pulling on the extensor tendons for the extension of the wrist and fingers the simulated adhesions demonstrated no difficulty in proximal gliding of the tendons

Fig. 16 Upon flexing the wrist and the digits the adhesions moved distally, the simulated adhesions demonstrated difficulty gliding beneath the retinaculum. Restriction of combined flexion of the fingers and wrist was noted

early controlled motion of the wrist and digits utilizing a tenodesis motion program following injuries within close vicinity to the extensor retinaculum. Chinchalkar [38] recommends a dynamic wrist hinge splint (Figs. 17A and B) whereas, Eissens [39] recommends an early controlled active motion program. These papers have no clinical data, however, the goal of treatment is to maximize independent as well as combined mobility of the wrist and digits. Close communication between the surgeon and therapist is critical prior to initiating wrist tenodesis in order to custom tailor the rehabilitation program based on amount of tendon debridement during the repair in order to safely initiate motion and maximize outcome. Wrist tenodesis can begin during the inflammatory phase of wound healing within 3–5 days following tenorrhaphy. Wrist joint flexion may be limited between 0 and 10 degrees initially and then gradually increase by 10 degrees per week. Tenodesis can be performed out of the traditional dynamic splint or within a Double Reverse Klienert splint which includes a hinged wrist component and dynamic digital outriggers [38, 40].

Multiple EDC repairs may benefit from differential tendon gliding exercises beginning during the inflammatory phase of healing. This can be accomplished by actively flexing one digit at a time while the other digits are maintained in dynamic traction extension. The MCP joints can be moved from 30–40 degrees during the first week. This can be increased by 10–15 degrees weekly.

Fig. 17 Wrist tenodesis splint for early controlled motion of the extensor tendons. **A**, Wrist flexion-finger extension; **B**, Wrist extension-finger flexion

Table 2. Description of various outcome measures used following extensor tendon repair in zones VI–VIII**Total Active Motion (TAM) Assessment of Extensor Tendon Repairs**

Kleinert HE, Verdan C (1983). Report of the committee on tendon injuries. *Journal of Hand Surgery*, 8:794–798

Excellent	TAM = TAM of contralateral digit
Good	TAM > 75% TAM of contralateral digit
Fair	TAM greater than 50% of contralateral digit
Poor	TAM less than 50% TAM of contralateral digit
TAM = [MCP + PIP + DIP flexion) – (MCP + PIP + DIP extension lag)	

Strickland–Glogovac formula

Strickland JW, Glogovac SV (1980). Digital function following extensor tendon repair in zone II: A comparison of immobilization and controlled passive motion techniques. *Journal of Hand Surgery*, 5:537–543.

$$[(\text{Active PIPJ} + \text{DIPJ flexion}) - \text{extension lag}] / 175 \text{ degrees} \times 100$$

Excellent	75 to 100% Good
Good	50–75%
Fair	25–49%
Poor	0–24%

Miller's assessment of extensor Tendon repair

Miller H (1942). Repair of severed tendons of the hand and wrist. statistical analysis of 300 cases. *Surgery, Gynecology and Obstetrics*, 75: 693–698.

Excellent	Same ROM as opposite side
Good	Loss of 20 degrees of flexion and/or 45–10 degrees of extension lag
Poor	>45 degrees lss of flexion and/or >45 degrees extension lag

Dargan system extensor lad vs lag

Dargan EL (1969). Management of extensor tendon injuries of the hand. *Surgery, Gynecology and Obstetrics*, 128:1269–1273

Excellent	No extensor lad and with flexion of pulps to mid-palm
Good	Extensor lag < 15 degrees with flexion of pulps to mid palm
Fair	Extensor lag 15–35 degrees or pulp to palm distance < 2 cm
Poor	Extensor lag > 45 degrees or pulp to palm distance > 2 cm

Proposed modifications to current outcome measures used following extensor tendon repair

Various outcome measures are used in the literature following extensor tendon repair which makes comparing the outcomes of various rehabilitation regimes difficult (see Table 2) [41–44]. These different classification systems use different cut-off points for the assignment of ROM into the categories of poor, fair, good, or excellent. All of the outcome measures used measure digital ROM with the wrist in neutral position to increase interrater reliability by standardizing the assessment. This method of assessment will increase interrater reliability, however,

it will not capture limitations in combined motions of the wrist and hand which is essential for completion of various activities of daily living and work duties.

None of the studies addressing post-operative rehabilitation following zones VI–VIII extensor tendon repair considered total active extension and flexion of the digits in combination with motion of the wrist. Based on our clinical and experimental trials we propose that future studies which include subjects with extensor tendon repairs within close proximity to or within the extensor retinaculum not only use Total Active Motion (TAM) as originally described by Klienert and Verdan [41]. TAM should also be recorded with the wrist in full flexion and

extension respectively. By recording both traditional TAM and TAM in conjunction with wrist motion will provide the clinical community with greater information when reviewing future studies as to the success of the specific rehabilitation regime followed.

Conclusion

Extensor tendon injuries in the vicinity of the extensor retinaculum are vulnerable to adhesion formation which can restrict combined motion of the wrist and digits. Based on clinical and cadaveric observations we propose that early controlled mobilization utilizing controlled digital ROM, wrist tenodesis, and differential tendon gliding be implemented following such injuries. A randomized clinical trial of this method of management should provide evidence that early controlled mobilization following repair of these injuries is beneficial to minimize this complication. However, we propose modifications be made to current outcome measures used in order to substantiate the significance of these treatment programs.

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