Injury, Int. J. Care Injured 44 (2013) 397–402

Contents lists available at SciVerse ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Rehabilitation of flexor and extensor tendon injuries in the hand: Current updates

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ARTICLE INFO

Keywords:
Current trends
Rehabilitation
Flexor tendon injury
Extensor tendon injury
Early motion
Relative motion
Safe splint position
Splint controlled motion
Immediate controlled active motion (ICAM)

ABSTRACT

In recent years, a significant amount of research in the field of tendon injury in the hand has contributed to advances in both surgical and rehabilitation techniques. The introduction of early motion has improved tendon healing, reduced complications, and enhanced final outcomes. There is overwhelming evidence to show that carefully devised rehabilitation programs are critical to achieving favourable outcomes. Whatever the type, or level, of flexor or extensor injury, the ultimate goal of both the surgeon and therapist is to protect the repair, modify peritendinous adhesions, promote optimal tendon excursion and preserve joint motion. Early tendon motion regimens are initiated at surgery or within 5 days post repair. Intra-operative information from the surgeon to the therapist is vital to the choice of splint protected position to reduce repair rupture/gap forces, and to commencement of active, or splint controlled, motion for tendon excursion. Decisions should align with the phases of healing, the clinician's observations, frequent range of motion measurements and patient input. Clinical concepts pertinent to early motion rehabilitation decisions are presented by zone of injury for both flexor and extensor tendons during the early phases of healing.

Introduction

Critical decisions by clinicians at presentation of tendon injuries determine the destiny of the delicately balanced flexor and extensor tendon systems. Inadequate intervention can result in deformity, loss of motion, joint contractures, and subsequent loss of function. Surgical correction of these complications can be technically difficult and expensive, with suboptimal outcomes. Recent advances in surgical and rehabilitation treatment of acute flexor and extensor tendon injuries, in all zones of injury, have affected these outcomes positively.[1–6] Introduction of early motion has improved tendon healing, reduced complications and enhanced final outcomes.[7–9] Careful selection of the postoperative splint and exercise regimen is as important as the repair technique.[3,10,11] To assist decision-making when early motion is used, we will discuss intra-operative information which is vital to determining safe splint position (SSP), active versus splint controlled motion (SCM), and exercise progression within the initial phases of tendon healing.

General concepts

Surgeon-therapist communication is essential to clarify details of the injury and repair, and safe motion parameters. Following repair, the injury is protected in a zone appropriate position using adequate dressing and temporary materials. Subsequent decisions regarding splint design and the appropriate amount of early motion are guided by the surgeon's assessment of the quality and type of repair and the amount of motion in the joints nearest to the repair which is deemed to be safe in respect of minimizing gapping and rupture of the repair. Other factors that influence decision-making include the individual's biological response to injury, severity of the soft tissue and bone involvement, and confidence in the integrity of the repair.

Decision-making should align with the phases of healing, viz. inflammatory (0–5 days), fibroplasia (3–21 days) and remodelling (21 days–3 months). After repair, peritendinous adhesions become an obstacle to tendon excursion in some zones, with timely motion essential to regaining normal excursion. After flexor injury, active motion is classified as "early" from 4–5 days. After extensor injury, motion started at 0–5 days is classified as "immediate" and as "early" at 5–10 days.

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0020–1383/$ – see front matter © 2013 Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.injury.2013.01.022

Flexor tendon rehabilitation

Zone I

Following repair of the flexor digitorum profundus (FDP) in zone 1, the postoperative regimen will be dictated by the type and anatomical location of the surgical repair. Open lacerations of the FDP tendon in zone I can be subdivided into three levels: (1) under the A4 pulley, (2) just distal to the A4 pulley and (3) at, or close to, the insertion.[9] Following repair or re-insertion, oedema and friction resistance to gliding will reduce tendon excursion through the A4 pulley, increasing the likelihood of adhesion formation. Exercises should focus on achieving first passive, followed by active distal interphalangeal joint (DIP) motion where possible.[12] In the presence of a vulnerable repair, the Kleinert type regimen, even with modification, is unsuitable as this mobilises the DIP joint poorly.[13] Undesirable consequences of injury and surgery at this level are tendon tethering and DIP joint flexion deformity (Table 1).

Zone II

Considerable attention has been paid to rehabilitation techniques for tendon repairs at this level.[1,6,13–15] One of the primary objectives of current rehabilitation regimens at this level is the preservation of differential tendon glide and the exercise programme should be designed to promote this (Table 1). Passive flexion must be restored before active digital flexion exercises are initiated. A passive regimen is a safer option when the repair is considered to be vulnerable.[13,16]

In an oedematous finger, where there is resistance to active motion and tendon glide, splinting the metacarpophalangeal joints (MP) in excessive flexion will bias active motion to the proximal interphalangeal joint (PIP). Confining motion to the PIP joint only will encourage cross adherence and may encourage the patient to attempt DIP joint flexion at the end of its range. Tang has demonstrated that the strength of the repair decreases as the angle of tension increases.[17]

Injuries to the pulley system will also place extra stresses on the repair and patients should, therefore, be discouraged from using maximal effort to flex the DIP joints at the end of the range of flexion.[18] Active motion should be initiated from the DIP joint and this is facilitated in most patients by positioning the wrist joint in 10°–30°extension and the MP joints in 30° of flexion (Fig. 1).

Zone III

There is little published information relating to zone III rehabilitation and therapists have been obliged to adapt the rehabilitation regimens designed for zone II injuries. Lacerations in the mid palm may include damage, or denervate, the intrinsic muscles with resultant loss of function, claw deformity and scarring. If there has been significant intrinsic muscle involvement, the MP joints should be positioned in 60°–70° of flexion and the wrist in slight extension (Table 1).

Zone IV

Tendon lacerations within the carpal tunnel are not common. Concomitant damage to the median nerve and, less commonly, the

Table 1
Flexor tendon rehabilitation regimens for each zone of injury.

Rehabilitation regimens flexor tendons zones 1–5
- Protective dorsal splint for 6 weeks
- Restore passive digital flexion prior to active motion
- Commence active motion 3–5 days post surgery
- Initiate early active motion in compliant patients if the presence of robust repair
- Promote differential glide to prevent cross adherence and preserve tendon glide
- Encourage active digital extension exercises to prevent extension deficits
- Apply prophylactic digital extension splints at night if required
- Incorporate active wrist motion at 3 weeks
- At 6 weeks commence stretching of residual fixed flexion deformity
- At 6 weeks commence night extension splinting
- Commence light functional activity at 6 weeks
- Return to normal activities at 10–12 weeks

Special considerations

Zone 1
- Splint position – wrist at 10°–30° extension and MCP joints at 30° flexion
- Emphasise active DIP joint flexion to ensure tendon glide
- Increased risk of muscle tendon unit shortening in delayed repairs of avulsion type injuries
- Increased risk of DIP joint fixed flexion deformities
- Initiate early passive extension of IP joints with all other joints in flexion and no tension on FDP
- Consider serial plaster of Paris casts to treat residual IP joint fixed flexion deformities at 6 weeks if tendon glide is assured

Zone 2
- Splint position – wrist at 10° - 30° extension and MCP joints at 30° flexion
- Perform passive digital flexion exercises until free motion achieved especially in oedematous finger
- Encourage hourly exercise – 10 repetitions of active flexion IP joints – slowly increase range of flexion over 3 weeks
- Do not initiate place and hold until full active tendon glide assured
- Increased risk of cross adherence and IP joint fixed flexion deformity
- Zone 3
- Splint position - wrist at 10° - 30° extension
- In absence of nerve injury or intrinsic damage splint MCP joints at 30° flexion
- In cases of intrinsic muscle injury or denervation splint MCP joints 60° - 70° flexion to inhibit claw deformity and maximise tendon excursion

Zones 4 and 5
- Following major nerve injury splint wrist in neutral position for 2 weeks
- Splint MCP joints at 60° - 70° flexion to inhibit the development of claw deformity and maximise tendon excursion
- At 6 weeks commence restoration of composite extension by stretching and serial splinting
- Beware intrinsic muscle tightness. Avoid prolonged splinting
- In presence of nerve injury incorporate early sensory re education techniques to preserve cortical representation

Fig. 1. The dorsal thermoplastic splint should be positioned to facilitate active motion initiated from the DIP joint to preserve maximum tendon glide.

ulnar nerve may be present, with resultant intrinsic muscle paralysis and loss of sensation. At this level, adhesions between the tendons in the restricted space under the retinaculum very quickly become established and it is imperative that the postoperative exercise regimen promotes the maximum available differential tendon glide, using an active motion regimen (Table 1).

Flexion of the wrist incurs a risk of prolapse of tendons out of the carpal canal as the transverse retinacular ligament has been divided to achieve the repair. Wrist extension may increase tension on the nerve repair and, therefore, splinting the wrist in a neutral position is generally the best compromise.

Loss of intrinsic muscle action and muscle-tendon unit shortening can result in a resting position of the digits from which joint motion and, therefore, tendon glide cannot be optimised. To facilitate tendon motion, prevent clawing and achieve a greater range of IP joint flexion the MP joints should be positioned in 60°–70° of flexion.

Zone V

Injuries at the level of the wrist and forearm may range from an isolated tendon to a complex 'spaghetti wrist' involving neurovascular structures. In cases of injury to isolated wrist tendons, the dorsal protective splint should extend to the MP joints only and the hand may be mobilised freely during light function. Where the injury is more extensive, involving finger tendons and nerve injuries, a full splint is used with the splint position dictated by both patient comfort and facilitation of active motion. Active protocols are indicated at this level, as repairs are unlikely to rupture unless the patient uses the hand.[19] Exercises which focus on differential glide should be included in the regimen as cross adherence can be a problem, although it does not appear to affect functional outcome. In the presence of nerve repairs, the wrist should be positioned in neutral or, in severe injuries, a small amount of wrist flexion may be appropriate in the early postoperative period. The MP joints will require positioning in 60°–70° of flexion to facilitate digital flexion and inhibit the development of claw deformity.

Sensory re education techniques should also be incorporated early to assist in the preservation of cortical representation, which will inevitably occur within the somatosensory cortex.[20]

Flexor pollicis longus (FPL)

There is little substantial evidence in the literature to inform therapy practice but the FPL tendon appears to have a greater tendency to rupture when active motion regimens are applied following a 2 strand core suture.[21] Recent studies appear to support the use of active motion programmes following a multi-strand core technique and no epitendinous suture.[22,23] If there is any doubt as to the ability of the repair to withstand active motion, the therapist should employ passive techniques such as the Kleinert regimen.[13] Whatever the method chosen, care must be taken to ensure that movement is initiated at the interphalangeal (IP) joint. A neutral position at the wrist will optimise both flexion and extension at this joint. Positioning the wrist in extension in the presence of a shortened tendon will impede active extension at the IP joint and place stress upon the repair.

Partial flexor tendon injuries

Partial tendon injuries are capable of withstanding the stresses of active motion and are less likely to rupture. Injuries greater than 40% of the tendon, which are repaired, will require some dorsal splint protection but this may be removed at 3–4 weeks.

Extensor tendon rehabilitation

Extensor tendon concepts

Normal tendon excursion in proximal digit zones is greater than in distal zones. The estimated amount of motion needed to retain extensor tendon excursion after repair is 5 mm in zones 5–7 and T4–5 of the thumb and 4 mm in zones F3–4.[24,25] In contrast, zones F1–3 and T1–2 have only 1–2 mm of normal tendon excursion, negating the need for motion after repair.[24–27] After repair, adhesions become obstacles to tendon excursion in some zones, with immediate to early motion essential to regain normal excursion. However, in the more distal zones, immobilisation as opposed to motion is imperative.

Communication with the surgeon regarding the specifics of the repair and safe motion parameters provide details essential to design of the SSP and SCM programs. SSP shields the repair from gapping forces, and must be established at the time of repair, or, preferably, no later than 5 days for all zones, thus laying the framework for improved final outcomes. Suture type and strength in extensor tendons are not the only answers.[3,11]

For safe mobilisation, attention to splint construction details, healing timeframes, observing and listening to what the patient describes as motion begins are vital. SCM commences during the first three postoperative weeks in all zones, with out-of-splint controlled motion exercises starting after 3 weeks for most zones. The purpose of SCM is safe tendon excursion, distally and proximally. Active motion is preferable as it produces greater tendon excursion and is more effective in preventing adhesions and preserving motion.[28] Nonetheless, risk of tendon gapping, or rupture, is greatest during the first 21 days after repair, precisely

when SCM starts. The clinician must be mindful that extensor tendon gapping equates with loss of active extension, as a result of too much flexion. Splint construction must permit flexion to offset adhesion formation without attenuating, or gapping, the tendon repair. We recommend active flexion only in SSP during the first 3–4 postoperative weeks. Passive extension combined with active hold (place and hold) to promote proximal tendon excursion and prevent joint flexion deformity is equally important.

Measuring range of motion in key joints allows the clinician to decide whether, or not, to progress the motion program on a basis of logic. Early and subtle change (10°) in loss of active extension warn of tendon attenuation and is a signal to discontinue motion progression for 1 week. After a week, we advise measuring extension to be sure there is no active lag before the motion program begins again.

Safe splint position (SSP)

Zones F1–2 and T1–2

Although involvement of zones F1–2 may appear a minor injury, outcomes are often worse than for other zones.[29] In these zones, tendon excursion is limited; tendon attenuation of 0.5 mm results in a 10° DIP extension lag and a 5 mm gap yields a 25° lag.[30] Sutures are not a remedy as the tendon is too flat to receive core sutures. One quarter of these injuries result in more than 10° extension lag.[31] Appearance and inability to actively extend the DIP joint are common patient concerns. Minimal loss of thumb IP movement may affect the dexterity needed for use of hand held devices significantly.[32] Fortunately, the distal EPL is larger and can be sutured with a core suture.

The SSP in the 0–5 days period for zone F1–2 divisions immobilizes the DIP in neutral to slight hyper-extension. The splint must not shift, fall off or change shape with normal hand use. A splint that includes the PIP meets this requirement. A splint that combines DIP extension with 20° of PIP flexion further decreases tension on the repair, relaxes the lateral bands, and controls PIP hyperextension. Immobilisation for 6–12 weeks is not uncommon for F1–2 injuries, whether repaired or not. The SSP in the 0–5 days period for zone T1–2 divisions immobilizes the IP in hyperextension, with MP motion unloading the EPL repair during motion through the intrinsic muscle insertions into the extensor apparatus.

Zones F3 and zones T3–4

A boutonnière deformity results from failure to repair, or properly position the PIP joint, after injuries in zones F3 and T3–4. In zone 3, loss of central tendon integrity results in loss of finger PIP and thumb MP extension. In the fingers, PIP joint flexion is further compounded by palmar displacement of the lateral bands, also pulling the DIP into hyperextension. In T3–4 injuries, the unopposed intrinsic thumb muscles (via their contribution to the extensor apparatus) pull the thumb into palmar adduction, MP flexion and IP hyperextension (i.e. a boutonnière deformity).

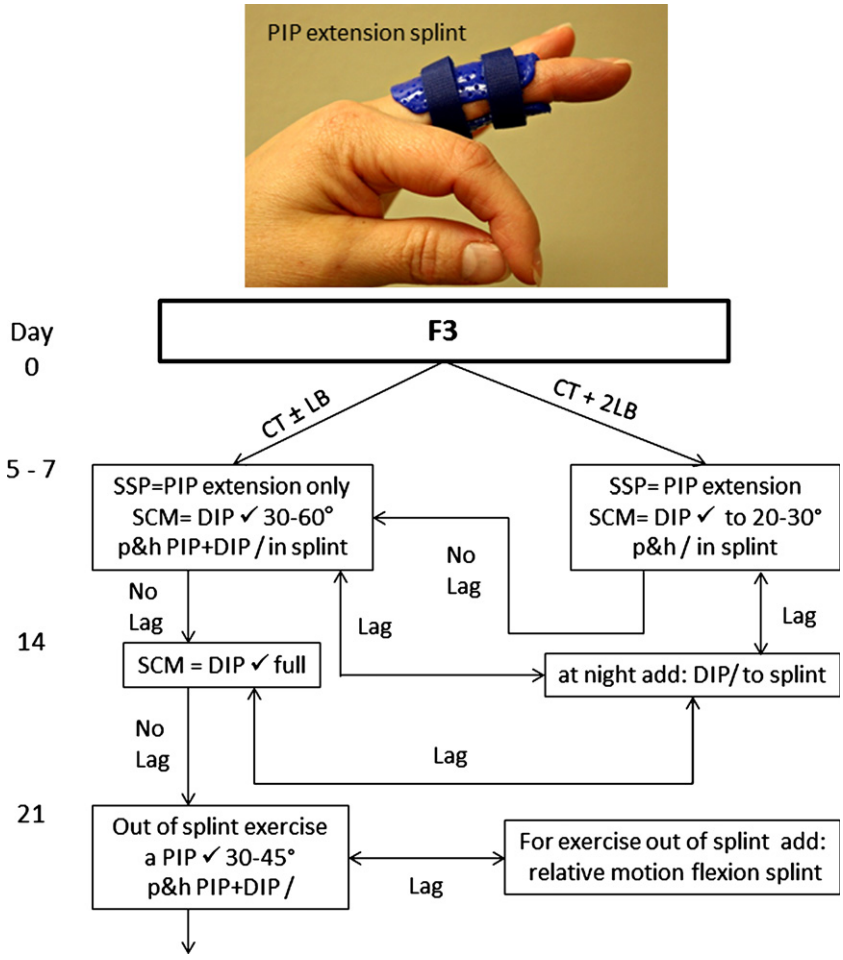

Fig. 2. Zone F3 extensor tendon decision algorithm for safe splint position and splint controlled motion progression during the first 3 postoperative weeks. SSP, safe splint position; SCM, splint controlled motion; ✓, flexion; /, extension; a, active; p&h, place and hold; CT, central tendon; LB, lateral bands.

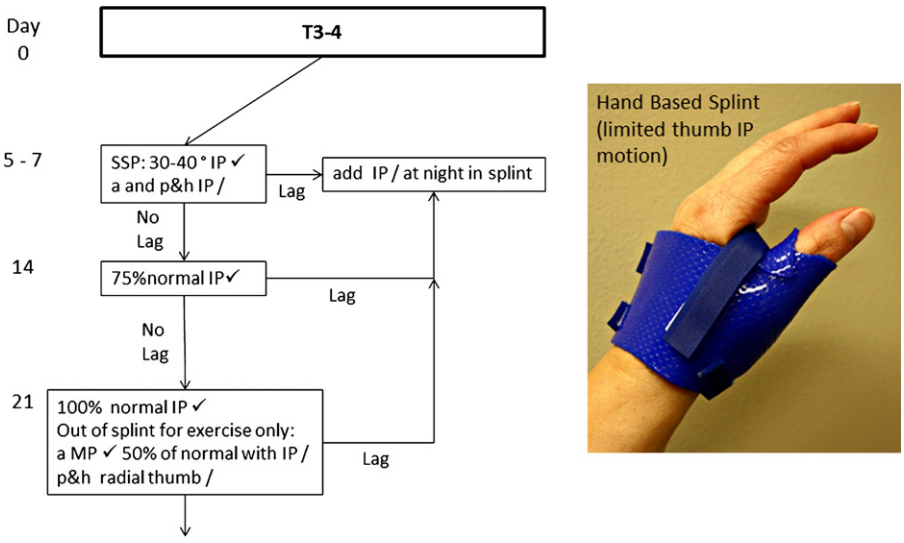

Fig. 3. Zone T3–4 extensor tendon decision algorithm for safe splint position and splint controlled motion progression during the first 3 postoperative weeks. SSP, safe splint position; SCM, splint controlled motion; ✓, flexion; /, extension; a, active; p&h, place and hold.

The SSP in the 0–5 days period for the zone F3 central tendon (CT) division, with, or without, lateral band (LB) involvement, is with the PIP and DIP immobilized in neutral extension. Splinted safely, active movement of the MP in all planes promotes safe proximal excursion of the EDC and the extensor apparatus.

The SSP in the 0–5 days period for divisions involving only the CT or CT and one LB (with an intact LB) allow 30–60° DIP flexion. DIP flexion is limited to 20–30° when CT and both LBs are involved (Fig. 2). DIP flexion permits the LBs to move at the injury site while unloading the CT. Composite PIP and DIP place and hold extensions in the splint are also initiated at this time.

The SSP in the 0–5 days period for zone T3–4 is a functionally positioned, hand-based splint with the IP limited to 30–40° flexion (Fig. 3). Within the splint, proximal excursion of the extensor apparatus is encouraged by active and place and hold IP extension/hyperextension periodically throughout the day.

Zones F4–7

Tendon excursion in zones 4–7 is the greatest, necessitating controlled motion after repair to discourage adhesions. *Immediate* SCM is important to limit excursion of the tendon repaired in zones 4–7. A simple yet effective splint that does just this is the relative motion, or immediate controlled active motion (ICAM), splint.[33,34] The finger splint called the relative motion extension yoke positions the injured digit(s) in 15–20° more MP extension/hyperextension than the adjacent digits. The yoke combined with a splint that immobilizes the wrist in 20° extension effectively shields the repair from excess tension (Fig. 4). The only situation in

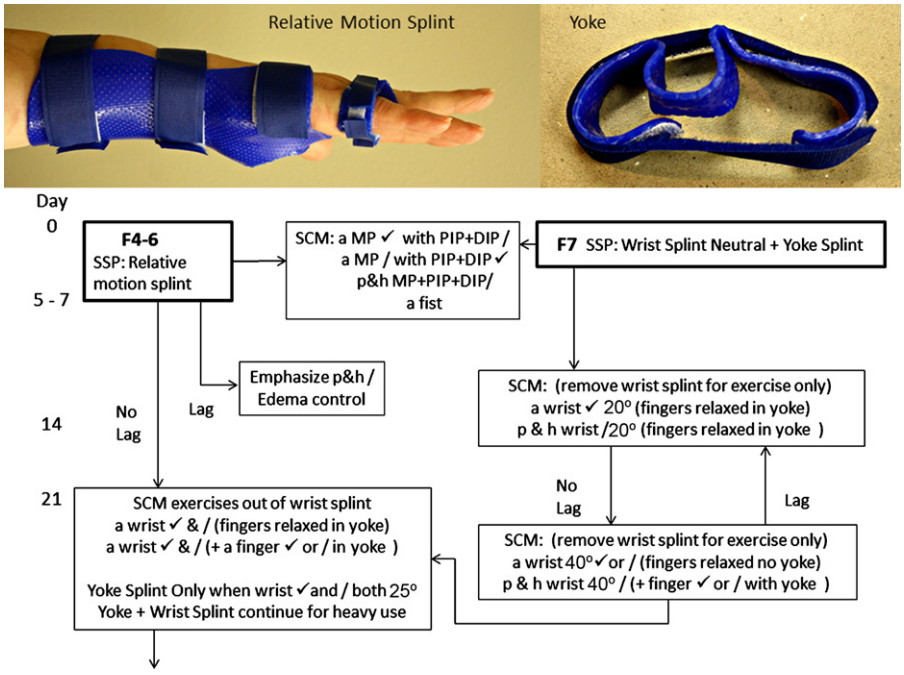

Fig. 4. Zone F4–6 and F7 extensor tendon decision algorithm for safe splint position and splint controlled motion progression during the first 3 postoperative weeks. SSP, safe splint position; SCM, splint controlled motion; ✓, flexion; /, extension; a, active; p&h, place and hold.

which this splint is unsuitable is when all of EDC, EIP, and EDM have been repaired. In these cases, an alternative splint style is required.[35–37]

Zones F7 and T5 retinaculum level

The wrist retinaculum can limit tendon excursion in all extensor compartments and it is essential that the surgeon has resected part of the retinaculum appropriate to the level of the tendon repairs to avoid this problem. Based on cadaver studies, positioning the wrist in neutral, or not more than 20° extension, eliminates bunching of the retinacular tendons with proximal excursion.[38] We recommend the relative motion extension yoke splint (Fig. 4) for zone F7 injuries with the wrist positioned in neutral, for T5 EPL injuries with the wrist neutral and the thumb column in radial extension, and for T5 and EPB/APL injuries with 20° of wrist extension and no deviation, with the thumb positioned functionally.

Decision-making SCM

We believe decisions made within the first 3 week after tendon repair have the greatest impact on final outcome. Early motion requires the clinician to be well informed, observant and to be guided by goniometric measurement. Figs. 2–4 are suggested algorithms, as examples of how this decision-making process could be used.

Conclusion

Immediate to early motion is now the standard rehabilitation program for most repaired tendon injuries. Active motion regimens are desirable after repair of the flexor tendons in all zones but are not always suitable for all extensor tendon repairs. For the latter, there are no standard protocols and the therapist must communicate directly with the surgeon and then assimilate a considerable amount of information before selecting the most appropriate treatment for each individual patient. Pursuit of optimal tendon glide must not take precedence over safety. Recent and ongoing advances in the surgery and rehabilitation of these injuries should stimulate re-evaluation of current methods.

Conflict of interest

The authors acknowledge no conflicts of interest.

Acknowledgement

Special thanks to Professor Emeritus, Susan Harris, PT, PhD (Canada) for assistance in writing this article.

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