Injuries of the Flexor Tendons: Focus on the Superficial Digital Flexor Tendon

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Of the two flexor tendons in horses’ lower limbs, the superficial digital flexor tendon is more commonly injured than the deep digital flexor tendon. Flexor tendon injuries are caused by either overstrain of the tendon or direct trauma. Overstrain injuries have a typical swelling of the tendon that requires ultrasonographic evaluation to confirm the diagnosis. Treatment of these injuries includes anti-inflammatory therapy initially followed by a rehabilitation program. New therapies are emerging for modulating healing of these injuries. Flexor tendon lacerations are usually the result of direct penetrating trauma to the limb. Management of these injuries includes surgical management combined with appropriate coaptation. Involvement of a tendon sheath complicates management with the potential formation of septic tenosynovitis. The prognosis for returning successfully to athletic function in the case of overstrain injuries is fair, but re-injury is common, and for tendon lacerations, it is guarded to poor.

KEYWORDS horse tendon, superficial digital flexor tendon, deep digital flexor tendon, bowed tendon, overstrain injury, tendon laceration

The flexor tendons of horses’ lower limbs are important weight-bearing structures at rest and during locomotion. The anatomic arrangement of tendons and joints in the lower limb provides an efficient transfer of muscular energy for rapid locomotion. Of the two flexor tendons, the superficial digital flexor tendon (SDFT) is more commonly injured than the deep digital flexor tendon (DDFT). The SDFT provides a spring-like store of energy in the galloping horse and is subject to strains close to its mechanical limits, making it susceptible to overstrain injuries. Tendon damage may occur as a result of either overstrain of the tendon or a traumatic penetrating injury.

Strain-Induced Tendon Injuries

Strain-induced tendon injuries are seen relatively commonly over a variety of different equine sporting disciplines. Most equine athletes place loads on the flexor tendons during training and competition that are close to the physiologic limit of the tendon. Thoroughbred racehorses appear to train and compete closer to this limit than other equine athletes. The incidence of flexor tendon injuries in Thoroughbred racehorses ranges from 8% to 43% in different populations, with the injuries being more prevalent in horses older than 2 years of age. In racing Thoroughbreds, SDFT forelimb injuries predominate, and a slight predilection for injury to the lead or inside leg exists.

Non-racehorse athletes also suffer from a variety of strain-related tendon injuries. SDFT injuries are commonly seen in jumpers, eventers, and polo ponies. Dressage horses, on the other hand, rarely injure their SDFT and are more likely to develop a DDFT injury either in the metatarsal region of the hind limb or in the palmar heel region of the forelimb. Since tendons are operating close to their load-bearing capacity in sport horses, there is little leeway for factors that may increase loading on the tendon. A variety of factors may contribute to an injury by increasing the peak loads on tendons during exercise, and some of these are discussed below.

Foot Balance. Poor foot balance, particularly low heels and long toes, has traditionally been suggested to increase the risk of tendon injuries. This has not been supported by biomechanical studies which suggest the possibility that this conformation is protective. Current research suggests that raising a horse’s heel will decrease the load on the DDFT, increasing fetlock joint extension and subsequently the load on SDFT and suspensory. Further studies looking at the influence of foot balance at high speed on tendon strains are required. With this contradiction in mind, attempts should be made to obtain an ideal neutral foot balance. With any sudden changes in foot balance, even in cases where it is improved, it is wise to allow a period of adaptation before maximally loading the tendon.
Track Surfaces. Tracks that are very hard result in higher speeds and increased peak impact loads. These fast tracks are therefore more likely to produce overstrain injuries of tendons. However, tracks where the surface is uneven, slippery, or shifty seem also to contribute to damaging loading patterns on tendons. Numerous factors influence the mechanical behavior of a track surface; the weather and track maintenance have a major influence. Moisture content affects all tracks’ mechanical properties, and extreme temperatures appear to affect some synthetic tracks’ mechanical characteristics dramatically. Experience over years with a particular track type will allow identification of track conditions that may predispose to tendon injuries.

Fatigue. Fatigue is influenced primarily by the horse’s work schedule, level of fitness, and intensity of competition. Fatigue should be considered as a contributor to tendon injuries. With the onset of muscle fatigue, a horse’s stride characteristics change, altering the forces on the tendons. Fatigue in any sport results in an inevitable loss of form and coordination in each stride, which is likely to result in an increase risk of injury.

Contralateral Limb Lameness. At high speed, lameness may result in excessive loading of the tendons in the contralateral limb.

Weight. Horses who are overweight or carrying excess weight will produce greater forces on their tendons compared with lower weight individuals.

Overstrain may occur as either an isolated incident or due to accumulation of repetitive strains. Isolated overstrain injuries are seen when the tendon receives a single bout of extra-physiologic load. This may be caused by excessive bouts of high-speed exercise or a single excess force on the tendon, such as when jumping an excessive height. Alternatively, tendons may be injured if they receive a knock while under heavy load, causing a sudden increase in strain locally within the loaded tendon. Occasionally peripheral tendon injuries will have an accompanying skin contusion; these are likely the result of a direct damaging blow on the loaded tendon. Isolated overload injuries are an uncommon cause of tendon overstrain in normal tendons.

Repetitive strain is the most common scenario contributing to tendon overstrain injuries. Since tendons accumulate subclinical micro-damage with age and progressive cycling, the tendon becomes weaker and less able to cope with a given load. This progresses to a point where the tendon is subjected to a level of strain which it previously could have dealt with. But due to its loss of elasticity and strength, the tendon becomes overloaded, which results in disruption of the tendon fibers and a clinical tendon injury. These injuries typically occur at or just below the mid metacarpal level in the “core” or central region of the SDFT. This area of the SDFT appears to be preferentially loaded and degenerates more with age and exercise than other areas within the tendon.

While a core lesion of the mid or distal metacarpal SDFT is the most common presentation, injuries are seen at all levels of the tendon from insertion to musculotendinous junction, affecting the core or tendons periphery. Distal tendon injuries within the digital sheath are also relatively common. The ten-
lame at all. However, in rare cases, a significant severe lameness may accompany a moderate tendonitis. There does not appear to be a good correlation between the level of pain on palpation and lameness with the severity of the lesion, except in the most severe of lesions.

Clinically apparent swelling, heat, and pain on palpation indicate the need for careful ultrasonographic evaluation. Review of a tendon at 1 to 3 weeks after injury may provide a more accurate indication of lesion severity and is particularly important when a lesion is suspected but not well defined on the initial examination.4,5,16,17

A quality ultrasound examination is essential for identification and documentation of the position and severity of the lesion. An ultrasound machine with a linear 7.5- to 10-MHz probe with a stand-off is a suitable machine for the evaluation of the majority of flexor tendon injuries. Both the clinical tendon and the contralateral clinically normal tendon should be examined, because subclinical ultrasonographic changes may be noted in the normal tendon.

Severity of the injury is determined based on the following ultrasonographic measurements assessed systematically down the limb: echogenicity of the lesion, cross-sectional area (CSA) of affected and contralateral tendon, percentage CSA occupied by the lesion, and position and length of the lesion. A scoring system using some of the above measurements has been used to categorize the severity of SDFT injuries.18 This may be useful for prognostication and ultrasonographic monitoring of healing.19

Within the confines of tendon sheaths, ultrasound may fail to demonstrate some lesions, including longitudinal tears of digital flexor tendons or tears of the manica flexoria.20,21 Tenoscopy offers both diagnostic and therapeutic options when a tendon lesion is suspected within a tendon sheath.21

While a tendon injury is suspected, the horse’s activity level should be limited to stall rest, with only limited hand walking until injury to the tendon can be ruled out ultrasonographically or tenoscopically.

Treatment

Anti-Inflammatory Therapy

The aim of early and rapid control of the inflammatory cascade is to minimize further damage to the tendon structure secondary to the inflammatory response. Non-steroidal anti-inflammatory drugs are indicated as the mainstay of anti-inflammatory therapy for tendon injuries, a 3- to 5-day course is typical. A single dose of short-acting corticosteroids may offer a more potent initial anti-inflammatory effect. Medical therapy is combined with physical anti-inflammatory therapies, including cold therapy for 5 days (20 minutes icing, 3 times daily) and pressure bandaging for approximately 3 to 4 weeks.

Therapies Aimed at Modulating More Ideal Healing

Polysulfated glycosaminoglycans (PSGAGs) have also been indicated to be beneficial during the early phase of tendon healing.22,23 Other therapies aimed at production of the most ideal healing tissue include the use of growth factors (IGF-1) or stem cells.

Rehabilitation Programs

Exercise and mobilization of the healing tendon can begin soon after injury once the inflammation is subsiding. However, if the horse is lame or the injury is severe enough that there is loss of fetlock support, then this should be delayed until it is judged that suitable healing has taken place to prevent further damage. At this stage, the horse’s foot balance should be corrected if required and carefully maintained during the rehabilitation period.

A graded exercise program is the mainstay of therapy and many have been suggested.19,24,25 The program should be flexible and adjusted based on the severity of the injury and monitored by regular clinical and ultrasonographic assessment of the tendon. Typically, walking commences once the inflammatory phase has subsided after the first week, with gradually increasing duration. Trotting is introduced after 12 weeks and cantering after approximately 32 weeks. Race training is not usually resumed until approximately 48 weeks, with many horses requiring longer. Typically, the total time required before re-introduction to race training is 8 to 12 months; a worse prognosis is documented for horses rested for less than 6 months.5,17,25 Controlled exercise rehabilitation programs appear to dramatically improve the numbers of horses returning to competition compared with pasture turnout alone.19

Prognosis

The prognosis for SDFT injuries in the Thoroughbred is reported to range from 20% to 60% of horses returning to successful racing and up to 80% sustaining a re-injury.5,26-28 Standardbred racehorses and sport horses have a better prognosis for successful return to competition than Thoroughbred racehorses. Ultimately, the severity of the damage will have a major influence on the outcome. A significant number of horses with re-injuries occur in the opposite unaffected limb.

Although not recommended due to safety concerns, racing or competition can continue with mildly damaged tendons, but progressive damage to the tendon will occur, worsening the long-term prognosis. Standardbred racehorses are more likely to successfully compete and for a longer duration with an acute tendon injury than Thoroughbred racehorses.

Bandage Bows

Peritendinous inflammation “bandage bow” may sometimes clinically resemble a tendonitis. The inflammation is usually associated with trauma to the limb caused by blunt force or uneven excessive pressure applied by a bandage. Clinically, there is apparent tendon swelling, typically with less intense pain on palpation when compared with tendonitis cases. There is no damage to the tendon itself; however, the subcutaneous and peritendinous tissues become inflamed and swollen. Palpation of the tendon margins is difficult due to the subcutaneous and peritendinous swelling. Ultrasound confirmation of the diagnosis is often required to rule out tendonitis. Treatment consists of aggressive anti-inflammatory therapy and cessation of pace work until all inflammation has resolved. Slow resolution of inflammation or residual thickening should prompt a follow-up ultrasonographic examination.
Tendon Lacerations

Tendon lacerations occur most commonly as a consequence of paddock accidents, transport injuries, or during competition caused by other horses or self-inflicted. The impact forces involved in tendon lacerations that occur during racing or competition are particularly high. Relatively blunt horseshoes can cause disruption of whole tendons with accompanying severe skin and soft tissue injuries. The severity of tissue damage is often not apparent for a couple of days due to vascular damage and deep bruising. These injuries are also usually heavily contaminated with sand and dirt.

Assessment

Assessment of distal limb wounds that may involve tendons commences with observation of the horse while weight-bearing on the affected limb and at the walk. Horses are typically mild to moderately lame at the walk with acute tendon lacerations. Evaluation of fetlock angle while weight-bearing and at the walk provides information regarding compromise of its major support structures, the SDFT and the suspensory apparatus. Damage to either of these structures results in dropping of the fetlock (hyperextension of the metacarpophalangeal joint). With complete laceration of the SDFT, there is significant dropping of the fetlock (Fig. 2). The DDFT, on the other hand, offers limited fetlock support but maintains the foot in its position while weight-bearing. A complete loss of DDFT support results in the toe becoming raised off the ground while weight-bearing (hyperextension of the distal interphalangeal joint). In the case where the fetlock is dropped and the toe is elevated, then both SDFT and DDFT have been lacerated.

A thorough knowledge of the anatomy of the distal limb is essential to identify structures that may be involved in a given wound. Thorough exploration of the wound with a gloved finger is essential with the limb weight-bearing and non-weight-bearing, to assess both tendon damage and other structures involved. Palpation of both lacerated ends of a tendon may not always be possible due to retraction of tendon ends and the fact that the skin wound may not correspond with the tendon laceration when at rest or non-weight-bearing.

If it is suspected that there is significant compromise to a tendon, either a complete laceration or more than 50% lacerated, an obviously dropped fetlock, or an elevated toe, then the horse’s limb should be immobilized for transport to minimize any further damage. Ongoing loss of tendon support due to vascular injury, progressive infection, or inadequate coaptation can occur. This may result in progressive damage to the remaining tendon tissue and subsequent tendon rupture up to 2 weeks post injury.

If the wound is over a synovial structure, most commonly the digital palmar/plantar sheath, then it should be appropriately assessed for any communication with the wound. Potential trauma to bones near the injury site should also be assessed radiographically. Sesamoid and splint bones are occasionally damaged with tendon lacerations. Bone phase scintigraphy may be of assistance after the first week if bone involvement is suspected but radiographic evidence is lacking. This is particularly useful in cases of septic osteitis of a sesamoid bone. With some severe injuries, blood supply to the distal limb may be compromised. Doppler ultrasonography or vascular phase scintigraphy 48 hours post injury may be useful to determine viability of the distal limb.

Wound Management and Debridement

Wound management will depend primarily on the location of the tendon injury and most importantly whether the laceration involves the sheathed section of a tendon. The duration of the injury and its level of contamination or the presence of infection will determine initial management aimed at avoiding or resolving infection.

Non-Sheathed Flexor Tendon Lacerations

Non-sheathed flexor tendon lacerations heal predominately by an intrinsic healing process. The epitenon and endotenon provide the majority of progenitor cells for scar formation and healing of the tendon defect. With this in mind, the aim of tendon laceration repair in this region should be to realign and reduce the gap between the lacerated tendon ends and preserve their blood supply for the intrinsic healing process. Careful anatomic reconstruction of the surrounding tissues, particularly the paratenon, will minimize adhesion formation and preserve tendon gliding function.

Wounds that are relatively clean caused by sharp objects and of short duration (typically less than 6 hours old) are suitable for immediate primary repair. Whereas wounds that are contaminated, caused by blunt objects, or infected are better candidates for delayed primary closure.

Tendons suitable for primary repair should be debrided of all contaminated or avascular tissue. The skin, subcutaneous tissues, lacerated tendon, and paratenon all usually require some debridement. Limited debridement is preferred if a primary closure is to be achieved. Assessing the vascularity of the tendon ends is difficult in acute wounds since tendons are relatively avascular structures and active hemorrhage is not

**Figure 2** Complete laceration of the SDFT results in moderate dropping of the fetlock joint (metacarpophalangeal joint hyperextension).
particularly obvious during debridement. With that in mind, all frayed and discolored tendon is likely avascular and should be debrided along with nonviable or heavily contaminated subcutaneous tissues.

Delayed repairs can usually be performed any time the wound has reached a suitable clean contaminated status. Ideally the tendon is repaired within a week of injury. In the meantime, the wound may be wet to dry bandaged once or twice daily using sterile technique and bandages while the horse is treated with broad spectrum antibiotics. The advantages of a delayed repair include accurate assessment of the vascularity of damaged tendon and skin. Retraction of the lacerated tendon ends and skin edges is a disadvantage that can make primary closure and gap minimization difficult in delayed repairs.

Tenorraphy should be considered for all non-sheathed flexor tendon lacerations which involve a significant amount of the tendon approximately 50% or greater. However, any tendon laceration that could be better aligned with a tenorraphy apposing its lacerated ends would benefit. The three-loop pulley and the compound locking loop are the two most popular suture patterns.31 The three-loop pulley is easier to apply, results in less suture material in the wound, and seems to align the tendon ends with less crimping than the locking loop. The preferred suture material is a monofilament absorbable suture (Maxon-polyglyconate or PDS-polydioxanone) which maintains adequate strength over the initial 4 weeks of healing. The distal limb typically requires being held in mild flexion while the tendon is being sutured; it will then be cast in a similar position. If the tendon ends are debrided or there is loss of a portion of the tendon, then it is not unusual to have a gap at the tenorraphy site with the sutures providing alignment and preventing further gapping. Bioabsorbable matrices and autologous extensor tendon grafts are currently being investigated, which may be useful in these situations where a gap is left.32

When a tenorraphy is performed, it is advantageous for both blood supply and gliding function to close the paratenon over the repaired tendon. It can be difficult to identify and close in acute cases; it is often more easily identified and utilized in delayed repairs. The subcutaneous tissues and skin are then closed, and typically a small longitudinal stab incision needs to be placed through the skin distal to the repair to assist drainage (Fig. 3). The stab is usually sufficient without the need for a drain. A cast is the most ideal form of coaptation for tendon lacerations after primary repair.

Sheathed Flexor Tendon Lacerations

Sheathed flexor tendon lacerations heal by a predominately extrinsic process where the progenitor cells for scar formation are derived from the tendon sheath’s synovial lining. This creates complications with the formation of restrictive

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Figure 3 A partial SDFT laceration, with approximately 50% of the tendon affected. (A) Day of presentation 24 hours after injury showing a moderately contaminated wound. The wound was wet to dry bandaged for 4 days and the horse placed on antibiotics. (B) The wound on day 5 ready for a delayed primary closure. (C) A three-loop pulley tenorraphy was performed and the paratenon has been closed over the tenorraphy site. (D) This was followed by primary closure of the remaining subcutaneous tissues and skin. A small stab incision has been placed distal to the closure to provide drainage. (Color version of figure is available online.)
adhesions between structures within the sheath occurring in the majority of cases.

Most severe lacerations within sheaths heal as one large scar resulting in tendons adhered to the sheath wall, each other, and in some cases complete ablation of the sheath itself. This can result in significant ongoing lameness and in many cases complete loss of the gliding function of the tendons within the sheath. Cases with severe discomfort may require a fetlock arthrodesis to become paddock sound.

The major complicating factor with sheathed lacerations is the development of septic tenosynovitis. If the sheath is likely infected, bacterial culture and sensitivity samples should be submitted to determine appropriate antimicrobial therapy. Ideally these cases are dealt with by debridement under general anesthesia as soon after injury as possible with the aid of tenoscopy. This allows removal of foreign material from the sheath, debridement of the injured structures within the sheath, and copious lavage to reduce the bacterial load.

Septic tenosynovitis is managed with antibiotics, lavage, and drainage. Appropriate antibiotic parenteral therapy may be augmented by intravenous limb perfusion and intrasynovial delivery. Adequate lavage and drainage is required and can be provided by a variety of methods, including tenoscopy, combined with daily lavage or indwelling lavage and drainage systems.

This creates major problems regarding management of the wound and sheath combined with coaptation. The majority of unsuccessful cases seem to be due to the development of support limb laminitis. Case management is on an individual basis determined by the severity of the injury, the need for coaptation, level of comfort, and the presence of infection. Typically splints such as the Kimzey splint are useful initially, and casts only become indicated once the risk of infection is minimal. Currently, tenorraphy within tendon sheaths is not recommended with failure of the technique to achieve healing even under ideal conditions.

Coaptation

Many forms of coaptation are available for management of tendon lacerations. The appropriate choice depends on the level of support and mobility required and the need to access the wound. Tendon lacerations affecting greater than 50% of the tendon warrant coaptation in the form of cast or splint. Lacerations that are smaller with an accompanying wound benefit from the immobility to assist healing of the skin and minimizing the size of the scar. Complete tendon lacerations should be cast for a minimum of 6 to 8 weeks and provided decreasing coaptation after this period up to 12 weeks. At 6 weeks, the breaking strength of the tendon approximates the horse’s body weight. At this stage, they are likely suitable to come out of a cast and be managed with a less supportive form of coaptation, such as a modified fetlock support shoe.

Casts

A well-applied cast offers the most ideal form of overall immobilization for repaired or healing flexor tendon lacerations. For forelimbs, generally a distal limb cast is sufficient unless the injury is extremely high in the proximal third of the tendon, in which case a full-limb cast would be more beneficial from both a mechanical and wound position standpoint. Hindlimb flexor tendon lacerations are, in theory, best managed with a full limb cast to immobilize the reciprocal apparatus, since the action of flexing the tarsus results in increased strains on the SDFT. However, tendon lacerations occurring in the distal two-thirds of the metatarsus in hindlimbs can be managed adequately with only a distal limb cast.

When placing casts in cases with a loss of fetlock support, the limb is ideally placed such that weight-bearing occurs down the boney column (with the dorsal cortices of the bones in the lower limb aligned and the fetlock in a degree of flexion) (Fig. 4). The limb is then not relying on the damaged tendon ligament structures down the palmar/plantar surface of the limb for support, reducing the strain on the healing SDFT. If a limb with loss of fetlock support is placed in a cast in a normal weight-bearing position, the fetlock will subside into the cast and a large pressure sore will develop rapidly on the palmar distal aspect of the fetlock (Fig. 5).

Slightly more fetlock flexion is required for a hindlimb distal limb cast to minimize the pull of the reciprocal apparatus on the SDFT. In this position, the contralateral limb will require an elevated shoe to attempt to even limb lengths; alternatively, the horse can be placed in a sand stall.

Splints

The most commonly applied commercial splint is the forelimb model Kimzey leg saver splint (Kimzey Metal Products, Woodland, CA). It is designed as an emergency device to be applied to limbs with loss of palmar/plantar support. It is excellent for initial management of tendon lacerations, particularly for transport to a referral facility. The ability to gain easy access to the limb makes it useful for managing horses with tendon sheath injuries and wounds destined for delayed primary closure and requiring regular wound access.

The forelimb model splint can be modified to best fit either forelimbs or hindlimbs by bending the upright section at the level of the distal interphalangeal joint or the fetlock joint for the desired fit (http://www.kimzeymetalproducts.com). Placing
the horse in a sand stall or alternately welding a flat base plate on the splint will provide a more stable platform for weight-bearing (Figs. 6 and 7). Maintaining a horse in a Kimzey splint becomes progressively difficult beyond the first week with the development of pressure sores, particularly of the heels, palmar fetlock, and dorsal proximal cannon. Careful bandaging and the use of orthopedic felt at these predisposed sites can extend its useful duration. Managing a horse longer than 3 weeks comfortably in the splint is extremely difficult, and the subsequent splint rubs can then make casting the limb extremely difficult.

Other forms of more basic splints have been described, including dorsal and plantar splints, but they are useful for emergency transport only and are of limited use for long-term management. Board splints and other modifications, such as the Hitchcock splint, have been described for

both emergency and long-term management for loss of fetlock support due to traumatic disruption of the suspensory apparatus. These devices can also be utilized in management of tendon lacerations. However, horses are rarely fully weight-bearing in these types of splints and run an increased risk of support limb laminitis.
Support Shoes and Modified Shoe Splint Combinations

Fetlock support shoes, such as the Roberts shoe, are an option for providing fetlock support for SDFT injuries that can suitably bear some weight but are at risk of damage if not coapted (Fig. 8). They are typically used once the level of healing is adequate to take strains consistent with the horse’s body weight. The author uses a combination of an extended heel shoe combined with a palmar splint attached to the shoe, offering fetlock support in cases which don’t need complete immobilization but require more support than a heavy bandage alone. It is a modification of the fetlock support shoe with some additional support provided up the palmar surface of the limb (Fig. 9). This form of shoe splint combination works well for both SDFT injuries offering some fetlock support and for DDFT injuries offering the extended heel shoe. Extended heel shoes alone offer limited support to the SDFT but offer excellent support for the DDFT. The heel extension must be very generous to have maximal effect, ideally as far as the palmar/plantar fetlock. This shoe splint set up is able to be maintained for a prolonged period of time if required with minimal complications.

Prognosis

The prognosis for survival with flexor tendon lacerations is good with 1 retrospective review of 50 cases of digital flexor tendon lacerations having 78% survival at 1 year, with similar survival rates for partial lacerations or complete lacerations of 1 or both tendons. The same study found the prognosis for return to athletic endeavor to be fair; a retrospective review of 50 cases reported a return to function of 54%. Although not supported by studies, the prognosis for athletic return is assumed to be more favorable for partial lacerations of tendons compared with full lacerations, and hindlimbs carry a better prognosis than forelimbs. Involvement of a tendon sheath with a tendon laceration impacts negatively on the prognosis due to the potential for sepsis of the digital flexor tendon sheath affecting both survival and return to function. Early treatment is advised with an improved prognosis when tenoscopic lavage, debridement, and repair are performed within 36 hours of injury.

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