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**Case Report**

# Proximal extensor mechanism reconstruction: modern principles in zone IX injuries: a case report

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## ABSTRACT

Zone IX extensor tendon injuries of the forearm are uncommon but complex lesions involving the musculotendinous unit and, frequently, the posterior interosseous nerve, resulting in significant functional impairment despite limited external injury. We present the case of a 27-year-old woman with a sharp laceration to the proximal dorsal forearm causing complete loss of active extension of the second through fifth digits. Surgical exploration confirmed complete transection of the extensor digitorum communis tendons with proximal retraction, which were repaired primarily using U-shaped 3-0 absorbable Vicryl sutures, followed by postoperative immobilization in a functional extension position. A narrative review of the current literature addressing epidemiology, anatomy, imaging, surgical management, suture biomechanics, and rehabilitation of zone IX extensor injuries was also performed. This case highlights that successful management requires comprehensive anatomical assessment, evaluation of posterior interosseous nerve integrity, stable primary repair with appropriate tension, and structured rehabilitation. It also emphasizes the limited evidence available for these injuries and the need for further research on zone-specific epidemiology, rehabilitation protocols, and biological augmentation strategies to optimize functional outcomes.

**Keywords:** Extensor tendon injury, Zone IX, Proximal forearm, Extensor digitorum communis, Tendon repair, Posterior interosseous nerve, Hand surgery

## INTRODUCTION

Extensor mechanism injuries of the hand and forearm are a frequent reason for evaluation in emergency departments and reconstructive surgery services, primarily due to their superficial anatomical location. Unlike the flexor system, the extensor tendons are positioned subcutaneously along the dorsum of the hand and forearm, making them particularly vulnerable to direct trauma, especially lacerations caused by sharp objects. This anatomical condition, combined with limited soft-tissue coverage, predisposes not only to tendon injury but also to frequent associated skin damage and immediate functional impairment, clinically manifested by loss of active finger extension.[1,2]

The diagnosis of these injuries is predominantly clinical and relies on a focused physical examination aimed at identifying functional discontinuity of the extensor mechanism. Evaluation includes wound inspection, assessment of active range of motion, and identification of specific deficits according to the tendon involved. However, in complex cases or when diagnostic uncertainty exists, imaging studies such as musculoskeletal ultrasound and magnetic resonance imaging may serve as useful adjuncts to determine the extent of injury, tendon-end retraction, and possible involvement of adjacent structures.

The zone-based classification of extensor tendon injuries, described by Verdan, represents a key element in therapeutic decision-making, as it correlates anatomical location with injury pattern and functional prognosis. In this context, injuries located in zone VIII, corresponding to the distal forearm, are characterized by involvement of the musculotendinous junction, which entails specific considerations regarding surgical management and recovery potential. Unlike more distal zones, where pure tendon injuries predominate, this region frequently presents with associated muscle involvement, potentially increasing the complexity of repair and influencing functional outcomes.[3]

The goal of treatment in extensor mechanism injuries is to restore anatomical and functional tendon continuity while preserving the balance of forces required for adequate digital extension and preventing adhesion formation that may restrict mobility. In most cases, this is achieved through primary surgical repair followed by a structured early rehabilitation protocol that promotes tendon healing and minimizes complications. The combination of appropriate surgical technique and optimal postoperative management is essential to achieve satisfactory functional outcomes.[5]

## CASE REPORT

A 27-year-old female patient with no relevant past medical history presented with trauma resulting from a direct assault by third parties using a sharp object, located on the posterior surface of the right forearm at the proximal third.

She attended the emergency department for initial evaluation. On focused physical examination, an incised-contused wound was identified on the dorsal aspect of the forearm, with functional impairment characterized by inability to actively extend the second through fifth digits, suggesting injury to the tendinous structures of the extensor compartment.

She was evaluated by the plastic and reconstructive surgery service, where a functional deficit compatible with extensor tendon injury was confirmed; therefore, urgent surgical management was indicated.

The procedure was performed in the operating room under standard monitoring, after obtaining informed consent. With the patient in the supine position and the affected upper limb placed on an auxiliary hand table, an anesthetic block was administered at the level of the elbow using lidocaine infiltration, achieving adequate regional analgesia. The extremity was then prepared and draped in sterile fashion using an iodine-based solution. An Esmarch bandage was applied to the proximal arm.

Surgical exploration was initiated by extending the pre-existing wound on the dorsal aspect of the proximal third of the forearm, followed by careful layered dissection. The subcutaneous tissue showed mild contusive injury and a localized hematoma. Deep exploration revealed complete lacerations of the extensor digitorum communis tendons corresponding to the second, third, fourth, and fifth digits, with proximal retraction of the tendon ends. No major vascular injury or macroscopic nerve involvement was identified within the surgical field.

Debridement of the tendon edges was performed until viable tissue was obtained, followed by identification and release of the retracted ends. Primary tenorrhaphy was then carried out using U-shaped sutures with 3-0 absorbable Vicryl, achieving adequate coaptation of the tendon ends and restoration of tendon continuity while maintaining physiological tension. The stability of the repair was verified through passive mobilization of the fingers, demonstrating adequate transmission of extensor force without evidence of suture gapping.

Meticulous hemostasis was performed, followed by copious irrigation with saline solution. Layered closure was carried out, with skin approximation using simple interrupted 3-0 nylon sutures. The tourniquet was then released, confirming adequate distal perfusion and absence of active bleeding. Finally, a sterile dressing and splint were applied, positioning the wrist and fingers in a functional position with slight extension.

The surgical findings included an incised-contused wound on the dorsal aspect of the right forearm at the proximal third, with complete transection of the extensor digitorum communis tendons corresponding to the second through fifth digits, associated with proximal retraction of the tendon ends. No major vascular injury or macroscopic nerve involvement was identified. The surrounding tissue showed mild contusive damage and a localized hematoma (Figures 1 and 2).

The postoperative diagnosis was traumatic transection of the extensor tendons —extensor digitorum communis— of the right forearm, which was surgically repaired. The patient had an adequate postoperative course and was discharged home (Figure 3).

Intraoperative findings confirmed complete transection of the extensor digitorum communis tendons corresponding to digits two through five, with proximal retraction of tendon ends, mild contusive damage to surrounding tissue, and a localized hematoma. No macroscopic vascular or neural injury was identified. Primary tenorrhaphy achieved adequate coaptation and restoration of tendon continuity, verified by passive digital mobilization intraoperatively. The patient had an uneventful postoperative course and was discharged without complications. Literature review demonstrated that zone IX injuries carry a higher risk of combined musculotendinous and posterior interosseous nerve involvement than more distal zones, requiring surgical management as a regional reconstructive procedure rather than isolated tendon repair.[6]

**Figure 1: Preoperative image showing the sharp laceration in extensor zone IX.**

**Figure 2: Intraoperative image showing repair of the extensor digitorum communis muscle.**

**Figure 3: Postoperative image of the anterior surface of the forearm.**

## DISCUSSION

In this discussion, the classic nine-zone convention for extensor tendon injuries is adopted: zone VIII corresponds to the distal forearm, proximal to the extensor retinaculum, whereas zone IX includes the remaining, more proximal portion of the forearm. This convention remains the most widely used in clinical practice, although recent literature has highlighted historical inconsistencies and proposed simplified classifications to improve the correlation between anatomy, surgical technique, and rehabilitation.[7] Clinically, zone IX is particularly relevant because it combines injuries involving the muscle belly, the myotendinous junction, the extrinsic tendons, and, frequently, branches of the posterior interosseous nerve. Therefore, it should not be understood as a “simple” tendon laceration, but rather as a composite injury of the proximal dorsal forearm.

The exact epidemiological burden of zone IX injuries remains uncertain. The best available population-based data on traumatic tendon injuries of the hand and wrist report an approximate incidence of 33.2 per 100,000 person-years, with male predominance, a peak incidence between 20 and 29 years of age, and a higher frequency of extensor than flexor tendon injuries. In series of open extensor tendon injuries, sharp laceration is the dominant mechanism. However, registries rarely stratify injuries specifically by zone IX, requiring extrapolation from hand, wrist, and forearm series. In Mexico, this limitation is even greater: there is no national registry specifically addressing hand injuries or subsequent disability related to extensor tendon trauma. The best published data come from a referral center, where hand and wrist injuries accounted for 8.9% of all emergency department visits in 2015. Among 2,184 hand and wrist injuries treated over one year, fractures were the most frequent, followed by contusions and sprains; extensor tendon injuries accounted for 40 cases (1.83%). The same article emphasized that Mexico lacks a national registry of hand injuries and subsequent disability; therefore, national figures specifically addressing zone IX are unavailable and should be interpreted as an information gap rather than an absence of disease.[8]

From a diagnostic standpoint, clinical examination remains the initial cornerstone: a dorsal forearm wound, deficit in wrist, finger, or thumb extension, and systematic neurovascular assessment. High-resolution ultrasonography has gained an increasingly central role in acute injuries and, in experienced hands, can delineate tendon continuity, retraction, and associated lesions.[9] In delayed presentations, it has even shown superior performance to magnetic resonance imaging for extensor tendon injuries in some series. Treatment depends on the completeness of the lesion, tissue quality, presence of neurological injury, and substance loss. Complete zone IX lacerations usually require primary repair with debridement, individual identification of tendons and nerve branches, precise tension adjustment, and protected rehabilitation. The innovations with the greatest current translational potential include WALANT surgery for dynamic tension adjustment, protected early mobilization protocols, and—with still emerging evidence—anti-adhesion barriers and reinforcing biomaterials.

The modern zoning system for tendon injuries of the hand and forearm was consolidated through the work of Claude Verdan and the 1983 report of the International Committee on Tendon Injuries chaired by Kleinert. In the classic scheme, extensor injuries of the digits, hand, and wrist were initially described according to sequential anatomical zones; a ninth zone was later added to include the proximal forearm. Since then, the Verdan–Kleinert classification has remained the common language for therapeutic decision-making, comparison of clinical series, and surgical education.[10]

For the purposes of the present discussion, zone IX is understood as the proximal portion of the forearm, located proximal to zone VIII, the latter corresponding to the distal forearm immediately proximal to the extensor retinaculum. The importance of this distinction is not merely semantic: zone VIII is more commonly associated with musculotendinous and distal muscle-belly injuries, whereas zone IX carries an increased likelihood of combined injury to branches of the posterior interosseous nerve, thereby modifying prognosis, intraoperative exploration, and rehabilitation. Fischer and Tang specifically emphasized that injuries in zones VIII–IX are “not merely tendon injuries,” given the close anatomical relationship among the musculotendinous junction, muscle bellies, and motor nerve branches.[11]

The classic classification, however, has recently been subject to revision. Tang has noted that the historical system combines anatomical segments with heterogeneous therapeutic problems and has proposed, first, a clarification of the extensor mechanism zones and, subsequently, a simplified five-zone classification that better groups treatment and rehabilitation principles.[12] These proposals have not replaced the classic system, but they are relevant because they reflect an emerging consensus: proximal forearm injuries should be analyzed as an anatomical-functional continuum rather than as a simple proximal extension of digital tendon injuries.

The dorsal aspect of the forearm is anatomically complex. The ultrasonographic review by Mohana-Borges and Souza emphasizes that the forearm contains 20 muscles and a dense network of nerves and vessels, which is why a clear understanding of fascial compartments is essential for both diagnosis and surgical safety.[13] On the surface, the dominant proximal landmark is the lateral epicondyle, the subcutaneous border of the ulna serves as a constant medial reference, and the radial axis, distal anatomical snuffbox, and extensor retinaculum define the transition between zones VIII and VII.[14] Through inspection and palpation, a lateral column or “mobile wad,” a central dorsal extensor mass, and an ulnar column represented primarily by the extensor carpi ulnaris can be recognized.

From a functional anatomical perspective, the posterior compartment may be described as comprising a lateral column, a superficial dorsal group, and a deep dorsal group. The lateral column includes the brachioradialis, extensor carpi radialis longus, and extensor carpi radialis brevis. The superficial dorsal layer includes the extensor digitorum communis, extensor digiti minimi, extensor carpi ulnaris, and anconeus. The deep layer comprises the supinator, abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, and extensor indicis proprius. In zone IX injuries, this organization is clinically important because the laceration may not follow a strictly “linear” trajectory: an apparently single wound may injure superficial tendons, deep motor branches, and retracted muscle bellies in a staggered pattern.

Innervation is equally decisive. Recent anatomical studies show that the radial nerve gives branches to the brachioradialis and extensor carpi radialis longus before bifurcation; innervation of the extensor carpi radialis brevis is variable and may arise from the radial nerve, its deep branch, or the posterior interosseous nerve.[15] After passing through the supinator, the posterior interosseous nerve supplies most of the extensor compartment and, in most studied limbs, is organized into two major pathways for superficial and deep muscles. Therefore, a zone IX injury may mimic a pure motor neuropathy, while posterior interosseous nerve palsy may simulate an isolated tendon laceration; both entities must be actively considered.[16]

The diagnosis of proximal forearm extensor injury is, first and foremost, clinical. A history of penetrating or sharp trauma to the dorsal aspect of the forearm should raise suspicion for combined tendon, muscle, and nerve injury. Examination should individually assess wrist, metacarpophalangeal, thumb, and index finger extension, evaluate strength against resistance, and identify subtle asymmetries. Preserved passive extension with loss of active extension supports injury to the extensor mechanism, whereas more diffuse weakness without palpable discontinuity should prompt exclusion of posterior interosseous nerve injury. In addition, associated injuries to the skin, bone, and joints are frequent; therefore, evaluation cannot be limited to the tendon alone.

Plain radiography remains useful for identifying radiopaque foreign bodies, fractures, or associated avulsion injuries. However, the greatest recent diagnostic gain has been observed with high-resolution ultrasonography. In a series of late-presenting tendon injuries, ultrasonography achieved 84% sensitivity and accuracy for extensor injuries, compared with 44% sensitivity and 47% accuracy for magnetic resonance imaging, respectively. In acute forearm lacerations, a 2025 prospective study reported that high-resolution ultrasonography was a rapid and highly sensitive/specific tool for planning surgical exploration, reinforcing its value in assessing tendon continuity, retraction, and associated neurovascular injuries. Nevertheless, diagnostic performance depends on operator expertise, timing of injury, and technical quality of the study.[17]

Magnetic resonance imaging (MRI) retains a role in complex or chronic injuries, in the assessment of scar tissue, or when diagnostic uncertainty persists after clinical examination and ultrasonography.[18] Its main advantage is panoramic visualization of deep soft tissues; its disadvantages in acute trauma include lower accessibility, higher cost, and, in some series, inferior performance compared with ultrasonography for extensor tendon injuries. In zone IX, where the question is not always simply "Is the tendon ruptured?" but also "Which motor branches and how much muscle are involved?", the most reasonable strategy is a clinical–ultrasonographic sequence, reserving MRI for selected cases.

Nonoperative treatment has a limited role in zone IX injuries and is generally restricted to selected partial lacerations without significant extensor lag, provided that clinical examination is reliable, appropriate splinting is available, and close follow-up can be ensured. Even in this setting, the evidence remains weak. The systematic review by Dickson and colleagues concluded that there is scarce and low-quality evidence supporting the management of partial extensor tendon lacerations of the hand and forearm, while the subsequent national practice survey demonstrated substantial variation among surgeons, reflecting a genuine state of clinical uncertainty.[19] Complete lacerations, in contrast, continue to be managed predominantly with surgery.

In zone IX, primary repair should be approached as a regional reconstructive procedure rather than as the isolated closure of a single tendon. High-yield principles include careful irrigation and debridement; extension of the wound to fully expose the injury tract; individual identification of muscle bellies, musculotendinous junctions, and posterior interosseous nerve branches; preferential repair of thumb and wrist extensors when they serve as tension references; and sequential reconstruction of the remaining tendons. Reviews addressing zones VIII–IX often recommend multiple figure-of-eight sutures for the muscle belly and musculotendinous junction, whereas tendon segments with sufficient caliber may be repaired using techniques such as modified Kessler or modified Bunnell, with or without an additional peripheral suture depending on tissue quality and tendon thickness. When nerve transection is present, primary neurorrhaphy or nerve reconstruction should be performed during the same surgical procedure whenever local conditions allow.[20]

Repair tension is particularly critical. A repair that is too loose will result in extensor lag, whereas an overly tight repair will lead to loss of flexion, increased friction, and adhesion formation. In proximal forearm injuries, where muscle tissue is friable and tendon excursion depends on intact musculotendinous units, tension adjustment should be performed with the wrist and fingers in a protective functional position, comparing the digital cascade and residual excursion.[21] Traditionally, after repair, static splinting has been recommended with the wrist positioned at approximately 45° of extension and the metacarpophalangeal joints at 15–20° for 4–5 weeks. Today, however, the general trend favors protected early mobilization when repair strength and tissue quality allow it. In zone IX, this decision must be individualized more carefully than in mid-hand zones because of the involvement of muscle and nerve structures.[22]

Among the innovations with the most immediate clinical applicability are WALANT surgery and protected early mobilization protocols. In a recent outpatient series, extensor tendon repair under WALANT was safe and effective, with a low complication rate and favorable functional outcomes. In addition, real-time intraoperative adjustment facilitates correction of repair tension and detection of gapping or entrapment. In zone VII extensor reconstruction under WALANT, intraoperative measurement of total excursion has even been used to decide between bridge grafting and side-to-side tendon transfer. Although these data do not specifically derive from traumatic zone IX injuries, they provide an attractive model for proximal forearm lesions, where appropriate tensioning is one of the most important determinants of functional outcome.

Biological innovation remains more promising than established. In 2025, improved early outcomes in extensor lag were reported with the use of a bioresorbable polylactide sheet placed around the repair in zone VI extensor tendon injuries, suggesting that anti-adhesion barriers may have a future role in more proximal injuries.[23] Recent reviews on biomaterial products for tendon surgery show that the market for augmentation devices has expanded over the past 15 years; additionally, tissue engineering, scaffolds, cell-based therapy, platelet-rich plasma, and exosomes represent active areas of investigation. However, the evidence specific to extensor tendon injuries of the hand and forearm—and even more so to zone IX—remains scarce, heterogeneous, and far less developed than the evidence available for the rotator cuff or Achilles tendon. Therefore, these approaches should currently be regarded as experimental or selectively used adjuncts rather than the standard of care.

Suture biomechanics provides concrete lessons for zone IX. In extensor tendons, Woo and colleagues demonstrated that, in zone IV, the modified Becker technique provided the strongest repair, with an initial gapping force of approximately 28.8 N. Subsequently, Lee and colleagues showed that the running interlocking horizontal mattress technique was significantly stiffer, produced less shortening (1.7 mm versus 6.2–6.3 mm), and achieved similar ultimate failure loads (51–53 N) compared with augmented Becker and modified Bunnell repairs. Taken together, these studies support a central concept: successful repair does not depend solely on "closing" the tendon, but rather on balancing resistance to gap formation, sufficient stiffness for protected mobilization, minimal shortening, and low suture bulk.[24,25]

When the injury primarily involves the muscle belly—a frequent scenario in zones VIII–IX—the evidence is considerably weaker. The classic work by Botte and colleagues demonstrated that severe lacerations of the forearm muscle belly could be reconstructed using tendon grafts, achieving useful functional recovery.[26] However, subsequent reviews and experimental studies on muscle lacerations have emphasized that muscle repair is technically challenging because sutures tend to “cut through” the tissue, no universally superior technique exists, and biomechanical models remain heterogeneous. More recent studies have compared configurations such as Mason–Allen, figure-of-eight, perimeter repairs, and anchor-suture techniques, but their direct clinical translation to the proximal dorsal forearm remains insufficient.[27,28]

## CONCLUSION

This case reinforces the concept that zone IX extensor tendon injuries should be approached as complex musculotendinous lesions requiring comprehensive anatomical assessment, meticulous surgical repair, and structured rehabilitation to achieve optimal functional recovery. The favorable postoperative outcome observed in this patient supports the effectiveness of timely primary repair combined with appropriate postoperative management, while emphasizing the importance of recognizing associated posterior interosseous nerve injury and respecting the biomechanical principles that govern musculotendinous healing. Beyond its clinical relevance, this report contributes to the limited body of literature dedicated specifically to zone IX injuries by integrating current evidence with practical surgical experience and highlighting key diagnostic and therapeutic considerations unique to this anatomical region. By addressing an uncommon and underreported injury pattern, this study expands the current understanding of zone IX extensor tendon reconstruction and provides clinically applicable evidence that may help guide surgical decision-making, postoperative rehabilitation, and future research aimed at improving functional outcomes in these challenging injuries.

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