



University of Kentucky
UKnowledge

Rehabilitation Sciences Faculty Publications

Rehabilitation Sciences

2001

Wrist and Hand Injuries in the Athlete

Timothy L. Uhl

University of Kentucky, tluhl2@uky.edu

Philip Blazar

Greg Pitts

Kelly Ramsdell

[Click here to let us know how access to this document benefits you.](#)

Follow this and additional works at: https://uknowledge.uky.edu/rehabsci_facpub

 Part of the [Rehabilitation and Therapy Commons](#)

Repository Citation

Uhl, Timothy L.; Blazar, Philip; Pitts, Greg; and Ramsdell, Kelly, "Wrist and Hand Injuries in the Athlete" (2001). *Rehabilitation Sciences Faculty Publications*. 35.

https://uknowledge.uky.edu/rehabsci_facpub/35

This Book Chapter is brought to you for free and open access by the Rehabilitation Sciences at UKnowledge. It has been accepted for inclusion in Rehabilitation Sciences Faculty Publications by an authorized administrator of UKnowledge. For more information, please contact UKnowledge@lsv.uky.edu.

Wrist and Hand Injuries in the Athlete**Notes/Citation Information**

Published in *Upper Extremity Injuries in Sports, Home Study Course 2001*, Kevin Wilk (Ed.), p. 1-26.

The copyright holder has granted permission for posting the chapter here.

UPPER EXTREMITY INJURIES IN SPORTS



Wrist and Hand Injuries in the Athlete

*Tim L. Uhl, PhD, ATC, PT
Philip Blazar, MD
Greg Pitts, MS, OTR/L, CHT
Kelly Ramsdell, ATC*

SPTS
SPORTS PHYSICAL THERAPY SECTION



CHAPTER 2



Introduction

Athletes subject themselves to considerable disability. No matter the sport, the hand and upper extremity are among the most commonly injured sites. Frequently, the most debilitating complications of these conditions are the result of misdiagnosis or delayed diagnosis.¹ Unfortunately, many patients with these delayed and misdiagnosis injuries need to be treated with surgical procedures. To compound the dilemma in treating hand and wrist injuries in this population, one needs to appreciate the athletic personality and the mentality that wishes to dismiss hand injuries as minor. It is essential to educate athletes by clearly communicating the risks and complications inherent to these injuries and the applicable therapy.

The purpose of this chapter is to discuss the anatomy, mechanism of injury, diagnosis, and treatment of common athletic injuries as it relates to the fingers, wrist, and hand. Appreciation of the anatomy and mechanism of injury is extremely helpful in diagnosing the pathology. Early and accurate diagnosis minimizes the delayed problems of pain and dysfunction in hand injuries. As with any other sport injury the primary goal is to return the athlete to full participation as soon as possible without risking further injury or permanent disability.² Common sense management of the injury is presented in regards to acute treatment, protective splinting and surgical intervention. Specific rehabilitation exercises are outlined at the end of the chapter to avoid repetition, since many of the same exercises are used in the various rehabilitation regimens described.

Evaluation Considerations

Evaluation of the athlete with a hand injury begins with a thorough history and physical examination focused on the hand. The history should focus on the mechanism of injury, timing of presentation, prior treatment (if any), prior hand injuries, and general past medical history. An occupational and recreational history should focus on job/sport requirements, level of participation, and the individuals wants and needs with regard to return to participation. Some individuals may be willing to accept minimal risk of loss of function on a long-term basis to participate in athletic competition. A college quarterback with a gamekeeper's thumb may be willing to accept some residual loss of motion, if surgical reconstruction is delayed until after the season, and he can finish the season functioning in a brace.

Another important consideration is hand involvement. If the dominant hand is injured the compliance of rest and wearing a splint for a high school or college student may not be feasible. Consideration should be given to the psychosocial implications during the evaluation and management phases of a hand injury. Asking a person to wear a brace on their dominant hand for 6 weeks that limits their grooming activities and draws attention to their dysfunction can have negative social reaction.

Hand anatomy is quite complex and critical to the evaluation and treatment process. A complete description is beyond the scope of this text. We have chosen to focus this article on several of the more common hand injuries seen in the athletic population, including a description of the relevant anatomy.

Extensor Tendon Injuries (Mallet Finger)

Anatomy

The extensor mechanism anatomy at the distal interphalangeal (DIP) joint is the confluence of the distal continuation of the two lateral bands arising from the intrinsic tendon that split off from the central slip at the mid-portion of the middle phalanx. Together, these structures join to form one tendon just distal to the dorsal tubercle on the proximal portion of the middle phalanx. The tendon attaches to the dorsal part of the capsule and inserts into a ridge distal to the articular cartilage at the dorsal base of the distal phalanx.

Mechanism of Injury

Sudden, acute, forceful flexion of the extended finger at the DIP joint most frequently accounts for this injury. A classic example is being struck on the fingertip with a ball. Forced hyperextension of the DIP joint may cause a fracture of the dorsal base of the distal phalanx or an isolated tendon rupture.

Classification

Classification of these injuries can be helpful in guiding treatment. Four types of extensor tendon injuries have been described. Type 1, the most common, is extensor tendon avulsion from the distal phalanx with loss of tendon continuity and possibly a small chip avulsion fracture. Type 2 is a tendon and skin laceration at or proximal to the DIP joint. Type 3 is a deep abrasion with skin and tendon loss. Type 4 encompasses fractures of the distal phalanx other than small chip avulsions.³

Diagnosis

Conventional AP and lateral radiographs should be obtained to evaluate for fracture in all cases. **(Figure 1)** Clinical evaluation reveals that the athlete presents with a flexion deformity and inability to actively extend the distal phalanx with the proximal interphalangeal (PIP) joint stabilized in full extension.

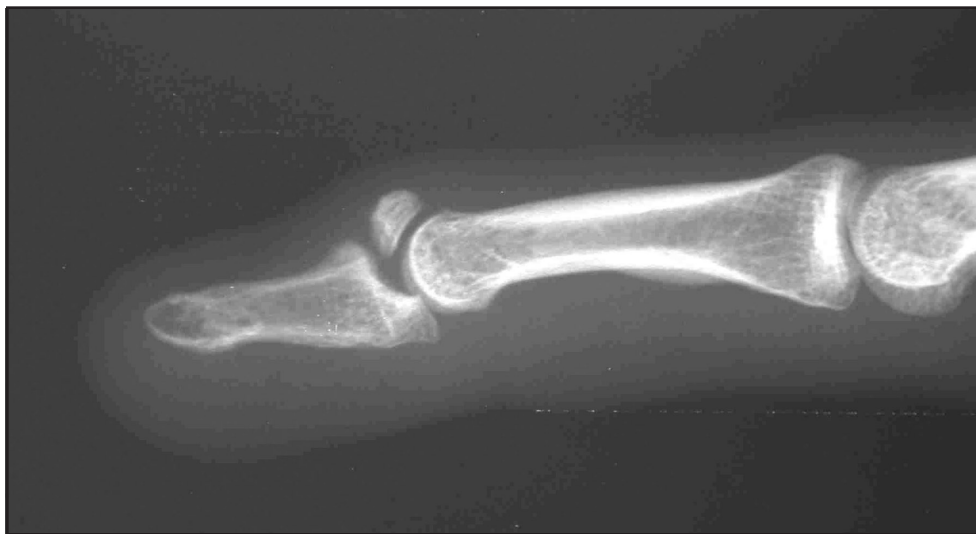


Figure 1. Radiograph of a mallet finger fracture.

Acute Treatment

In the athletic population the vast majority of mallet fingers are closed ruptures, Type 1. Treatment is directed at maintaining the DIP joint in extension, which approximates the injured ends of the tendon. Type 1 extensor avulsion responds to either volar or dorsal splinting in 0° of extension. A prefabricated splint (Link, America Inc., Denville, NJ) is available which encourages PIP joint motion while providing 3 point stabilization of the DIP joint. Dorsal splinting offers the benefit of maintaining volar sensation. Splints are worn 24 hours a day for 6-8 weeks.^{4,6} Delayed presentation of the injury by greater than four weeks may require 8+ weeks of immobilization.⁷ Splinting duration may be extended if the injury occurs during the competitive season to prevent reoccurrence.⁶ Patients are told that if the finger is allowed to “droop” at all that the clock is set back to zero and any healing that has occurred will be disrupted. It is the responsibility of the therapist/trainer to educate the athlete to assure skin integrity. The splint and skin must be kept dry to prevent maceration. Initial removal of any splint should be supervised to assure the DIP is kept in full extension.⁸

Occasionally an individual is unable or unwilling to accept the rigors of splint treatment. This is a relatively rare situation, even in athletes. All splinting protocols have been associated with occasional loss of DIP flexion but loss of extension is more common.⁸ Patients should understand that a 5°-10° extensor lag at the conclusion of treatment is typical and not an indication for further surgical intervention.

Surgical Treatment

In this scenario an “internal splint” with a percutaneous Kirschner wire (K-wire) may be performed. The wire is typically inserted under local anesthesia with the DIP joint held at full extension not hyperextended. Hyperextension can increase the risk of the most common complication of surgical and nonsurgical treatment, skin breakdown.^{3,9}

Malunion of an intra-articular fracture alters joint congruity and requires surgical correction or arthrodesis that can be avoided with immediate diagnosis and appropriate treatment. Untreated mallet fingers may result in “swan-neck” deformities, especially in individuals with ligamentous laxity. This deformity is secondary to retraction of the extensor mechanism and results in a disability of greater significance than DIP flexion loss. Patients may experience painful snapping of the digit with flexion, poor dexterity due to the hyperextension of the proximal interphalangeal joint, and loss of power grip.

In children less than 14 years old, epiphyseal injuries at the base of the distal phalanx may mimic mallet finger deformities. These injuries require closed reduction and splinting and are associated with nail base displacement from the eponychial fold.¹⁰ Nail base displacement is considered an open fracture, the nail should be removed, the laceration in the nail bed examined and repaired if necessary. Reduction may require percutaneous pinning or application of a long arm cast to ensure compliance. Hardware fixation primarily causes surgery-related complications with nail deformities present in as many as 18% of the cases. This complication may be reduced with a more volar orientation of the K-wire.

Post-operative rehabilitation

Rehabilitation of mallet finger is initiated following immobilization. Active range of motion exercises are initiated at this time to establish normal range of motion. During the first week of motion, no more than 20-25° of flexion should be allowed.¹¹ One consideration to prevent over stretching the extensor tendon is to use a volar splint template method that gradually allows 10° increments weekly. Modifying a volar splint weekly, until full DIP flexion is obtained. Passive DIP flexion may be initiated if there is a significant loss in active flexion that does not seem to be returning with the active exercises and if terminal extension is less than 5°. The athlete may begin strengthening exercises as long as there is no loss of terminal DIP extension and range of motion is improving. Exercises should gradually proceed to resistive grasp and pinch exercises, with prehension and coordination activities facilitating normal functional activities.

Flexor Tendon Injury (Jersey Finger)

Anatomy

The flexor digitorum profundus (FDP) inserts into the distal phalanx. Tendon rupture most commonly occurs at its bony insertion site. The flexor digitorum profundus is the primary flexor for the index, middle, ring, and small fingers. The median nerve innervates the index finger flexor digitorum profundus. The function of the index finger is fine motor dexterity and sensory input. The ulnar nerve innervates the middle, ring and small finger flexor digitorum profundus. The primary function of these fingers is power grasp. These injuries can be serious if left unattended due to the loss of power and dexterity associated with the injury.

The ring finger anatomy is believed to account for its predominance sustaining more than 75% of these injuries.¹² Gunter¹³ pointed to the common flexor muscle belly of the FDP to the middle, ring, and little fingers as a factor in ring finger predilection as these three digits act as a unit and certain anatomic differences of the ring finger make it relatively weaker. Manske and Lesker¹⁴ found that the breaking strength of the ring FDP was markedly reduced compared with the middle finger.

Mechanism of Injury

The classic mechanism, for which the injury is named, is forceful hyperextension of the DIP joint with the FDP in maximal contraction. An example of this mechanism is a football player pulling on an opponent's jersey to make a tackle and the jersey is ripped out of the tackler's grip.

Classification

Leddy and Packer¹⁵ have created a three-type classification system based on the level of retraction and the presence of a bony fragment. The significance of the Type 1 injury, in which the tendon retracts into the palm, lies in the fact that the disrupted vincular system compromises the blood supply to the tendon. In patients with Type 2 profundus avulsion, the tendon retracts to the PIP joint. The long vinculum remains intact, and because the tendon stays in its sheath, perfusion is maintained. Occasionally, a small fleck of bone may be seen on radiographs at the level of the PIP joint. In patients with Type 3 injuries, typically a more considerable bony fragment prevents retraction past the A4 pulley. The tendon length and the blood supply to the tendon are preserved because of the limited retraction.

Diagnosis

Patients with ruptured flexor tendon may present for evaluation acutely after injury, or following a period of unresolved functional deficit. Physical examination reveals swelling and local tenderness about the DIP joint. The physical finding which confirms the diagnosis is the inability to actively flex the DIP joint. PIP joint flexion is present to varying degrees because of the intact flexor superficialis tendon. In evaluating the digit with a classic mechanism of injury, one must check active DIP joint flexion by stabilizing the PIP joint to avoid missing the correct diagnosis. A radiograph is mandatory in patients unable to flex a digit, as avulsion of the distal phalanx base is common and may affect treatment.

Acute Treatment

Type 1 avulsions of the flexor tendon must be surgically repaired within 7-10 days. These injuries are at the greatest risk of tendon avascularity. Surgical repair involves reinserting the tendon to the distal phalanx. This has classically been done with a suture that is passed through the distal phalanx and tied over a button on the dorsum of the digit. (**Figure 2**) Some surgeons have begun reattaching tendons with suture anchors to avoid problems associated with buttons (skin irritation, infection etc.). In some rare cases the bony avulsion will include a fragment that is large enough, such as in Type 3 injuries, to be approximated and secured with a screw.

Many athletes elect not to have these injuries repaired due to the long rehab process and time lost during the season. In the situation of delayed presentation and poor tissue, salvage procedures are typically recommended if hyperextension of the DIP joint develops. Patients with Types 2 and 3 injuries can be considered for delayed operative repair; however, Type 2 injuries may quite readily become Type 1 injuries in athletes who continue to play and sustain long vinculum rupture.⁵

Post-operative rehabilitation

Treatment for a flexor tendon injury typically has a duration of 10–12 weeks. The athlete will typically start either the Duran or Kleinert protocol (a modified Duran and Kleinert protocol is outlined in **Table 1**) based upon the attending physicians recommendations, three to five days status post surgical repair.^{16,17} Patient education will emphasize the importance of avoiding



Figure 2. Flexor digitorum profundus tendon repair.

Table 1. Modified Kleinert-Duran Protocol

3 days - 3 weeks

- The athlete is placed in the dorsal block splint
 - Wrist in 20 degrees of flexion
 - Metacarpal phalangeal joints are placed in 60 degrees flexion
 - Interphalangeal joints are placed in maximum extension
 - Dynamic traction via palmar pulley with night resting strap
- Exercise
 - Active extension of interphalangeal joints to the hood of the splint, 8 repetitions every hour without traction through the palmar pulley.
 - Passive flexion of the digits, working toward full fist and isolated MCP, PIP, and DIP flexion, 10 repetitions 4-6 times a day in splint.
 - Use coban wrapping to control edema
 - At 2 weeks post-operatively the fingers can be placed into a fist-like posture and initiate AROM of wrist flexion and extension

3 - 4 1/2 weeks

- Splint
 - Modified to a neutral wrist position or slight extension to diminish stress on flexor tendon repair.
 - The MP joint can stay 90° of flexion
- Exercise
 - If edema is at a minimum basic conditioning activity can be assumed with no functional movement of hand with the splint.
 - The athlete can start active range motion within the dorsal block splint
 - Passive range motion should always be conducted prior to active range motion to diminish joint stiffness and facilitate functional movement in the splint.
 - Begin scar tissue massage as long as wound is healing satisfactorily

4½ to six weeks

- Splint
 - The dorsal block splint can be worn at night
 - A post-operative flexor tendon splint can be worn during the day with the splint removed for full active range motion of the wrist and hand every hour
- Exercise
 - Biofeedback training for fine motor and gross motor self-care tasks
 - Emphasize tendon gliding with basic four hand postures (Figure X), dorsal compartment range of motion (elbow extended, pronated, full fist, actively flex the wrist) and volar compartment range of motion (elbow extended, supinated, fingers extended, actively extend the wrist)

Table 1. Modified Kleinert-Duran Protocol cont.

- Passive range of motion inside the protective dorsal block splint should be explored if a proximal interphalangeal joint flexion contracture is noted. The attending physician should agree to this treatment prior to initiating.
- No lift, carry, push, or pull is to be done with the repaired hand

6 weeks

- Splint
 - Dorsal block splint and post-operative flexor tendon splint is discontinued
- Exercise
 - Continue intrinsic and extrinsic compartment stretching
 - start functional retraining with self-care activities at a sedentary physical level (not to exceed 5lbs)
 - Passive over pressure exercise can be performed in a protected posture (flexed wrist to stretch the lumbricals)
 - biofeedback for neuromotor reeducation
 - Light resisted activities for increasing motor output of the flexor tendons.

7-8 weeks

- Splint
 - Protective distal interphalangeal joint splint at 30° of flexion to be used with gross motor strengthening activities and athletic activities
- Exercise
 - Start isometric and isotonic strengthening “theraputty”
 - Functional activities progressed to a light physical demand level (not to exceed 10lbs)
 - Functional passive range motion to restore intrinsic and extrinsic motion without protective posture
 - Start pushing activities (Push-ups and bench press) and general conditioning tasks but avoid pulling exercises

10 to 12 weeks

- Splint
 - Buddy tape with functional activities that exceed a medium physical demand level (25lbs)
 - Use protective distal interphalangeal joint splint when conducting competitive activities
 - At 12 weeks all splints can be discontinued
- Exercise
 - Continue progressive strengthening exercises
 - Continue stretching exercises to regain full motion
 - Start sport specific training activities in order to return to full sport participation including pulling exercises (pull downs and dead lifts)
 - Start total body conditioning exercises

active range of motion with gross motor and fine motor movement of the fingers. The attending therapist/trainer will focus on controlling edema with compression, elevation, and movement based upon the selected protocol. The athlete will actively extend the fingers to the dorsal block splint 8 repetitions per hour. The athlete must have the capacity to passively stretch all fingers to the palm and actively extend fingers to the dorsal block splint prior to leaving the first treatment session. In those cases with excessive edema full passive flexion may not be obtained initially but should be followed more frequently to assure motion is achieved. Active range of motion of the wrist can start at two weeks post-operatively with fingers parked in flexion.¹⁸ The athlete must be cautioned not to allow their fingers, or wrists, to actively flex or extend outside the protected dorsal block splint.

The Kleinert method provides a dynamic flexion assist to all digits. These flexion assists are normally attached with hooks and superglue. This splint facilitates a stretch reflex that provides a stretch to the extensor mechanism while passive flexing and relaxing the repaired flexor mechanism during active extension. (Figure 3)

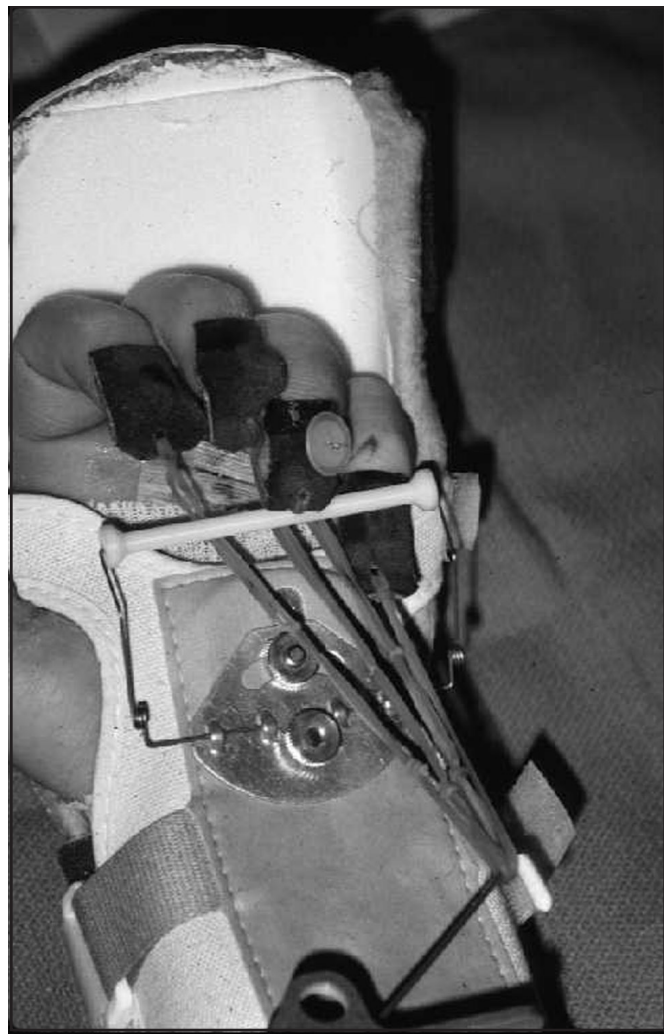


Figure 3. Dynamic flexor tendon splint to facilitate flexor musculature relaxation.

Ulnar Collateral Ligament Injury (Gamekeeper's thumb)

Anatomy

The ulnar collateral ligament (UCL) of the thumb supplies structural lateral support of the thumb for fine motor functional activities and weight bearing tasks. Ulnar stability of the thumb metacarpophalangeal (MCP) joint is maintained by a combination of static and dynamic structures. MCP joint static restraints are the proper collateral ligament in flexion and the accessory collateral ligament in extension. The proper collateral ligament runs from the metacarpal head to the volar aspect of the proximal phalanx. It is tight in flexion and loose in extension. The accessory collateral ligament lies volar to the proper collateral and inserts into the volar plate. It tightens in extension and becomes loose in flexion. Dynamic stability is provided by the adductor pollicis aponeurosis that lies superficial to the extensor mechanism, into which it inserts over the dorsal capsule and ulnar collateral ligament.¹⁹

Mechanism

A severe, sudden valgus force placed on the already abducted thumb is the most common mechanism of injury. The ulnar collateral ligament typically ruptures at its distal insertion site into the base of the proximal phalanx. This injury is common in sports involving grasping activities such as football, wrestling, and skiing.²⁰

Classification

The two classifications of this injury are (1) incomplete, or proper collateral ligament injury with accessory collateral preserved, and (2) complete, in which the ligament rupture is complete and the distal end may displace superficial and proximal to the adductor aponeurosis. This condition is referred to as a Stener's lesion.¹⁹ In patients with complete ruptures, the incidence of adductor aponeurosis interposition and ligament displacement is controversial but has been reported in as many as 80% of cases.²¹ A complete ligament injury may be present, even with a nondisplaced avulsion injury present on conventional radiographs.²²

With a Stener lesion, functional ligament reapproximation is blocked leading to chronic instability. Conservative treatment of unstable ulnar collateral ligament ruptures has been shown to have a 50% failure rate.²³ Chronic instability may compromise pinch and grasp strength, cause considerable discomfort, leading to avoidance and potentially post-traumatic arthrosis. Failure to report the injury immediately and/or a missed diagnosis can result in chronic MCP joint instability. If a complete rupture occurs, surgery is the most likely course to correct the instability.

Diagnostic Evaluation

When the ulnar collateral ligament is damaged, patients will have pain associated with lateral instability while conducting basic self-care and competitive sporting activities. A complete tear of the ulnar collateral ligament can result in complete instability and significant complaints of pain while conducting all forms of thumb intensive tasks. There is no consensus on whether stressing the ulnar collateral can produce a Stener lesion. The author feels that checking for valgus instability is an essential part of the exam; however, individuals comfortable with assessing this aspect of the physical exam should do so. Stress testing should be done after radiographs are obtained to rule out a nondisplaced fracture that might be displaced with valgus loading.

Conventional radiographic evaluations with posteroanterior and lateral views are mandatory. An avulsed fragment from the ulnar side of the proximal phalanx may be seen. Radiographs demonstrating volar subluxation and radial deviation of the proximal phalanx suggests complete ligament disruption. More than 3 mm of volar subluxation of the proximal phalanx on the lateral view indicates gross instability.²³ Stress views are considered the best means of determining the extent of ligament compromise; however, in the setting of gross instability they are unnecessary. Before obtaining stress views, plain films are needed to determine whether metacarpal or proximal phalanx fractures are present because they are contraindications to stress views.²³ MR imaging and arthrography provide little additional information to stress views at increased cost.

Acute Treatment

Nonoperative treatment of an incomplete injury may be a short arm thumb spica cast for approximately 6-10 weeks. The short arm thumb spica cast should encase both the IP and MP joints placing the thumb in slight adduction, approximately 40° from the palm.⁴ A thumb based custom-made thumb spica splint incorporating the IP and MP joints can also be fabricated to provide immobilization. Approximately 3-4 weeks post-injury, a linear plane active range of motion program can be started within pain tolerance.^{4,24} Use of a protective splint is recommended until patient is pain free and complete range of motion is obtained.^{25,26} Progression into lateral pinch strengthening (thumb adduction to extended index finger) and oppositional strengthening is started at 8-12 weeks.²⁷

Surgical Treatment

Operative repair is generally recommended for complete ruptures in the athletic population. Surgical treatment of these injuries is indicated for those acute injuries that have gross clinical instability, the inability to reduce due to bone or soft tissue, significant articular surface fragment, bony displacement, or a rotation fracture fragment. Surgical management of UCL chronic instability is determined by the patient's pain, instability, and loss of pinch strength.²⁸ Generally, active and gentle passive linear plane range of motion exercises can begin at 6 weeks post-operative.⁴ Progressive strengthening exercises to include isometrics and isotonic, below pain threshold, can begin at 8 weeks. Avoid lateral pinching and opposition resistive exercises until 10 weeks post-operative. A gradual return to weight training and ballistic activity can begin between 10-14 weeks with clearance from the attending physician.^{4,29}

Triangular Fibrocartilage Complex Injury

Anatomy

The articular disc is the centerpiece of the triangular fibrocartilage complex (TFCC). This disc originates from the sigmoid notch of the distal radius, inserting into the fovea at the base of the ulnar styloid process. Together with the volar fibers of the articular disc, the ulnolunate and ulnotriquetral ligaments merge, creating the TFCC. The other components of the TFCC include the meniscal homologue, dorsal and volar radioulnar ligaments, and extensor carpi ulnaris tendon sheath. The TFCC assists with stabilization of the distal radioulnar joint and ulnocarpal stability, buttressing the proximal carpal row. The thin central portion of the disc is avascular and does not allow for repair in contrast to the thicker peripheral 40% of the TFCC, which is more ligamentous, vascular, and receptive to repair.³⁰ The main function of the triangular fibrocartilage complex is to act as a strut, which stabilizes the distal radioulnar joint while conducting functional pronation and supination activities.³¹

Mechanism

The TFCC is critical in the support of the ulnar carpus. The triangular fibrocartilage complex acts as a decelerator and a shock absorber when conducting the radial and ulnar deviation activities. The structure absorbs up to 20% of axial load to the forearm with a neutral ulnar variance.³¹ The TFCC can sustain injuries in both the medial meniscus disc area and the outer lateral disc areas. This structure is commonly injured with distal radius fractures and wrist sprains. These injuries are very common in persons over 50.

Classification

Palmar's classification divides TFCC injuries into two types: (1) traumatic (Type 1) and (2) degenerative (Type 2).³¹ Type 1 is further classified into four subtypes based upon the location of the insult. Type 1A is the most common lesion, a horizontal tear in the articular disc adjacent to the sigmoid notch of the distal radius. Type 1B is an avulsion of the TFCC from the ulna. Type 1C is an avulsion of the ulnocarpal ligaments from the carpus. Type 1D is an avulsion from the sigmoid notch of the radius.

Degenerative Type 2 tears are believed to result from ulnocarpal impaction. They are divided into five stages: (A) thinning of the TFCC without perforation; (B) thinning of the disc with chondromalacia of the ulnar head or lunate; (C) disc perforation with chondromalacia; (D) disc perforation with chondromalacia and lunotriquetral ligament tear; and (E) disc perforation with chondromalacia, lunotriquetral tear, and ulnocarpal arthritis. Central perforations are usually attributed to degenerative processes.³¹ Triangular fibrocartilage complex perforations increase with age. An estimated 7% incidence rate occurs by age 30 and a 53% incidence rate by age 60.³¹

Diagnosis

Ulnar-sided wrist pain after a traumatic episode, whether it be loading, tractioning, or rotating, should make TFCC injury suspect. These patients often complain of pain with pronation, supination, radial, and ulnar deviation activities with the wrist loaded and extended. Catching and snapping of the wrist are frequently appreciated. Athletes often complain of pain and discomfort when conducting strengthening activities such as dips, bench press, overhead press, and dumbbell exercises. These activities have the elements of weight bearing and ulnar deviation. These patients will have pain and discomfort with palpation directly over the ulnar side of the wrist.

One must consider other soft-tissue pathology, such as extensor carpi ulnaris tendinitis, scapholunate dissociation, lunotriquetral interosseous ligament injury, and distal radioulnar joint instability. Typically, distal radioulnar joint instability is from a Type 1B lesion. Osseous possibilities in the differential diagnosis include carpal fracture, ulnar styloid fracture, and distal radius fracture.

Acute Treatment

Nonoperative treatment with avoidance of painful activities should be the first option because many resolve with minimal joint stability compromise and discomfort.³² Management can be accomplished with anti-inflammatory medication and a resting splint for approximately 4-6 weeks to limit pronation, supination, and joint loading activities. A custom fitted long arm splint with the elbow at 90° of flexion, the forearm in a neutral position, and the wrist in 10-20° extension is the treatment of choice.³³ The patient should avoid heavy lift/carry and push/pull activities. Overhead and torquing tasks that incorporate radial/ulnar deviation and pronation/supination activities are also contraindicated. A minimum of 3 months of conservative treatment should be given prior to considering surgical intervention. A common pitfall is starting these patients on pronation/supination and radial/ulnar deviation exercises too early without adequate control of flexion/extension tasks.

Arthroscopic surgery is considered following failed non-operative treatment and persistent instability or pain.³³ Arthroscopy provides better visualization of the complex than does any open procedure. Arthroscopic debridement versus repair is determined at the time of evaluation.

Scaphoid Fracture

Anatomy

The scaphoid spans both carpal rows and subsequently has less mobility than other carpal bones. The scaphoid articulates with the radius, trapezium, trapezoid, capitate, and the lunate. The scaphoid elongates with ulnar deviation and volar flexes with radial deviation. Forces applied through the thumb, index, and middle finger are translated through the scaphoid to the radius. Functional stability of the scaphoid is critical in the foundation of hand function. The radial side of the wrist including the scaphoid bears approximately 80% of all forces translated through the hand with functional activities.³⁴

Detailed evaluations of the scaphoid vascularity claim a particularly poor proximal pole blood supply. The major blood supply of the scaphoid comes from the radial artery and enters at either the wrist or dorsoradial ridge. Although the distal scaphoid has an independent circulation, the proximal two thirds rely on intraosseous retrograde flow. This scenario predisposes the bone to poor healing and puts it at a greater risk for avascular necrosis.^{35,36} The healing timelines for scaphoid fractures are dependent upon the location and severity index. The published timelines for scaphoid fracture healing is 3 to 18 months.³⁷

Mechanism

The scaphoid is the most commonly fractured bone of the carpus. The injury normally occurs when an athlete falls on the outstretched hand. Scaphoid fractures are considered to be a very serious injury due to the poor blood supply.

Classification

There are three classic fracture sites associated with the scaphoid bone. Fractures of the middle third are the most common (60%), and those of the distal third the least common (10%), with proximal pole accounting for the remaining 30%.³⁷ Distal pole non-dislocated fractures heal the quickest and normally do not need surgical intervention. Scaphoid fractures of the body require long duration of immobilization to achieve appropriate healing. Proximal pole scaphoid fractures often require surgical intervention and 3-4 months of immobilization to realize appropriate healing.³⁸

Diagnosis

The first significant sign of a scaphoid fracture is the complaint of pain and discomfort at the anatomical snuffbox. The anatomical snuffbox is located at the distal portion of the radius between the two muscle groups of the first and third dorsal compartments. If an athlete has complaints of discomfort in this area, extreme caution should be exercised until a complete medical examination is completed. These are very serious injuries, which can result in severe loss of function. If these problems go undetected, the athlete can develop substantial arthritic changes resulting in the need for salvage surgical procedures such as a wrist fusion or a proximal pole carpectomy.

Conventional radiographs may be negative in the nondisplaced fracture for as many as 14 days. Recommended radiographic views include posteroanterior, lateral, semipronated oblique, and semisupinated oblique.³⁸ MR imaging may be useful in detecting subtle, nondisplaced fractures and diagnosing avascular necrosis (AVN) of the proximal pole. CT in the plane of the scaphoid more definitively details displacement. Ninety–five percent of all scaphoid fractures unite within 3 months with correct and early detection.³⁹

Acute Treatment

The fracture location and severity are the first considerations of treatment. It is important to note that scaphoid fractures are often accompanied by ligamentous injuries, which can affect wrist stability with functional activities. Non-displaced fractures are typically treated in a thumb spica cast. Scaphoid fractures of the proximal two thirds require long arm splinting, incorporating the distal humerus to prevent forearm rotation and restrict thumb motion with casting beyond the interphalangeal joint. The elbow is positioned at 70° of flexion, forearm and wrist in the neutral position. Athletes opting for conservative treatment must understand the average time of immobilization to be upward of 4-6 months. This is followed by the use of a custom-made forearm-based thumb spica splint for an additional 3-6 months. Wrist hyperextension and ulnar deviation makes the fracture vulnerable to displacement. This a critical point to consider in managing these injuries due to the demands placed on athletes.

Acceptable reduction of the scaphoid requires less than 10° of angulation and 1 mm or less of displacement.⁴⁰ Values more than these have been correlated with unstable injuries susceptible to nonunion and are considered displaced fractures. Open reduction internal fixation of a displaced scaphoid fracture remains the accepted standard treatment.⁴¹

Surgical Treatment

Unstable (displaced) fractures are treated with open reduction and internal fixation. Typically fixation is provided with a screw or wire. Volar and dorsal approaches are both performed, although many authors prefer a volar approach to minimize the risk of injury to remaining blood supply. Early open reduction internal fixation continues to be supported, especially in the athletic population as the most appropriate therapy for proximal fractures. This aggressive management appears to decrease the frequency of late displacement and subsequently delayed union, nonunion, and avascular necrosis. Surgical treatment may be considered in the athletic population to minimize the time required until the athlete can return to competition.⁴²

Post-immobilization rehabilitation

Range of motion and a strengthening program is started once a physician has given clearance based upon radiographic healing. The strengthening program normally consists of isotonic intrinsic hand strengthening and isometric extrinsic hand strengthening. Wrist movements are only conducted in linear motion patterns below the athlete's pain threshold.

Before aggressive stretching is initiated the physician must confirm fracture union. The use of dynamic wrist flexion and extension splinting is indicated if no ligamentous injury coexists with the scaphoid fracture. The dynamic splints are commercially available and provide a slow progressive stretch below the pain threshold. If joint capsules are contracted, heat modalities may be needed to help lengthen contractures.

The athlete is gradually exposed to ulnar and radial deviation at the 12-16 weeks status after injury/surgery. Weight bearing exercises, such as closed kinetic chain strengthening push-ups and bench press activities, can be initiated at 12-16 weeks status, post injury, if no ligamentous injuries coexist. Return to full strength and motion may take up to 6 months.

Metacarpal and Phalangeal Fractures

Anatomy

The metacarpal bones have many unique characteristics. The first metacarpal bone has a vast range of articulations. This metacarpal articulates on a saddle joint and allows the thumb a large range of functional postures, which supplies both precision pinch and power pinch with daily activities. The second and third metacarpals are fused at the carpus and supply a stable fixation for conducting force or dexterity distally with the index and middle finger. The fourth and fifth metacarpal float and allow a large range of coupling patterns for gross grasp and power grasp while lifting objects. The metacarpals form the oblique and the transverse arches of the hand. These arches enhance the coefficient of friction with many objects due to their ability to conform to many shapes, which we encounter in our daily lives.

Mechanism

Metacarpal and phalangeal fractures are among the most common injuries encountered in the athletic population. The fourth and fifth metacarpal is fractured normally as a result of the hand striking an immovable object such as a helmet, facemask or wall. These metacarpals are very susceptible to fracture due to their unique biomechanical structure and function with the hand. Axial loading on the extended fingers, as occurs in many ball sports, commonly injures the phalanges.(Figure 1) Thumb metacarpal base fractures, also known as Bennett's fracture, result from an axial load directed on the flexed metacarpal. An obvious deformity may not present initially with a Bennett's fracture.^{43,44}

Articular fractures involving the MCP and PIP joints in particular may cause considerable instability. Patients with these injuries typically present with trauma to more than one digit. Despite pain, swelling, and tenderness, the presentation may be delayed because these patients frequently perceive their injuries to be mild.

Diagnosis

Angular and rotational deformities, especially in comparison with injured digits, provide insight to the location and extent of injury. To assess rotational deformity, one can compare the plane of the nail to those adjacent for a coplanar relationship. Varus and valgus joint stability must be evaluated in patients with a potential intra-articular fracture. Tendon integrity and neurovascular status is fundamental to any thorough examination, particularly with adjacent wounds present.

Anteroposterior and lateral radiographs are mandatory for any digit injury with suspicion of fracture or persistence of symptoms beyond 1 week. Fractures of the thumb metacarpal base may require special views such as a true trapeziometacarpal, a true anteroposterior view of the basal joint, and stress posteroanterior views. Valgus stress view to check for subluxation of the MCP joint are also indicated.

Acute Treatment

Most metacarpal fractures are functionally stable, with or without, closed reduction and are treated with splinting in a safe position and early mobilization. **(Figure 4)** This safe position immobilization places the wrist in 20°-30° of extension, the MCP joint in maximum flexion, and the interphalangeal joints in full extension. (Segmuller) As a general guideline, permanent loss of digital motion has a greater likelihood with immobilization for more than 3 weeks in adults or 4



Figure 4. Thermoplastic splint fabricated to hold the hand in “safe position” MCP flexed to 90° and IP joints free to move.

weeks in children.⁴⁵ More complex injuries are treated with various options to restore alignment and stability. These treatment options are dictated by the fracture stability, location, degree of comminution, articular involvement, angulation, and rotation of the fracture. Treatment options include closed reduction with casting, closed reduction with percutaneous pinning, open reduction internal fixation with K-wires, or plate-and-screw implants.

Fractures of the proximal interphalangeal joint are normally a very serious injury due to the potential swelling and stiffness of the joint, resulting in a decrease in active range of motion that can affect fine motor and gross motor dexterity for activities of daily living. If the proximal interphalangeal joint is allowed to become stiff it can result in a disappointing cosmetic appearance and a large functional deficit.

Stable proximal interphalangeal joint fractures should be immobilized in the safe posture through customized protective splinting. The athlete should come out of the custom-made splint every hour and participate in active range of motion, active assisted range of motion and functional activities at a sedentary physical demand level. Unstable proximal interphalangeal joint fractures must be made stable through internal fixation, external fixation, or a distraction method.

Sport participation is another important consideration during acute treatment. The recent rule changes in football allowing sport participation with a cast covered with 1/2 inch closed cell foam has enabled early return of athletes to participation. This early return places added

responsibility on the sports medicine team to assure the fracture is adequately stabilized, protected, and maintained in correct alignment during the healing process.

Post-immobilization rehabilitation

Rehabilitation of metacarpal fractures managed by closed reduction includes active motion of the joints not splinted during initial immobilization, which usually lasts 3-6 weeks.⁸ Edema should be managed with ice, elevation, and compressive dressing throughout splinting phase and after, to facilitate motion and reduce adhesions. Often the interphalangeal joints are allowed flexion to keep contractile tissue from adaptive shortening, which can result in extra-articular tightness. Gentle active PIP and DIP flexion and extension exercises can be initiated as early as 3 weeks, if tolerated by patient and X-rays show appropriate healing for interphalangeal joint fractures.^{4,8,46} Passive motion may be initiated upon clinical healing at approximately 5-6 weeks.^{4,8} Progressive strengthening can begin with the use of silicone putty and should be continued until grip strength is restored.⁴

Proximal Interphalangeal Dislocations

Anatomy

The stability of the proximal interphalangeal (PIP) joint is derived through the volar plate and the joint capsule. Proximal interphalangeal joints achieve motion through a complex intrinsic and extrinsic mechanism. The proximal interphalangeal joint has two main extrinsic structures that flex the finger. The flexor digitorum profundus and superficialis are responsible for flexion of the proximal interphalangeal joint. Extension of the proximal interphalangeal joint is achieved through the intrinsic musculature of the lumbricals, dorsal interossei, and palmar interossei. The extrinsic extension of the proximal phalangeal joint is achieved through the extensor digitorum communis, extensor indicis proprius for the index finger and extensor digiti minimi for the small finger.

Mechanism

These injuries are due to traumatic occurrences, such as a fall or crushing injury during a competitive sporting activity. Often, these injuries are associated with ball sports in which the athlete is attempting to catch or absorb force with their fingers from an oncoming ball.

Classification

The direction of dislocation is a critical point in understanding the structures and functional deficit associated with the injury. There are three types of PIP dislocations; the most common is the dorsal dislocation with the other two less common types being a volar and lateral dislocation.⁴⁷ The dorsal dislocation can result in a partial or complete tear of the extensor mechanism, volar plate, and disruption of the intrinsic extensor mechanism. The long-term results of this injury can result in a chronic boutonniere deformity. A volar dislocation of the proximal interphalangeal joint can also result in a partial or complete tear of the extensor hood mechanism that can lead to a chronic boutonniere deformity. This is due to disruption of the volar plate and displacement of the intrinsic extensor mechanism.

Diagnosis

The diagnosis of a PIP joint dislocation is made on clinical observation and radiographs. All patients with an interphalangeal joint injury with substantial deformity of the digit, a history for

subluxation, or limitation of motion require radiographs. Subtle subluxation can be difficult to distinguish from normal alignment unless a true lateral x-ray of the joint is obtained.

Acute Treatment

The dislocated PIP is typically treated with closed reduction and conservative splinting protocols to restore functional use of the injured proximal interphalangeal joint. However, surgical intervention may be necessary depending on the stability post reduction or the inability to reduce. Proximal interphalangeal joint injuries can lead to chronic pain and deformity if not adequately managed.

Dorsal dislocation of the PIP joint can be treated with a splint for 3-4 weeks in 30° flexion.⁴⁸⁻⁵⁰ Buddy-taping to prevent PIP hyperextension may replace splinting at approximately 2-3 weeks for sporting activity.^{8,50} Edema should be controlled with coban wrap. After initial immobilization period, protective active motion exercises are begun. The athlete is instructed not to extend the PIP beyond limits of the splint for 2 weeks to protect the volar plate and prevent hyperextension. The athlete is instructed to progress to full active motion exercises following the protected phase. Strengthening exercises are initiated at 6-8 weeks post injury. Protective splinting is continued during athletic events and training until complete pain-free motion is achieved. The athlete should be informed that this is a long rehab process.

If the joint remains unstable after reduction, it tends to re-dislocate in immobilization and surgical intervention is recommended. Fractures associated with greater than 25% of the joint surface involved are prone to instability and mandate evaluation by a hand surgeon early on in treatment. Surgical treatment consists of repair of displaced fragments if they are large enough. Frequently the displaced articular pieces are too small for internal fixation and other methods must be chosen to ensure joint reduction and stability.

Rehabilitation Exercise

Active motion exercises for the digits

Active range of motion (AROM) exercises for the fingers are used for all injuries but initiated only when cleared by the treating physician. Each exercise should be performed within the pain tolerance of the injured athlete. Sets and repetitions are dependent on the clinician's preference; generally 1-2 sets of 5-12 repetitions 4-6 times a day are used with these active exercises. The injured athlete is educated in all appropriate exercises. Upon demonstrating proper techniques with their exercises, the athlete is encouraged to take responsibility for performing the exercises several times a day independently. Performance of these exercises in a warm whirlpool is an excellent medium to loosen stiff joints as long as swelling is not a concern. The use of soft tissue massage is commonly prescribed to increase AROM or facilitate scar mobility. The use of thin silicone sheets such as Topigel™ over a completely healed incision site for several hours a day also assists in scar management.

Finger abduction and adduction

Spread the fingers apart and together. This will facilitate a decrease in edema along with working the intrinsic musculature of the hand. Recommended for all injuries.

Opposition

Touch every fingertip with the thumb starting with the index, then progress by sliding the thumb down the small finger into the palm of the hand to facilitate full flexion of the thumb. Recommended for UCL injuries of the thumb and scaphoid fractures.

MCP Flexion with IP flexion and extension

Flex the MCP to 90°, then alternate flexion and extension of the IP's into full flexion and full extension to facilitate the interossei and lumbricals.⁹ **(Figure 5a & 5b)** Recommended for all PIP joint injuries and any injuries that result in lack of extension at the PIP.



Figure 5a. Starting position for intrinsic flexion and extension exercise to facilitate activation of hand intrinsics (interossei and lumbricals). Metacarpophalangeal joints are flexed to 90° and interphalangeal joints are in full extension.



Figure 5b. Ending position in full flexion of interphalangeal joints.

Tendon gliding exercises or stage fisting

Involves the digits making various types of fists in a progression starting with full extension, followed by a table top (intrinsic plus position), flat fist, full fist, and finally to a hook position (intrinsic minus position). (Figure 6a-6d) These exercises are designed to facilitate the gliding of the Flexor Digitorum Superficialis (FDS) and Flexor Digitorum Profundus (FDP) tendon through the carpal tunnel. Recommended for all injuries.

Isolated tendon excursions or joint blocking exercises

These exercises are designed to isolate the flexor and extensor tendons to increase AROM of a specific joint. To perform these exercises hold the MCP of all fingers in extension. To isolate the FDS hold the finger below the crease of the PIP joint, then flex and extend the PIP joint. For FDP tendon excursion hold the finger below the DIP joint crease, then flex and extend the DIP joint. For flexor pollicis longus hold below the crease of the thumb IP joint, then flex and extend the IP joint. It is critical that the joints are properly stabilized during these exercises to prevent substitution. Recommended for all finger injuries.

Extensor Digitorum Communis exercise

Place all IP's in flexion with the MCPs in extension (intrinsic minus position) then actively flex and extend the MCP joints. If needed, wrap the IP joints to keep in flexion. These exercises



Figure 6a. Tendon gliding exercises, start with fingers fully extended. Metacarpophalangeal (MCP) joints flexed to 90° to form a “table top” position (intrinsic plus position).



Figure 6b. Flexion of the PIP joint forms a flat fist.



Figure 6c. Flexion of the DIP joints form a full fist.



Figure 6d. Extension of the MCP joints with PIP and DIP remaining flexed forms a hook position (intrinsic minus position.)

prevent adhesions to the extensor digitorum communis (EDC) tendons. Recommended for metacarpal fractures to decrease adhesions in the EDC tendons.

Passive motion exercises for the digits

The goal of rehabilitation for digits is to obtain full flexion without losing extension. Passive motion exercises should be gentle and should not be performed if extension of the digit is being compromised. Passive exercises are often combined with the active exercises as described above and are performed with gentle overpressure by either the patient or the treating trainer/therapist. It is recommended to hold the stretch for 5-10 seconds and repeat 5-10 times, 4-6 times a day. Pushing the joint beyond the pain should be avoided; this can cause an inflammatory reaction and slow progression. These exercises are generally initiated following 2 weeks of active motion activities. Care should be taken not to over stretch the extensor hood with aggressive passive flexion exercises.

One special technique that can be used to help regain normal range of motion of the digits is successive induction. This technique is a combination of proprioceptive neuromuscular facilitation techniques. An example of this technique is gaining DIP flexion following immobilization. Have the athlete actively flex the DIP through the available range. The therapist/trainer then lightly resists active extension of DIP for 3-5 seconds. The athlete immediately attempts to flex the DIP. The finger is then held in the new range and the process is repeated 4-6 times. The advantage of this technique is that no forced passive flexion is placed on the extensor hood. The athlete can be instructed to perform these exercises 2-3 times a day.

Strengthening exercise for the digits

All active motion exercises described above can be used for strengthening exercises with the use of manual resistance or light resistive rubber bands. Isolation techniques such as joint blocking are very useful for strengthening exercises to strengthen weakened tissue. Techniques are limited only by the imagination of the treating clinician.

Gripping exercise to strengthen the flexor tendons is common. Various techniques can be utilized from putty, soft rubber balls, wet washcloths, to resistive gripping devices. Progression should be guided by pain, maintenance of active extension, and healing restraints of the particular injury. Generally 2-3 sets of 10-25 repetitions are prescribed 2 times a day for all strengthening exercises.

Strengthening exercises for the wrist and forearm

These exercises facilitate active motion of the hand, wrist, and forearm and can be utilized as strengthening exercises by the incorporation of weights or resistive elastic bands. These have also been called the Super 7 exercises for the wrist. Stretching exercises are generally held for 10-15 seconds and repeated 3-5 times, 2 sessions per day.

Strengthening exercises are usually performed 2 times a day for 3 sets of 10 repetitions at progressive weights from 1-5 lbs. as tolerated.

1. Wrist flexion stretching with elbow extended and pronated, fingers fully flexed, passive over pressure from the opposite hand can be added.

2. Wrist extension stretching with elbow extended and supinated, fingers fully extended, passive over pressure from the opposite hand can be added.
3. Resisted wrist flexion, initiating the exercise with the wrist in maximal wrist extension and flexing through available amount of flexion.
4. Resisted wrist extension, initiating the exercise with the wrist in maximal wrist flexion and extending through the available amount of extension.
5. Resisted radial deviation, initiating the exercise with the wrist in maximal ulnar deviation and moving through the available range into maximal radial deviation.
6. Resisted ulnar deviation, initiating the exercise with the wrist in maximal radial deviation and moving through the available range into maximal ulnar deviation.
7. Resisted pronation/supination, this exercise is performed with the wrist beginning in neutral rotation and then maximally supinating the wrist and forearm. The direction is then reversed into maximal pronation using a weight or hammer held in the hand to provide resistance.

These specific exercises help to regain motion and strength in injured fingers and hands; however, functional level is a key consideration in the rehabilitation program. A method for classifying functional rehabilitation tasks in the hand is a hierarchical level of functional return. (Table 2)^{51,52} These levels can provide clear communication between therapist/trainer and physician during the rehabilitation process. This also minimizes the chance of overloading the recovering tissue thereby producing a set back, which is quite easy in hand rehabilitation. The recovery of full function is always a primary goal in hand and wrist injuries. The progression of surgical technology, creative rehabilitation techniques, and splinting allows earlier return of our injured athletes. These advances cannot replace a thorough initial evaluation and an informed discussion about the potential long-term outcomes of an under treated hand or wrist injury.

Table 2 Heirarchy of functional return⁵¹				
Activity	Pace	Load	Location	Goal
Fingering	Self-paced	No	Below shoulder	Increase duration
Linear motion patterns	Self-paced Therapist directed	No	Below shoulder	Force production
Awkward posture Pronation/supination Radial/ulnar deviation in controlled setting	Self-pace	No	Below and at shoulder level	Power production
Torque with load controlled pace	Self-pace	Yes	Below shoulder	Gradual exposure to risk factors
Torque with pace	Therapist directed	Yes	Below and at shoulder level	Work simulation
Overhead activity	Therapist directed	Yes	Above shoulder level	Work simulation

References

1. Foreman S, Gieck JH. Rehabilitative management of injuries to the hand. *Clin Sports Med* 1992; 11(1):239-252.
2. Leadbetter WB. An Introduction to Sports-Induced Soft-Tissue Inflammation. In: Leadbetter WB, Buckwalter JA, Gordon SL, editors. *Sports-Induced Inflammation*. Park Ridge: American Academy of Orthopaedic Surgeons, 1990: 3-23.
3. Stern PJ, Kastrup JJ. Complications and prognosis of treatment of mallet finger. *Journal of Hand Surgery (AM)* 1988; 13(3):329-334.
4. Calandruccio JH, Jobe MT, Akin K. Rehabilitation of the hand and wrist. In: Brotzman SB, editor. *Handbook of Orthopaedic Rehabilitation*. St. Louis: Mosby, 1996: 1-70.
5. McCue FC, Wooten SL. Closed tendon injuries of the hand in athletics. *Clin Sports Med* 1986; 5:741-755.
6. Gieck JH, McCue FC. Splinting of finger injuries. *J Athl Train* 1982; 17(3):215-215.
7. Sarberman SF, Diao E, Permer C.A. Mallet finger: Results of early vs. delayed-losed treatment. *Journal of Hand Surgery (AM)* 1994; 19(5):850-852.
8. Sadler JA, Koepfer JM. Rehabilitation and the splinting of the injured hand. In: Rettig AC, Rettig AC, editors. *Hand Injuries in Athlete*. Philadelphia: WB Saunders, 1992: 235-276.
9. Rayan GM, Mullins PT. Skin necrosis complicating mallet finger splinting and vascularity of the distal interphalangeal joint overlying skin. *Journal of Hand Surgery* 1987; 12A(4):548-552.
10. Engber WD, Clancy WG. Traumatic avulsion of the finger nail associated with injury to the phalangeal epiphyseal plate. *J Bone Joint Surg Am* 1978; 60A(5):713-714.
11. Rosenthal EA. The extensor tendons. In: Hunter JM, Schneider LH, Mackin EJ, Callahan AD, editors. *Rehabilitation of the Hand, Surgery and Therapy*. St. Louis: Mosby, 1990: 478-495.
12. Stamos BD, Leddy JP. Closed flexor tendon disruption in athletes. *Hand Clinics* 2000; 16(3):359-366.
13. Gunter GS. Traumatic avulsion of the insertion of flexor digitorum profundus. *Aust VZ Journal of Surgery* 1960; 30(1).
14. Manske PR, Lesker PA. Avulsion of the ring finger digitorum profundus tendon: an experimental study. *Hand* 1978; 10(1):52-55.
15. Leddy JP, Packer JW. Avulsion of the profundus tendon insertion in athletes. *Journal of Hand Surgery* 1977; 2(1):66-69.
16. Duran R, Houser R. Controlled passive motion following flexor tendon repair in zone 2 and 3. *AAOS symposium on tendon surgery in the hand*. St. Louis: Mosby, 1975.
17. Kleinert HE, Kutz JE, Cohen MJ. Primary repair of zone 2 flexor tendon lacerations. *AAOS symposium on tendon surgery in the hand*. St. Louis: Mosby, 1975.
18. Savage R. The influence of wrist position on the minimum force required for active movement of the interphalangeal joints. *Journal of Hand Surgery* 1988; 13B:262.
19. Stener B. Displacement of the ruptured ulnar collateral ligament of the metacarpophalangeal joint of the thumb: A clinical and anatomical study. *Journal of Bone and Joint Surgery(Br)* 1962; 44B:869-879.
20. McCue FC, Hakala M, Andrews JR, Gieck JH. Ulnar collateral ligament injuries of the thumb in athletes. *J Sports Med* 1974; 2(2):70-80.

21. Bowers WH, Hurst LC. Gamekeepers thumb. *J Bone Joint Surg Am* 1977; 59(4):519-524.
22. Heyman P, Gelberman RH, Duncan K, Hipp JA. Injuries of the ulnar collateral ligament of the thumb metacarpophalangeal joint. Biomechanical and prospective clinical studies on the usefulness of valgus stress testing. *Clin Orthop* 1993; 292:165-171.
23. Heyman P. Injuries to the ulnar collateral ligament of the thumb metacarpophalangeal joint. *Journal of the American Academy of Orthopaedic Surgeons* 1997; 5(4):224-229.
24. McCue FC, Cabrera JM. Common athletic digital joint injuries of the hand. In: Strickland JW, Rettig AC, editors. *Hand Injuries in Athletes*. Philadelphia: WB Saunders, 1992: 49-94.
25. Mayer VA, McCue FC. Rehabilitation and protection of the hand and wrist. In: Nicholas JA, Hershman EB, editors. *The Upper Extremity in Sports Medicine*. St. Louis: Mosby, 1995: 591-634.
26. McCue FC, Gieck JH. Hand and wrist injuries. In: Zachazewski JE, Magee DJ, Quillen WS, editors. *Athletic Injuries and Rehabilitation*. Philadelphia: WB Saunders, 1996: 585-597.
27. Neviasser RJ. Collateral ligament injuries of the thumb metacarpophalangeal joint. In: Strickland JW, Rettig AC, editors. *Hand Injuries in Athletes*. Philadelphia: WB Saunders, 1992: 95-105.
28. McCue FC, Garroway RY. Sport injuries to the hand and wrist. In: Schneider RC, editor. *Sport Injuries: Mechanism, Prevention, and Treatment*. Baltimore: Williams and Wilkins, 1985: 743-764.
29. Richard JR. Gamekeeper's thumb: Ulnar collateral ligament injury. *American Family Physician* 1996; 53(5):1775-1780.
30. Thiru RG, Ferlic DC, Clayton ML, McClure DC. Arterial anatomy of the triangular fibrocartilage of the wrist and its surgical significance. *Journal of Hand Surgery* 1986; 11(2):258-263.
31. Palmer AK. The distal radial ulnar joint. Anatomy, biomechanics, and triangular fibrocartilage complex abnormalities. *Hand Clinics* 1987; 3(1):31-40.
32. Lester B. Sport injuries. *The Acute Hand*. Stamford: Appleton & Lange, 1999: 361-390.
33. Garroway RY, McCue FC. Traumatic injury to the upper limb in adults. In: Dee L, Mango E, Hurst LC, editors. *Principles of Orthopaedic Practice*. New York: McGraw-Hill, 1989: 553-559.
34. Werner FM, Glisson RR, Murphy DJ, Palmer AK. Force transmission through the distal radioulnar carpal joint: effect of ulnar lengthening and shortening. *Handchirurgie,-Mikrochirurgie,-plastische-Chirurgie*; 1986; 18(5):304-308.
35. Gelberman RH, Menon J. The vascularity of the scaphoid bone. *Journal of Hand Surgery (AM)* 1980; 5(5):508-513.
36. Taleisnik J, Kelly PJ. The extraosseous and intraosseous blood supply of the scaphoid bone. *J Bone Joint Surg Am* 1966; 48A(6):1125-1137.
37. Herbert TJ, Fisher WE. Management of the fractured scaphoid using a new bone screw. *Journal of Bone and Joint Surgery(Br)* 1984; 66(1):114-123.
38. Zemel NP. Carpal fractures. In: Strickland JW, Rettig AC, editors. *Hand Injuries in Athletes*. Philadelphia: WB Saunders, 1992: 155-173.
39. Cooney WP, Dobyns JH, Linscheid RL. Fractures of the scaphoid: a rational approach to management. *Clin Orthop* 1980; 149:90-97.
40. Szabo RM, Manske D. Displaced fractures of the scaphoid. *Clin Orthop* 1988; 230:30-38.

41. Ring D, Jupiter JB, Herndon JH. Acute fractures of the scaphoid. *Journal of American Academy of Orthopaedic Surgeons* 2000; 8(4):225-231.
42. Rettig AC, Kollias SC. Internal fixation of acute stable scaphoid fractures in the athlete. *Am J Sports Med* 1996; 24:182-186.
43. Alms M. Fracture mechanics. *J Bone Joint Surg Am* 1961; 43B:162.
44. Burkhalter WE. Closed treatment of hand fractures. *Journal of Hand Surgery* 1989; 14A(2):390-393.
45. Strickland JW, Steichen JB, Kleinman WB, Flynn N. Factors influencing digital performance after phalangeal fracture. In: Strickland JW, Steichen JB, editors. *Difficult Problems in Hand Surgery*. St. Louis: Mosby, 1982: 126-139.
46. Saunders SR. Physical therapy management of hand fractures. *Phys Ther* 1989; 69(12):1065-1076.
47. Bailie DS, Benson LS, Marymount JV. Proximal interphalangeal joint injuries of the hand. Part I: anatomy and diagnosis. *American Journal of Orthopaedics* 1996; 25(7):474-477.
48. McCue FC, Meister K. Common sports hand injuries: An overview of aetiology, management and prevention. *Sports Med* 1993; 15(4):281-289.
49. Wilson RL, Carter MS. Joint injuries in the hand; Preservation of proximal interphalangeal joint function. In: Hunter JM, Schneider LH, Mackin EJ, Callahan AD, editors. *Rehabilitation of the Hand, Surgery and Therapy*. St. Louis: Mosby, 1990: 295-303.
50. Sampson S, Akelman E. Fractures and dislocations in the hand, wrist, and forearm. In: Dee L, Mango E, Hurst LC, editors. *Principles of Orthopaedic Practice*. New York: McGraw-Hill, 1989: 536-552.
51. Pitts DG, Hall LD, Murray PM. Rehabilitation aspects of external fixation for distal radius fractures. *Techniques in Hand and Upper Extremity Surgery* 1999; 3(3):210-220.
52. Lindsay M, Lindsay L, Pitts DG. Hierarchy of functional return. 2000. Personal Communication

Multiple Choice Questions

1. Which type of extensor tendon injury involves a tendon and skin laceration at or proximal to the DIP joint?
 - a. Type 1
 - b. Type 2
 - c. Type 3
 - d. Type 4

2. How long is the window of opportunity for surgical repair of a Type 1 avulsion of the flexor tendon, following initial injury?
 - a. 3-5 days
 - b. 7-10 days
 - c. 12-15 days
 - d. within 1 month

3. Ulnar sided wrist pain following a traumatic episode (loading, tractioning, or rotating), should make injury to what structure suspect?
 - a. metacarpal fracture
 - b. carpal fracture
 - c. ulnar styloid fracture
 - d. triangular fibrocartilage complex

4. What is the most common site for a scaphoid fracture?
 - a. proximal pole
 - b. middle third
 - c. distal third

5. In a dorsal or volar dislocation, partial or complete tear of the extensor mechanism with disruption of the volar plate and the intrinsic extensor mechanism can lead to a chronic:
 - a. Swan-neck deformity
 - b. Stener's lesion
 - c. Jersey finger
 - d. Boutonniere deformity

Answer Key:

1. B
2. B
3. D
4. B
5. D