

Scaphoid Fracture in the Elite Athlete

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KEYWORDS

• Scaphoid • Fracture • Wrist • Athlete

KEY POINTS

- Operative fixation is preferred to casting in the treatment of scaphoid fractures in elite athletes.
- Computed Tomography is used to evaluate scaphoid fractures at the start and end of care.
- Early internal fixation offers the patient faster healing, early restoration of motion and an earlier return to elite-level competition.
- Absolute compliance by the athlete and the training program that surrounds the athlete is necessary to return the athlete to competition at the earliest time possible.

SCAPHOID FRACTURE IN THE ELITE ATHLETE

Fracture of the scaphoid, the most commonly fractured carpal bone, presents a dilemma for the active athlete and the treating surgeon. Contemporary treatments¹⁻⁶ offer the athlete hope of an earlier return to participation and healing⁷ than was available 30 years ago. Operative fixation in this unique patient population has come to replace casting, which has been the traditional treatment. The indications, risks, and benefits of each method are discussed in this article.

ANATOMY AND MECHANISM OF INJURY

The Greek term scaphoid (skiff or boat) is usually thought to be preferable to the Latin term carpal navicular.⁸ Fracture of the scaphoid was first reported in the early twentieth century.^{9,10} The mechanism of injury has not changed in the last 90 years from the earliest descriptions, but the early recognition and treatments have evolved.

The annual incidence of acute scaphoid fracture was reported¹¹ to be 8 per 100,000 women and 38

per 100,000 men, with 69% occurring because of a fall on the outstretched hand (FOOSH injury).¹² It is suspected that the incidence of scaphoid fracture is much greater. Patients often present with an established scaphoid nonunion and a history of a remote sprain-type injury years before. Often, their initial wrist pain was not enough for them to seek medical care.

Functioning as a mechanical linkage between the carpal rows,⁸ the scaphoid is located between the carpal rows. It has 5 well-defined articular surfaces that are conveniently separated into a proximal pole (articulations with the radius and lunate), waist (articulates with the capitate), and distal pole (articulations with the trapezium and trapezoid). The distal scaphoid is palmar and the proximal scaphoid is dorsal. Most commonly, a FOOSH injury causes longitudinal loading of the scaphoid, producing a flexion moment that is resisted by the constraining ligaments at the proximal and distal poles and by the radioscapocapitate ligament crossing the waist. This condition causes progressively increasing tension on the dorsal cortex of the curved waist. However, not

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all scaphoid fractures are at the waist. Variations in torque and position of the wrist determine the ultimate applied forces that break the scaphoid. Various patterns of fracture can occur and are described later.

CLINICAL EXAMINATION

The typical patient who falls on an outstretched hand and sustains a scaphoid fracture in the middle of a game usually acknowledges some wrist pain. Many continue to play, but often feel weaker. Some players do not remember when they hurt their wrist and, in the days or weeks after the injury, the pain and weakness persist and they seek care. In baseball, the player is typically immediately out, but, in football, hockey, or soccer, they often continue to play through the game (depending on their position). After the game, the wrist pain and swelling become more evident and they should seek care.

After taking a careful history, which may reveal the mechanism of injury, a thorough wrist examination is performed. Swelling, particularly in the anatomic snuff-box (between the first and third extensor compartments at the level of the radial styloid) and just dorsal to the extensor pollicis longus, is typically present. Concavities in these 2 areas are normally lost secondary to the regional puffiness or fullness. In **Fig. 1**, ecchymosis is seen as well. The range of motion is measured. Flexion, extension, and radial deviation are usually diminished with a scaphoid waist fracture, and less so in distal pole fractures.

A complete wrist and upper extremity examination is performed to assess for associated injuries including concomitant distal radius fracture and any disruption of the stabilizing ligaments of the radiocarpal, radioulnar, and intercarpal joint spaces. In the wrist, careful assessment of the carpal



Fig. 1. Bicycle racer after fall with an acute right scaphoid fracture. See swelling in the snuff-box.

tunnel, Guyon canal, superficial radial nerve, radial and ulnar arteries, and the tendon sheaths is performed. Examination of the elbow is included because significant elbow injury can result from the FOOSH mechanism.

The fractured scaphoid is tender. Specific assessments include palpation of the distal pole at the distal wrist flexion crease, the waist through the snuff-box, and dorsally just distal to the Lister tubercle at the scapholunate joint. Dorsally directed pressure on the volar pole of the scaphoid is more specific and sensitive than scaphoid waist tenderness. Any wrist injury that results in decreased range of motion, snuff-box swelling, and scaphoid tenderness should have plain radiographs taken of the involved wrist with special scaphoid views.

IMAGING

Standard positions for plain radiographs include⁶ neutral rotation posteroanterior (PA), lateral, oblique, and ulnar deviation PA views. In addition to viewing the scaphoid and adjacent bones, the 3 smooth arcs (concentric Cs) described by Gilula¹³ should be assessed in both the coronal and lateral views. Loss of the 3 concentric arcs suggests disruption of the carpal alignment. Greater arc injuries¹⁴ should be considered, particularly with displaced scaphoid fractures or if the arcs described by Gilula¹³ are disrupted.

Although controversial, it is our preference to obtain a computed tomography (CT) scan on all waist and proximal pole fractures of the scaphoid to better assess displacement and comminution. The sagittal CT scan¹⁵ should be done in the longitudinal axial plane of the scaphoid. This plane gives the best view of the flexed scaphoid fracture (**Fig. 2**). The humpback deformity as described by Sanders¹⁵ is easily identified and the need for reduction, and possibly corticocancellous wedge grafting, is self-evident.

CLASSIFICATION AND TREATMENT

Several classifications of scaphoid fractures have been published.^{3,16–19} It is helpful to use these classifications when possible to describe the fracture to help identify specific aspects of the fracture that the treating surgeon may need to address.

Once all the radiographic images are reviewed, I classify the fracture according to the Herbert^{3,18} classification. Type A fractures are stable, acute fractures of the distal pole (type A1) (**Fig. 3**) and an incomplete fracture through the waist (type A2) (**Fig. 4**), and are treated in a short-arm thumb spica cast. A long-arm cast is considered if the

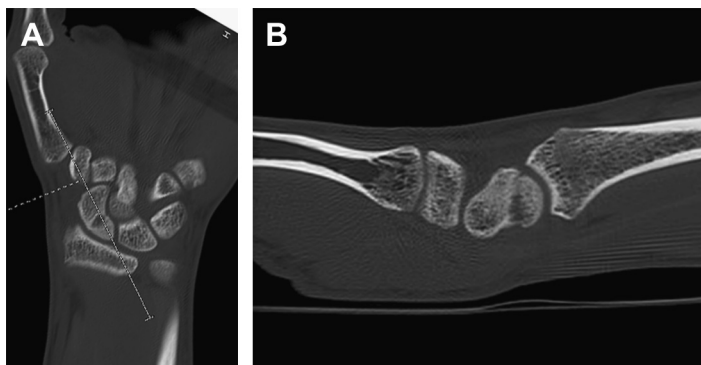


Fig. 2. (A) CT scan in the line of the longitudinal axis of the scaphoid. (B) CT scan in the line of the longitudinal axis of the scaphoid shows a humpback deformity if present.

patient is either noncompliant or remains painful in the shorter below-elbow cast.

Type B fractures are unstable because they are complete fractures at various angles of obliquity through the middle or proximal thirds of the body of the scaphoid. At times, they may initially appear nondisplaced, but, if complete, they are treated as unstable with internal fixation to neutralize shear forces across the obliquity. There are 4 types. Type B1 is a distal oblique fracture. The obliquity of this fracture is inherently unstable and often presents with some shortening (Fig. 5). It is critical to restore the anatomy during the reduction and maintain it with fixation (discussed later).

The type B2 fracture is the most common waist fracture. The PA film often does not reflect the amount of deformity that may be present. It is important to check the position of the lunate on the PA and lateral images. If the lunate is tilted

(looks triangular overlapping the capitate on the PA view, upward tilt (dorsal intercalated segmental instability position, best seen on true lateral view), then the proximal pole of the scaphoid (attached via the scapholunate ligament) is likely extended, and the distal pole flexed. The CT scan should show the flexion deformity of the displaced scaphoid fracture.

Type B3 fractures of the proximal pole may present the biggest challenge. These fractures are often missed on the plain films, and the symptoms may be minimal, but they linger. A carefully performed CT scan will show the fragment. It is hoped that it will be big enough to be held by one of the



Fig. 3. Type A1, distal pole scaphoid fracture.



Fig. 4. Subtle partial scaphoid waist fracture.



Fig. 5. Type B1 oblique scaphoid waist fracture.

fixation screws that are available. The very small proximal pole fractures present a significant challenge because they may be too small to fix with any of the conventional buried screws. One investigator²⁰ described excision of the proximal pole in patients who do not heal and have residual pain.

Type B4 fractures are waist fractures that result from a trans-scaphoid perilunate dislocation. About 60% of perilunate dislocations are associated with a displaced scaphoid.^{21,22} Mayfield and Johnson^{23,24} described the force transmission through the carpal bones and the resultant displacements and ligament injuries. In treating these injuries, open reduction and rigid internal fixation of the scaphoid, plus rigid fixation of the lunate triquetrum joint, is preferred. This method makes for a stable construct in which protected motion can usually begin by 4 to 6 weeks. Although the screw in the scaphoid is permanent, the screw transfixing the lunate triquetrum joint is usually removed after 12 weeks. If pins are used to fix the lunate triquetrum joint, then active motion is avoided until pin removal after 12 weeks.

The Herbert Type C scaphoid fracture is a delayed union. The injury is usually remote or not remembered. The patient presents with pain, loss of motion, often local tenderness, and snuff-box fullness. Imaging studies show displacement, resorption at the fracture site, and sometimes cyst formation (Fig. 6). On occasion, the proximal pole may appear more dense on the plain radiographs, suggesting either avascular necrosis or relative resorption of the adjacent bones.

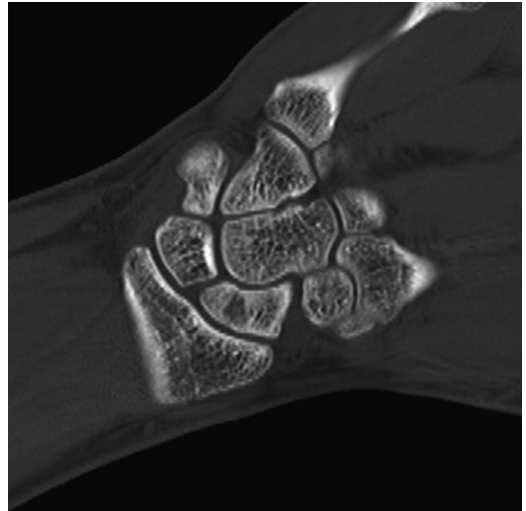


Fig. 6. Resorption at the scaphoid fracture site.

NONOPERATIVE TREATMENT OF SCAPHOID FRACTURES

Casting the patient with the nondisplaced scaphoid waist fracture has been the traditional treatment. Most patients are probably still treated this way.¹⁸ Fracture healing with casting has been reported to be as high as 88% to 95%.²⁵⁻²⁷ Most fractures of the distal pole of the scaphoid are best treated with casting, usually for only 6 weeks. For waist fractures and some proximal pole fractures, there has been some controversy about whether a short-arm thumb spica cast is enough to get the scaphoid to heal in the usual 12 weeks of casting. A short-arm thumb spica cast may suffice as long as patients become pain free in the cast. If they stay uncomfortable in a short-arm thumb spica cast, then they are switched to a long-arm thumb spica cast with the forearm in neutral for at least the first 6 weeks. In any noncompliant patient, a long-arm thumb spica cast is preferable. Immobilization has complications.²⁸ The stiffness, weakness, and deconditioning that can occur with casting are significant impairments for the elite athlete and usually end the player's season. However, for the nonathlete, avoiding surgery may be preferable and remains a valid alternative.

METHODS OF INTERNAL FIXATION

Herbert,² Slade and Jaskwich,⁵ and others²⁹ have developed and introduced methods of rigid internal fixation for scaphoid fractures. These techniques have in common a screw that is buried within the scaphoid and imparts compression across the fracture. Grafting with either cancellous bone grafts, corticocancellous bone grafts, or vascularized

bone grafts have been developed in the last 35 years. It is helpful for the surgeon to have all these choices available when planning and performing open reduction and internal fixation for scaphoid fractures. The preoperative CT helps formulate the reconstructive technique selected.

Most acute proximal pole and waist scaphoid fractures that are complete or displaced, in competitive athletes, are best treated with internal fixation.^{5,7} Early internal fixation offers the patient faster healing, early restoration of motion, and probably an earlier return to elite-level competition. However, surgery exposes the patient to specific complications (infection, wound problems, and anesthetic risk) that are do not arise in cast immobilization. When considering the treatment of everyday athletes who are not professional or on their way to being professional, there is some controversy in treating a nondisplaced or partial scaphoid waist fracture or proximal pole fracture; casting is still considered. There is no debate in treating displaced scaphoid fractures, which are best treated with open reduction and internal fixation.

PERCUTANEOUS INTERNAL FIXATION OF SCAPHOID FRACTURE: DORSAL APPROACH

Slade and Jaskwich⁵ and others have described this technique through a dorsal approach.^{29,30} To achieve an anatomic reduction, either the bone is nondisplaced, or it can be reduced with a reduction maneuver applying extension and ulnar deviation. However, anything short of anatomic reduction is an indication for the open reduction through either a dorsal or palmar approach. One advantage of the dorsal approach is that it allows more direct access to the central axis^{31–33} of the scaphoid, and thus maximum compression. The disadvantage is that it creates a hole in the weight-bearing surface of the proximal scaphoid.

All (nonarthroscopic) scaphoid surgery is done with a supine patient. Conscious sedation, along with either an axillary or supraclavicular block, is satisfactory anesthesia for most upper extremity surgery. Some of young elite athletes choose general anesthesia to avoid any possible risk of the occasional transient nerve injury associated with peripheral blocks.³¹ An upper arm tourniquet is used. After the arm is exsanguinated, the tourniquet is set at 100 mm Hg more than systolic pressure. In the supine position with the arm abducted to the side, the flexed wrist is held over a rolled towel, over the image intensifier, which is draped sterile into the operative field.

For nondisplaced or minimally displaced proximal pole and waist fractures, we prefer a limited open technique with a small (2 cm) (Fig. 7) dorsal



Fig. 7. Small dorsal incision to expose the proximal pole for percutaneous pinning of a scaphoid fracture.

incision approach. After dissecting down through some retinacular fibers, the tendons of the third and fourth compartments are retracted radially and ulnarly, respectively. Only the distal edge of the third compartment extensor retinaculum requires division to mobilize the extensor pollicis longus into a safe position. This division exposes the dorsal capsule overlying the scapholunate joint. A single capsulotomy is made and hematoma evacuated. The ulnar palmar aspect of the proximal pole (at the attachment of the scapholunate interosseous ligament) is directly viewed and a small (0.9 mm) guidewire for either the Synthes Headless Compression screw or Accutrak Standard or Mini tapered screw is placed. The ideal targeting point³² for the screw is 10% of the radiographic length of the contralateral scaphoid, which equates to 2 to 3 mm in a radial and slightly volar direction from the central part of the scapholunate interosseous ligament. Aim along the thumb ray by sighting down the thumb metacarpal, being mindful of the blood supply of the scaphoid, as described by Menapace and colleagues.³³ The dorsal radial edge of the proximal pole should be protected.

If the fracture is displaced, 1.6-mm K-wires can be used as joysticks to manipulate the distal and proximal fragments.³⁰ Once the fragments are aligned anatomically, the guidewire is placed. C-arm fluoroscopic assessment in several planes is critical to verify a central location of the wire. Central placement of the screw is biomechanically preferable.³⁴ PA, lateral, and oblique views of the scaphoid and the screw are necessary to verify that the screw is well placed and does not violate the cortex of the scaphoid. All surfaces of the scaphoid should be evaluated fluoroscopically. In particular, the dorsal radial aspect of the screw placement should be assessed by gradually pronating the forearm with the wrist in some extension.³⁵ This is the most likely place for the screw

to cut out and is difficult to visualize with standard PA and lateral projections. Once the guidewire is in position, the screw length is measured. A safe length is one that is at least 2 mm shorter than the distance of the guidewire to the subchondral bone of the distal pole. The compression screws should compress the fracture, closing, but usually not obliterating, the fracture line.

The length guides for the screw placement are calibrated from the bony surface of the scaphoid, which is another millimeter below the articular cartilage. With experience, screw length decisions get more accurate and shorter is usually safer. The compression screws are not designed to be backed out. Proceed slowly and carefully with screw insertion to get it right the first time.

After images are assessed following reduction and fixation, the wound is closed and the tourniquet released. The patient is immobilized in molded plaster splints over the surgical bandage. At 1 week after surgery, for waist fractures, a removable thumb spica splint is made by the certified hand therapist. (For extreme proximal pole fractures, we wait at least 4 weeks before we stop casting and begin early motion. The rest of the rehabilitation proceeds as described later.) If comfortable, the patient begins gentle range of motion of the wrist and forearm, which continues for 4 weeks. If the radiograph images continue to show a stable reduction and fixation, and motion is nearly normal, strengthening of forearm flexors and extensors begins with wrist curls. Weight-bearing exercises are avoided for at least 6 weeks and not resumed until the forearm strength has returned to normal and the scaphoid has healed. Follow-up CT is obtained every 6 weeks until complete healing (Fig. 8). The CT scan that is

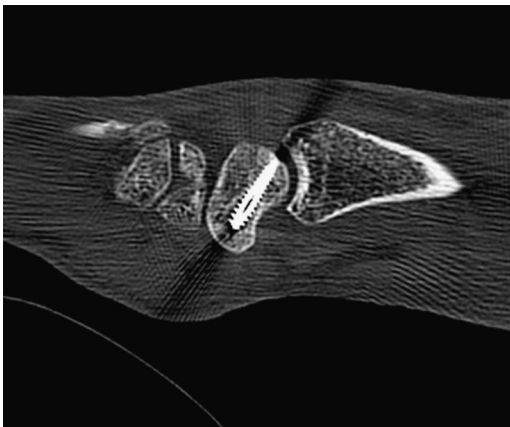


Fig. 8. CT of healed fracture. Sagittal cut of healed scaphoid with screw in place. CT scans with metal smoothing algorithm allow resolution with metal (in this case titanium) screw in place.

ordered for postoperative patients with a metal screw in place should request a metal smoothing algorithm to improve bone resolution.

It is important to determine when the scaphoid is healed enough to compete. During the course of rehabilitation, as athletes' motion improves, they begin conditioning and resistance training. At some point when there is at least 50% of bone bridging on CT scan, no pain, excellent motion, and at least 80% of normal grip strength, return to competition is considered. The athlete advances through a prescribed program, advancing through the skill sets needed to perform.

Return to competition is decided on an individual basis that depends on the sport and the player's position. In football, if that player is an interior lineman and can play with a short-arm cast, then he can return when off pain medication and a thumb spica cast is applied instead of the molded splint. The cast is changed after each week's game. Casting continues until full healing is seen on CT scan. If the scaphoid fracture occurs in the throwing arm of a quarterback or pitcher, or in a lacrosse player, it is unlikely that the player will return before enough healing of the fracture (more than 50% on CT) to permit a satisfactory rehabilitation of the upper extremity, as described earlier.

If hockey players can play with a cast under the glove, they may return before full healing. However, most elite hockey players cannot function effectively without smooth, painless, unimpaired wrist motion, particularly in the shooting (lower) hand. The hockey player's motion typically begins 1 week after surgery out of the protective molded splint. When not performing the specific exercises, they remain in the molded splint even when they sleep. It is helpful to set explicit limitations on the player's activity and exercise program. A careful written program is outlined with the team's trainers to ensure success. As part of the recovery following fracture treatment, maintenance of their elite-level conditioning is necessary. Their forearm strengthening gradually progresses as tolerated, with no weight bearing (eg, pushups) until the fracture is healed. Regular visits with the team physicians ensure compliance and a satisfactory outcome.

ARTHROSCOPICALLY ASSISTED PERCUTANEOUS FIXATION OF SCAPHOID FRACTURES

Several investigators^{29,36} have described a method of using arthroscopic assistance in determining the alignment of the reduced scaphoid and assessing adjacent injuries to the ligaments and other carpal bones. Experience with wrist arthroscopy should be a requirement before attempting to improve

the reduction with the help of an arthroscope. The scope is used to facilitate the dorsal approach to screw fixation. The miniopen dorsal approach is challenging. For some surgeons, adding arthroscopy to this method may not simplify it. The main indication might be a comminuted scaphoid fracture or a scaphoid fracture associated with an intra-articular distal radius styloid fracture, both of which can be treated by percutaneous screw fixation. The techniques are well described in the references cited in this article. There is no published evidence that arthroscopic assistance improves the outcome of the treatment of scaphoid fracture.

VOLAR APPROACH: PERCUTANEOUS INTERNAL FIXATION FOR SCAPHOID FRACTURES

Like the dorsal approach, passing the wires percutaneously offers no advantage compared with a small incision. The skin care, exposure, and closure are easier with the small incision. Under either general or peripheral nerve block anesthesia, the patient is supine on the operating room table. The arm is abducted to the side on a radiolucent hand table or over the image intensifier, and the wrist is extended over a rolled towel. The location for the incision is determined with the C-arm while holding a K-wire over the articulation of the distal pole of the scaphoid and the trapezium. Through a longitudinal zigzag incision or transverse incision in the wrist flexion crease, dissection is carried down to the volar pole of the scaphoid. The volar approach to placement of the screw has specific anatomic concerns regarding protecting the blood supply to the scaphoid.^{32,33} There is a safe zone for K-wire insertion by avoiding the radiodorsal portion of the scaphoid (70%–80% of the blood supply) and the volar surface of the scaphoid tuberosity (20%–30% of the blood supply). If needed, the contralateral scaphoid can be used as a measuring reference for the length of the screw. Similar to the dorsal approach, careful fluoroscopic assessment of the dorsal radial aspect of the scaphoid during wire placement should prevent penetration of the cortex.³⁷

The process for wire placement and then screw placement is similar to the dorsal approach. One major difference is that the proximal articular volar radial edge of the trapezium is violated by the drill as it passes along the guidewire. This violation is inherent with the volar approach, but does not seem to be a clinical problem.^{32,37} Again, the screw is measured to be at least 2 mm short of the inside length of the scaphoid. The goal is to get all the distal tip threads of the headless screw, or at least 5 mm of the tapered screw, across the fracture.

The postoperative regimen is the same as for the dorsal approach. There does not seem to be any major difference in clinical outcomes between the dorsal and volar approaches. For waist fractures, it is preferable to master both methods because certain fractures tend to favor one approach rather than the other.

PROXIMAL POLE FRACTURES

Proximal pole fractures are best treated with the dorsal approach. Especially when the fragments are thin, these fractures are the most difficult to treat successfully. The displaced proximal pole fracture fragment is wholly intra-articular and deprived of blood supply. Early anatomic reduction and internal fixation is recommended, although at times difficult to achieve. The blood supply for endosteal healing is provided by the larger distal fragment.

Guidewire placement is done with extreme care. There may be a tendency to spin the fragment when the screw is placed. Before drilling or screw placement begins, a second parallel derotation wire, perhaps 0.9 mm in diameter, can be placed peripherally. Sufficient subchondral bone in the proximal fragment is required for thread purchase. Care is taken to avoid having the trailing threads cross the fracture line with terminally threaded screw designs (ie, Synthes headless screw, Herbert screw). Size should be based on preoperative templating. The mini Acutrak screw is often preferable for the small proximal pole fractures. If the fragment is too small to accept a microscrew, plain K-wires can be used and the wrist immobilized until healed. Another alternative is excision if the fragment is small and fixation not practical.²⁰ Small proximal fragments can be excised as long as the scapholunate ligaments are intact. Initial treatment is cast immobilization. If the fracture does not heal and pain and synovitis continue, then excision through a dorsal approach is performed and the scapholunate ligament advanced into the defect. In the young athlete, healing may be good enough to avoid an arthrosis.

SCAPHOID MALUNION AND NONUNION

Scaphoid nonunion presents the challenge of reduction, bone grafting, and internal fixation. Malunion raises the dilemma of whether it should be accepted or treated with an osteotomy and bone graft.³⁵ Fernandez and Egli³⁵ describe 3 considerations when planning the treatment of scaphoid nonunion: (1) established nonunion without degenerative changes, (2) nonunion with minimal degenerative changes in which treatment of the

nonunion has to be combined with an additional operation to treat the degenerative changes, and (3) nonunion with advanced degenerative changes. The reason to treat nonunion of the scaphoid is to prevent progression to degenerative arthritis³⁸ of the joints around the scaphoid. This condition is termed scaphoid nonunion advanced collapse (SNAC wrist).³⁹ Nonunion may result from the initial treatment despite early recognition of the fracture. Most scaphoid nonunions are seen remotely after the injury was neglected and the fracture not recognized. Dorsal and volar open approaches have been successfully used to treat these fractures. There is evidence to support several methods including corticocancellous grafts from the iliac crest⁴⁰ and vascularized bone grafts from the distal radius^{41–50} and thumb metacarpal.⁴⁴ The details of these techniques are beyond the scope of this article. It will be a minimum of 3 to 6 months following this type of surgery before the athlete could be expected to have regained strength and motion and consider return to play. In some athletes, it could take a year. Careful monitoring of the condition of the healing scaphoid and the conditioning of the athlete through the recovery is necessary for a successful outcome.

External bone stimulation is often added to the treatment in many settings for the scaphoid fracture to augment the healing process.⁵¹ Electrical and ultrasound stimulation are available to improve scaphoid bone healing after fracture. The indication and clinical benefit are controversial and there is no level 1 evidence that it is indicated in acute fractures. However, in the elite athlete it is often added to the initial surgical treatment. The literature supports its use as an adjunct in treating scaphoid nonunions. Most of the use and experience is with long bone fractures. Hausman⁵² presented a poster exhibit at the American Academy of Orthopaedic Surgeons in 1991 on the use of low-intensity ultrasound in the treatment of scaphoid fractures. The results in his retrospective review of 8 cases were excellent.

SUMMARY

Scaphoid fracture remains a common, potentially devastating, injury that can impair wrist and hand function. Early recognition and treatment provides the best opportunity to heal and return to a normal activity level. Surgical treatment offers the patient a quicker return to the rehabilitation of the extremity and therefore an earlier return to elite play. There is now evidence that healing occurs faster if the fractured scaphoid is fixed with internal fixation. The worst results are often in

unrecognized fractures in which an established nonunion occurs. In all throwing and hand performance sports, scaphoid fracture may remove the athlete from competitive play for 6 months or longer if healing is delayed. It is advisable to protect the athlete until there is complete healing of the scaphoid fracture before return to play so re-fracture is prevented. In sports in which the athlete does not perform precision work with the involved hand, then a protective cast may suffice for earlier return to competition. It is important to help athletes rehabilitate their involved extremities, as well as their overall conditioning, as early as possible after surgery. However, absolute compliance by the athlete and the training program that surrounds the athlete is critical to protect the wrist until fully healed.

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