Complications After the Fractures of Metacarpal and Phalanges

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KEYWORDS

• Metacarpals • Phalanges • Complications
• Fractures • Open • Treatment

Fractures of the metacarpals and phalanges are common injuries, representing 40% of all upper extremity fractures.[1] Unfortunately, complications associated with these fractures are also prevalent, making treatment of such complications an essential part of caring for these injuries. Complications can arise with both conservative and surgical treatment of hand fractures. Closed treatment of fractures with immobilization can lead to malunion and stiffness.[2] Surgical treatment of unstable fractures adds the potential for hardware-related adhesions, tendon rupture, and infection.[2–4] Further treatment pitfalls can occur with the addition of open fractures and soft tissue injury to the hand and fingers.

Green[2] and later Creighton and Steichen[5] have written on complications of metacarpal and phalangeal fractures in previous editions of *Hand Clinics*. Green reviewed treatment of malunion and nonunion, and Creighton and Steichen have reported extensively on extensor tenolysis to address stiffness associated with these fractures. The treatment of complications associated with open fractures and infection are reviewed here in addition to current treatment options for malunion and stiffness.

OPEN FRACTURES

Open fractures of the hand are associated with injuries to the surrounding soft tissue. These fractures often involve injury to neurovascular structures or tendons. The incidence of open injuries has been reported to be as high as 34% to 68% of hand fractures.[6] The extent of soft tissue damage is directly correlated with the functional outcome for the patient.[6–8] The proper treatment of these fractures is based on the central tenets of early antibiotic administration, irrigation and debridement, stabilization, and soft tissue coverage. Rates of complications for infection, stiffness, nonunion, and malunion are all increased in open fractures.[6,8]

Classification

Open fractures of long bones have routinely been classified using the Gustilo and Anderson classification system.[9] This system is based on the size of laceration associated with the fracture and progressive soft tissue compromise. Open hand fractures and their outcomes do not necessarily correlate with this system, and attempts have been made to devise a classification system that incorporates concerns unique to the hands.

Swanson and colleagues[8] retrospectively reviewed open hand fractures and classified them based on clean versus contaminated and delay to treatment. Type I fractures are clean with no delay in treatment in a systemically well patient, and type II are contaminated or have a delay in treatment greater than 24 hours. The data showed a significant increase in infection rate when comparing type I to type II fractures (1.4% vs

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14%). Although this classification is basic, it demonstrates the importance of early treatment for improved outcomes.

McLain and colleagues[10] and later, Duncan and colleagues[7] modified the Gustilo and Anderson classification by downscaling the system to apply to fractures associated with the hands. McLain described type I fractures as clean wounds with smaller than 1-cm lacerations with no crush of skin or comminution of bone. Type II fractures were those with clean lacerations greater than 1 cm with no fracture comminution. Type III injuries had lacerations greater than 1 cm with contamination of the wound, soft tissue crush, comminuted fractures, or periosteal stripping. Duncan further subcategorized type III injuries to include lacerations greater than 2 cm or gross contamination (IIIA), periosteal stripping or elevation (IIIB), and associated neurovascular injury (IIIC). The familiarity of the orthopedic surgeon with the original Gustilo classification makes the modified classification devised by McLain and Duncan a reproducible and useful system to dictate treatment and predict outcomes.

Infection

Open fractures of the hand have shown an overall deep infection rate of 2% to 11%,[6,10] compared with an infection rate of less than 0.5% in closed fractures undergoing operative intervention. The rate of infection is directly correlated to the soft tissue involvement and contamination of the wound.[6–8,10] Gram-positive cocci, such as *Staphylococcus* and *Streptococcus*, are the most common bacteria isolated from open hand fractures. Human and animal bite wounds can produce mixed flora infections that routinely include *Eikenella* and *Pasteurella* species, respectively. Farm injuries have a high incidence of gram-negative bacteria. Antibiotic treatment of open fractures should provide broad coverage initially based on mechanism of injury. Cultures should be taken during the initial debridement and coverage should be tailored to the specified bacterium.

Timing of Treatment

An emergent operative debridement of open fractures is generally recommended to prevent infection. Timing to treatment of open hand fractures should be done urgently, but evidence has shown emergent treatment may not alter the outcomes for every open fracture class. Data to support early (within 6 hours) treatment of open hand fractures is not evident in the literature. McLain and colleagues[10] showed no increased incidence of infection in open hand fractures, regardless of grade, treated after 12 hours from injury when compared with those with no delay in treatment. This finding is contradictory to the earlier held belief that open hand fractures should be addressed in the 6 hours immediately after the injury occurs. Although each case must be evaluated separately, this potentially obviates the need for emergent operative intervention for these fractures. In certain open fractures, evidence allows for cases to be addressed during routine operative time on the morning after the injury. Regardless of time to surgery, prophylactic antibiotics and an adequate irrigation and immobilization of these injuries must occur on evaluation in the emergency department.

TREATMENT OF OPEN FRACTURES

The treatment of open fractures is based on an aggressive attempt to prevent complications that are so common in these injuries. Gonzales and colleagues[11] published an algorithm for treatment of open fractures based on the modified Gustilo classification of these injuries. The aim is to address open fractures in a systematic manner to prevent infection and other potential complications. Type I injuries are treated as an operative closed injury, with 24 hours of cefazolin or clindamycin, irrigation, debridement, and primary closure of wound. Fractures can be treated closed or with plate fixation, or percutaneously pinned. Extending the open wound for fixation should be done with caution as this extension has been shown to increase complications, essentially transforming a type I injury into a type IIIB injury.[7] Predicting whether an injury is type II or III can be difficult in the emergency room because the amount of soft tissue stripping and deep contamination may not be appreciated by inspection alone. For type II injuries, Gonzales and colleagues recommend treating these fractures operatively with irrigation and debridement, stabilizing the fractures with K-wires or external fixators, leaving the wounds open or loosely closed, and performing a second look debridement at 24 to 72 hours post injury. Intravenous antibiotics are continued for 72 hours. If during the second look the wound is clean, definitive fixation can be performed. If infection is present, these injuries are treated as a type III wound. Others would argue that a true type II injury does not have significant soft tissue stripping or contamination and should be definitively fixed during the initial debridement. For type III injuries, penicillin should be added if there is gross soil contamination. Here, there is little argument that the patient should be taken to the operating room for aggressive debridement and fracture fixation initially performed with either K-wires or external fixation. A second-look debridement should be performed within 24 to 72 hours and re-debrided as necessary thereafter. Quantitative cultures should be taken with each debridement and fixation or coverage withheld until bacterial counts drop to less than 10^5 per gram. Soft tissue coverage with a flap or graft should ideally be performed within a week to prevent secondary bacterial contamination.

Osteomyelitis

Infection of the bones of the hand is a potentially devastating complication of open hand fractures and penetrating injuries. Osteomyelitis is defined as a pyogenic infection of bone, usually caused by a direct inoculation of bacteria in the tubular bones of the hand. Although a rare complication of open fracture, osteomyelitis can have demoralizing outcomes, with more than 50% going on to amputation.[12] Diagnosis is based on clinical examination and plain radiographs, with advanced imaging being of little added benefit (**Fig. 1**).[13] Diagnosis is only confirmed after bone biopsy and positive cultures from the offending sequestrum. Once the diagnosis is made, nonoperative treatment is of little value. In the setting of fracture and osteomyelitis, the following 2-stage treatment protocol is performed.

After diagnosis, all implants are removed from the affected bone. Both soft tissue and bone cultures are taken intraoperatively. A debridement of infected soft tissue and bone is performed until bleeding viable bone is exposed. Antibiotic impregnated methyl methacrylate spacers are placed into the defect, and external or internal fixation is placed before wound closure. Fixation at this juncture is important to allow motion and prevent stiffness of uninvolved joints during this staged treatment. When cultures are positive, culture-specific antibiotics are started. Otherwise empirical treatment is based on the most likely cause of infection. Infectious disease consultation is recommended. Antibiotics are continued for 4 to 6 weeks postoperatively, and after this course is finished the patient is given a period of 4 weeks free of antibiotics to allow any residual infection to surface. If the patient remains asymptomatic and clinical laboratory markers including erythrocyte sedimentation rate and C-reactive protein have returned to normal, the patient is taken to the operating room for the second stage of the procedure. At this time, cultures are taken intraoperatively and sent for frozen sections. If no infectious material is present, the bone cement is removed and autologous grafting with internal fixation is performed.

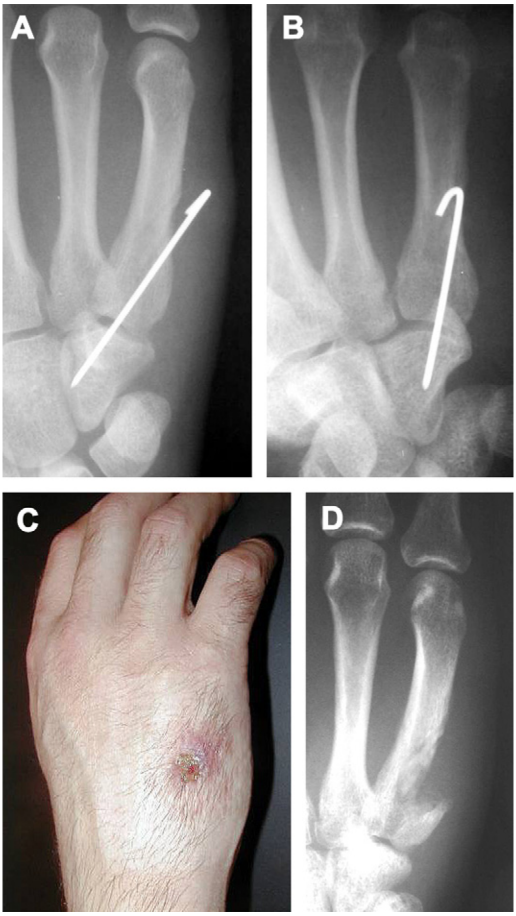

Fig. 1. Osteomyelitis after pinning. (*A*, *B*) Pinning of ring: small carpometacarpal dislocation. (*C*) Drainage from pin site. (*D*) Radiograph taken after pin removal. (*D*) Hypertrophic nonunion.

Nonunion

Nonunion after metacarpal and phalangeal fractures is a rare complication, frequently associated with concurrent soft tissue injury. Nonunions are often found in the setting of nerve injury, infection, and bone loss. Complex open fractures or a devascularizing approach to fixation can also lead to nonunion. Jupiter and colleagues[14] defined nonunion and delayed unions together as those fractures without clinical or radiographic evidence of healing at 4 months after the initial injury. The radiographic evidence of nonunion alone is usually insufficient, as radiographic fracture lines can be present up to 14 months after fracture.[15] Clinical evidence of pain is also unreliable, as many fractures are associated with nerve damage and stiffness that can cause pain. The combination of radiographic and clinical signs is the optimal way to diagnose nonunion. Similar to long bones, the nonunion classification of Weber and Cech can be attributed to hand fractures. These fractures can be defined as hypertrophic or atrophic, and similar treatment principles apply.

In hypertrophic nonunions, stability is often lacking and can result from inadequate immobilization, soft tissue interposition, or failed fixation. Treatment of this uncommon hand injury consists of stable fixation (**Fig. 2**).

Atrophic nonunions occur more frequently as bone loss from penetrating injuries or infection compromises bony apposition (**Fig. 3**). In these cases the fibrous interposing tissues or infection must be debrided, and bone graft must be used to bridge any bone deficiency. Stable fixation techniques can allow for early range of motion and prevention of joint stiffness. Prolonged immobilization is contraindicated in the treatment of nonunions to prevent stiffness. Tenolysis is often needed after surgical treatment of nonunion to improve functional results.[16,17]

Results of surgery for nonunion are sparse in the literature. The series of Smith and Rider[15] has shown that results with bone graft and plate fixation have been superior to Kirschner wire fixation for nonunions. In this study, even optimal treatment resulted in few well-functioning digits. Treatment of nonunion in an insensate digit or with severe soft tissue loss is rarely indicated. Even if bony union is achieved, a nonfunctional digit is a continued liability to the function of the hand.[16]

Fig. 2. (*A*) Radiograph taken 3 months after ring metacarpal shaft fracture; callous seen around fracture. (*B*) Computed tomography scan showing nonunion. (*C*) Treatment with debridement of nonunion and rigid internal fixation.

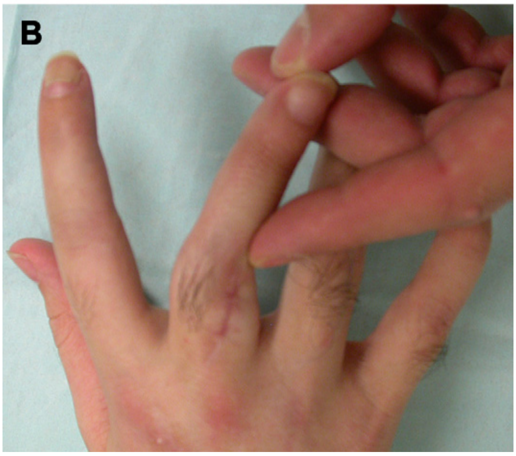

Fig. 3. (*A*) Radiograph of open fracture. (*B*) Nonunion diagnosis after open fracture.

In this setting amputation may provide the best outcome for the patient.

Malunion

Malunion after metacarpal and phalangeal fractures is the most common complication encountered after injury. Deformity can be in the form of shortening, rotation, or angular malalignment. Malunion is usually evident after closed treatment of unstable fractures, but can also arise after failed open reduction and internal fixation. In addition to negative functional effects, deformity may be cosmetically unappealing as well. Although guidelines have been developed to address surgical correction for malunion, treatment must be patient specific; indications must consider patients' vocational and avocational interests and activities, as well as expectations.

METACARPAL

Deforming forces acting on metacarpal fractures often lead to a shortening of the digit after spiral and oblique fractures. Shortening of the digit can alter the intricate balance of digital motion supplied by the extrinsic and intrinsic systems. Extensor tendon dysfunction is more likely than flexor tendon or interosseous muscle dysfunction after shortening of a metacarpal. Strauch and colleagues[18] have demonstrated a 7° extensor lag for every 2 mm of shortening found in metacarpal fractures. The ability of the metacarpophalangeal (MCP) joints to hyperextend on average 20° allows for functionality with some extensor lag. Therefore, a conclusion is drawn that 6 mm of shortening (21° extensor lag) is acceptable, as hyperextension can maintain motion to full extension. With greater than 6 mm of shortening, open reduction and internal fixation should be performed to reduce shortened oblique and spiral metacarpal fractures.

Angular Malunion

Angular malunion can exist in either the sagittal plane or coronal plane, and can cause both functional and cosmetic deficits. Metacarpal shaft fractures are generally angulated in the sagittal plane with an apex dorsal deformity. Acceptable angulation is debatable, but safe ranges allowing normal function range from 10° (index and middle fingers) to 20° (ring fingers) to 30° (small finger).[18] This range reflects the ability of the ring and small finger carpometacarpal joints to compensate for functional loss due to angulation. Often there is a mixed deformity including sagittal and coronal plane deformity; coronal plane is less tolerable and should be corrected if malunion results in angulation of the digit on examination.

Rotational Deformity

Although angular deformity can be compensated by adjacent joint motion, rotational malunion transmits deformity distally to affect the entire digit. For this reason rotational deformity is unacceptable in metacarpal malunion. Evaluation is made with the patient making a fist while monitoring for overlap of the digits and deviance from scaphoid tubercle convergence is conducted. Study of noninjured hands has shown that the contralateral hand can be used to assess rotational deformity when comparing digit rotation and scaphoid convergence. In contrast, digital overlap of the contralateral hand may not be reliable, as there is a high probability of asymmetry between uninjured hands in the same subject.[19] A small amount of rotational malunion that is missed on initial radiographs can cause significant functional impairment, as 5° of malrotation can cause 1.5 cm of digital overlap.[20]

Correction of rotational malunion in the metacarpal can be performed at the site of the previous fracture or more proximal at the base of the affected metacarpal, as described originally by Weckesser.[21] The decision regarding where to perform the osteotomy is dependent on the concurrent angular deformity and the amount of rotation associated with the fracture. In fractures with a mixed deformity of rotation and angulation the osteotomy should be performed at the site of the fracture, as a proximal osteotomy will not address the angular deformity. In a purely rotational metacarpal shaft malunion, osteotomy can be performed at the proximal metaphysis to correct deformities up to 18° to 20° in the affected digit.[22] Fixation can be performed with crossed K-wires or plate-and-screw construct. Although the K-wire fixation may be less invasive, the plate construct can provide stability for early motion. Recent studies have focused on the step-cut osteotomy as described by Manktelow and Mahoney.[23] The step-cut osteotomy is performed at the base of the metacarpal and provides increased bony apposition for healing, and is fixed with simple lag screws thus decreasing the incidence of soft tissue adhesions associated with plate fixation.[24]

PHALANGES

Malunions

Malunions of the proximal phalanx are often categorized into 4 groups: volar angulation, lateral angulation, shortening, or rotation. Malunions are frequently multidirectional (**Fig. 4**). Apex volar angulation is common, as the intrinsic muscles flex the proximal fragment and the extensor tendon pulls proximally on the distal fragment (**Fig. 5**). Failed closed reductions can often lead to malunion. The anteroposterior view often gives a false sense of anatomic reduction, and a lateral radiograph of the isolated digit must be performed to adequately visualize reduction of the volar angulation. The shortening of the digit causes a relative extensor tendon lengthening and a subsequent extensor lag at the proximal interphalangeal (PIP) joint.[25] This extensor lag can develop into a pseudo-claw deformity of the finger as the PIP joint develops a fixed flexion contracture.

Treatment of volar angulated malunion of the proximal phalanx is best performed via a closing wedge osteotomy using the dorsal periosteum as a hinge.[2] The closing wedge osteotomy does not further affect extensor tendon function, as the dorsal length is unchanged when the volar malunion is corrected. Fixation can then be performed with a lateral plate to avoid dorsal tendon adhesion.

Fig. 4. Malunion of proximal phalanx proximal metaphysis fracture.

Lateral angulation of the fractured phalanx is often a result of bone loss on the affected cortex. Clinical evaluation often reveals scissoring of the digits, but can be hidden as neighboring digits are used to trap the digit during flexion into a fist. Surgical treatment is performed using an opening wedge incomplete osteotomy at the concavity of the deformity. The osteotomy should spare the far cortex at the site of the malunion, as this cortex can also be used to hinge the osteotomy open to the correct angulation.[26] Bone graft is then interposed into the defect and a lateral buttress plate is applied. New locking plates can be used laterally or dorsally. Plate fixation must provide a stable construct to start early postoperative motion. In an evaluation of osteotomies performed for bony phalangeal malunions, Büchler and colleagues[26] found a 100% union rate and excellent or good results in 96% of patients.

Intra-articular malunion presents a problem, because an extra-articular osteotomy may correct angulation but will not reduce the articular incongruity.[27] If the fracture line can be identified, an osteotomy can be performed through the articular surface and then securely fixed with a congruent articular surface.[28] Isolated arthrodesis is also an option for chronic malunions at the PIP or distal interphalangeal (DIP) but is poorly tolerated at the MCP joints. In a chronic misaligned intra-articular volar lip fracture resulting in a PIP fracture-dislocation, resection of the middle phalanx base and hemi-hamate arthroplasty has been proven

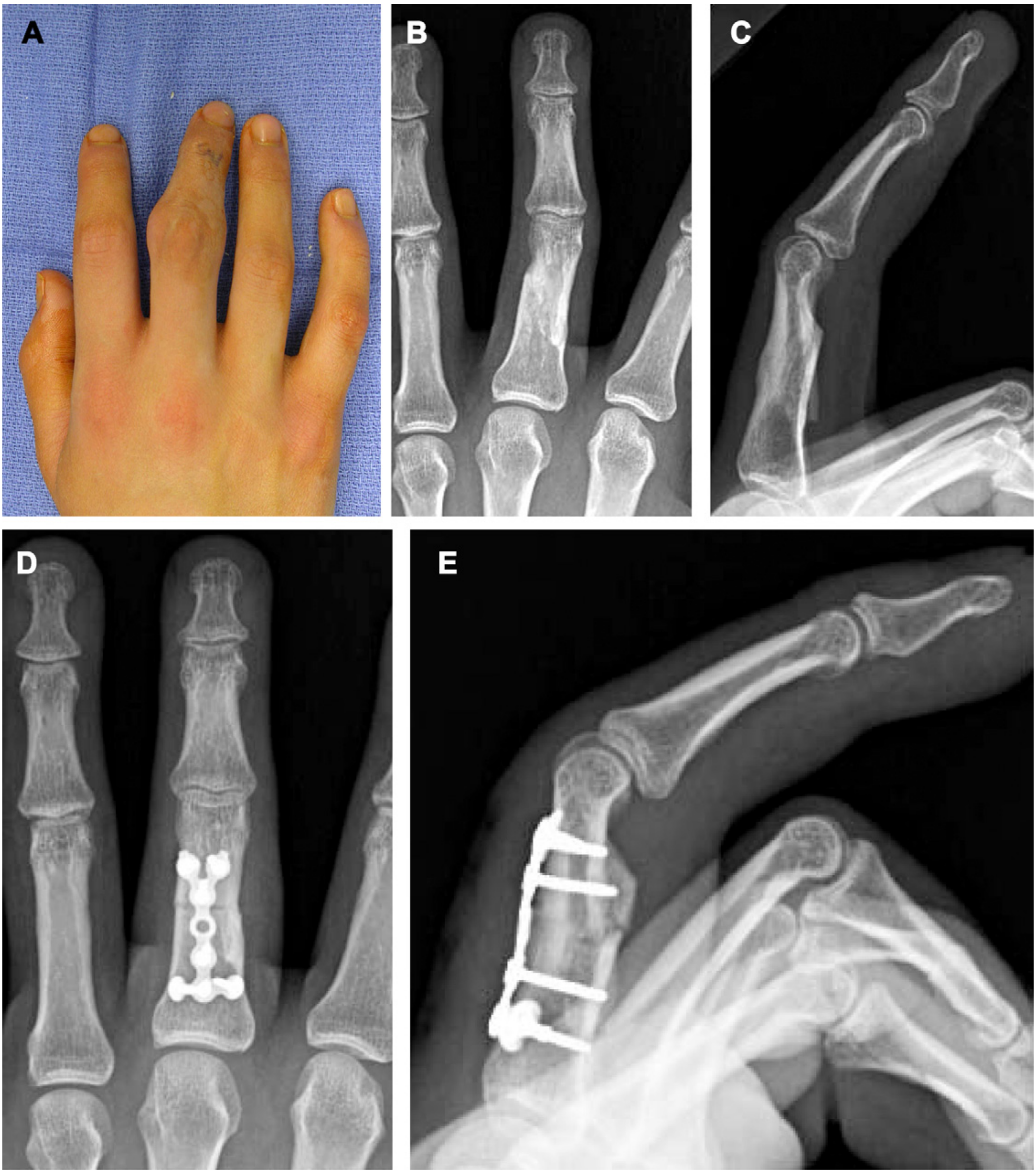

Fig. 5. (*A*) Deviation and rotation of digit. (*B*) Radiograph showing malunion. (*C–E*) Radiographs of multiplanar osteotomy with internal fixation.

to provide restoration of PIP function.[29] Other options for intra-articular malunions include osteochondral autograft and joint arthroplasty.

Stiffness

Stiffness after treatment of hand fractures is a common complication associated with tendon adhesion and immobilization. Conditions that predispose to stiffness include crush injuries, multiple finger injuries, open fractures, and immobilization longer than 4 weeks. Page and Stern[3] reported a significant decrease in loss of motion after plate fixation of phalangeal fractures as opposed to metacarpal fractures. As discussed earlier, the degree of open fracture correlates to postoperative range of motion and postoperative range of motion correlates to patient outcomes. Using total active range of motion as the outcome, Duncan and colleagues[7] reported on 140 open hand fractures. Grade I, II, and IIIA open fractures were associated with 63% good to excellent results. In contrast, grade IIIB and IIIC fractures were associated with 92% poor results. The stripping of periosteum and associated neurovascular injuries contributed to a complex injury pattern often associated with postoperative stiffness.

Principles of preventing joint stiffness are often associated with factors beyond the control of the operating room. Maximizing range of motion after fixation must be considered in the preoperative period. Although the plate-and-screw construct can provide excellent stability for early range of motion, tendon adhesions to the plate and tendon ruptures are encountered The advent of low-profile plates has increased the surgeon's options for fixation. Postoperative splinting in the safe or functional positions avoids stiffness as the MP and IP joints recover easily from flexion and extension, respectively. Close communication with hand therapists and patients concerning treatment goals are imperative to good outcomes. Edema and pain control in the early postoperative period can facilitate early motion. Active and passive range of motion and the use of dynamic splinting can optimize functional use of the hand.

Creighton and Steichen[5] have advocated extensor tenolysis and dorsal capsulotomy for decreased range of motion as a complication of phalangeal fractures. Indications include decreased active and passive flexion with maintained full extension, and a failure to improve in therapy. Soft tissue quiescence is a crucial factor to increase the effectiveness of tenolysis. Quiescence routinely requires a period of at minimum 3 months between procedures. Factors such as absence of erythema, minimal edema, and a mature scar are indicators that the soft tissues can appropriately tolerate another procedure. The technique is to elevate the central extensor tendon and lateral bands over the proximal phalanx and then release the interval between these 2 structures and the bone over the PIP joint. Elevation of the radial and ulnar portions of the terminal extensor tendon allows access to the dorsal capsule of the DIP joint. If the tenolysis alone does note achieve full active and passive range of motion, a dorsal capsulotomy can be performed. The postoperative regimen includes pain management protocols such as a transcutaneous electrical nerve stimulation unit and early range of motion, and is as important for good outcomes as the surgical procedure itself.

Surgeons who treat metacarpal and phalangeal fractures inevitably treat complications associated with these fractures. In all hand fractures the soft tissue component of the injury is directly correlated with outcomes, and should be addressed with the same attention as the fracture itself. Outcomes have improved since the institution of stable fixation and early motion. Further investigation into improved fixation methods, soft tissue handling, and postoperative rehabilitation will provide surgeons with the chances to prevent complications in these difficult fractures.

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