Bone Injuries: Treatment and Rehabilitation

John W. Packer, M.D., and Judy C. Colditz, O.T.R.†*

Restoration of hand function after skeletal disruption must achieve maximum range of motion with solid union of the underlying fractures. Too often the significance of fractures of the hand is underestimated. Correct diagnosis, accurate fracture reduction, and a program of early range of motion are imperative to achieve these goals.

EVALUATION

Physical Examination

A careful review of the mechanism of injury and a physical examination demonstrating swelling, pain, abnormalities in range of motion, and obvious deformity aid in diagnosis.

Recognition of the muscle and tendon forces on fragments of bone that will result in residual deformities of the fracture is the key to appropriate early management. The possibility of tendon rupture or injuries to the interphalangeal joints in certain types of avulsion fractures is always to be considered. Stress views, comparison views of the opposite side, or special rotation views to document subluxation or dislocation are mandatory when proper physical examination is obscured by swelling. The location of the injury may determine that special x-ray views are needed if the fracture is to be properly diagnosed. A true lateral x-ray of the finger is necessary to rule out injuries to the proximal and distal interphalangeal joints (Fig. 1).

Types of Fractures

The configuration of the fracture can present in many different ways (Table 1). Fracture management decisions are altered by whether the fractures are open or closed, stable or unstable, and the expected healing time. Open fractures require special attention to wound care. Closed injuries tend to be more stable because the soft tissue sleeve is not disrupted. Intra-articular fractures always require anatomic reduction. Metaphyseal fractures heal rapidly and do not require more then 2 to 3 weeks immobilization. Diaphyseal fractures more frequently displace and are relatively slow in healing but usually heal sufficiently in 3 to 4 weeks that guarded motion can be instituted.

Whether closed treatment or open treatment is chosen, the type of immobilization or internal fixation must achieve adequate stability of the fracture, proper fracture alignment, and prevention of excessive shortening, angulation, or rotation to allow safe early motion. Intra-articular fractures must have a smooth articular surface to allow unimpeded range of motion of the joint and prevent fibrous ankylosis.

GENERAL PRINCIPLES OF MANAGEMENT

Immobilization

The type and length of immobilization depend upon the location and the type of fracture

*Raleigh Orthopaedic Clinic, Raleigh, North Carolina
†Director, Raleigh Hand Rehabilitation Center, Raleigh, North Carolina

Figure 1. A lateral radiograph of the digit rules out injuries to the interphalangeal joints.

(Table 1 and Fig. 2). Long immobilization periods to gain bony union compromise tendon glide and joint function and prevent the normal pumping action, resulting in edema. Even minor fractures immobilized excessively will have decreased tissue mobility resulting is permanent stiffness. Although proper reduction and bony healing are essential, maintenance of the soft tissue glide is a primary goal for function. One must treat the patient and not the x-ray appearance.

In cases of significant soft tissue injury very early range of motion is necessary if function is to be regained. These fractures are stabilized by the best available means using Kirschner wires (K-wires), plates, or screws. When the fracture is stable guarded motion is begun.

When working to gain early motion one must be assured that the motion is through the adjacent joint rather than at the fracture site. Some reasonable immobilization in unstable fractures is necessary to allow early motion. Frequently open reduction and percutaneous fixation are necessary to accomplish this goal. Early motion prevents flexor and extensor adherence to torn periosteum, healing bone, or scarred tendon sheath.

Positioning

Positioning the wrist in slight dorsiflexion and immediate motion of all joints that do not require immobilization for maintenance of the fracture position will help maintain the normal tenodesis pattern of the hand. Positioning of joints to give maximum length to the collateral ligaments prevents unnecessary stiffness. Collateral ligament tightness preventing full joint motion requires a long course of exercise to overcome, and often static or dynamic splinting is needed to stretch the joint. It is especially important to prevent collateral ligament tightness in the metacarpophalangeal joints where these ligaments require a greater length during flexion (Fig. 3). Unless positioned in flexion, extension contractures are common.

Extensors are normally weaker than the powerful flexors. Wrist extension, interphalangeal extension, and metacarpophalangeal joint flexion maintain the balance of the hand by providing positioning of the motions most difficult to gain. This is referred to as the clam digger or intrinsic plus position. Although this position applies to many types of hand fractures the nature of the fracture may dictate a different position.

Edema Control

Although edema production is a normal response to injury, one's body is unable to isolate the edema and all adjacent tissues become bathed with this protein-rich exudate that forms new tissue. It is mandatory to maintain a minimum amount of edema to maintain joint motion. Immediately after injury, edema control is best accomplished by elevation and appropriate compressive dressings. If any uninjured digits can move, the active range of motion assists in establishing normal pumping action. In addition, when fracture healing has occurred, deep massage of the local tissues will assist the pumping action. Edema does not have to be grossly evident to prevent full range of motion. Because many fractures are sustained as a result of a crushing force, chronic edema often hinders full return of motion.

Pitting edema can best be treated by intermittent positive pressure with the Jobst pump (Fig. 4) followed by active range of motion, massage, compressive dressings, and continued elevation. Longer standing, more fibrotic edema responds best to deep massage, active and active resistive range of motion, and continuous application of pressure. Generalized hand edema is best controlled by an elastic Isotoner or Jobst glove. Digital edema is managed by a self-adherent Coban wrap. These elastic wraps maintain pressure while still allowing unimpeded motion. Many times these wraps are worn until the range of motion has returned to normal.

Other Factors Relating to Fracture Treatment

The patient's age is a great influence on healing time with youngsters healing more rap-

Table 1. *Configuration of Fractures in the Hand*

TYPE	CHARACTERISTICS	HEALING TIME
Greenstick (torus) fracture: Incomplete fracture which passes only part way through the bone, leaving one cortex incompletely fractured. Usually occurs in children (Fig. 2*A*).	Recurrence of angulation occurs unless fracture of both cortices complete.	Rapid to heal. Allows early mobilization within 1–2 wks.
Transverse fracture: Fracture line is perpendicular to long axis of bone, extending completely through the bone (Fig. 2*B*).	Angulation or rotation occurs easily. More stable if in metaphyseal area or has serrated edge. If tendency to angulate: Kirschner wire or plate fixation	Slow healing in diaphyseal area. Internal fixation allows joint motion before healing complete. May begin motion at 3 wks.
Oblique fracture: Fracture line at an oblique angle to long bone axis; may or may not have intra-articular component (Fig. 2*C*).	Muscle attachment may cause angulation. Shortening a common problem. Screw or Kirschner wire fixation necessary to begin early range of motion.	Large area of bone contact allows early healing. Begin gentle range of motion at 3 wks. Earlier with internal fixation.
Spiral fracture: Fracture line twists around and through the long bone axis (Fig. 2*D*).	Unstable: twists on itself. Causes rotation and shortening. Screw or Kirschner wire necessary for early range of motion.	Heals rapidly if stabilized. Gentle motion at 3 wks. Earlier with internal fixation.
Comminuted fracture: Broken into more than two pieces. May have multiple directions of fracture lines (Fig. 2*E*).	If unstable, allows shortening, malrotation, and/or angulation. External fixator, screws, Kirschner wires, or plates may be necessary.	Slow healing rate: Blood supply to fragments disrupted. Associated with soft tissue injury. If unstable maintain fixation 6 to 8 wks. Move uninvolved joints earlier.
Impacted fracture: End of fragments jammed into each other (Fig. 2*F*).	Usually stable. Shortening sometimes a problem. Excessive angulation requires disimpaction. Fixation with cast or splint.	Healing rapid Start immediate motion of uninvolved joints.
Intra-articular fracture: Fracture line extends into the articular cartilage. Joint surface may be irregular (Fig. 2*G*).	Anatomical reduction mandatory. If unstable or displaced requires open reduction internal fixation or traction.	Early motion necessary. Start after initial swelling controlled.
Avulsion fracture: Small fragment of bone pulled away from large bone where ligament or tendon attaches (Fig. 2*H*).	Open reduction internal fixation with suture, Kirschner wire, or screw frequently necessary to allow early range of motion. Often leads to late deformity.	Avoid stress to tendon or ligament: Four to six weeks. Start range of motion first week.
Segmental loss: Loss of bone associated with open injury (Fig. 2*I*).	Unstable: Shortening occurs if length not maintained. External fixator, wire spacer, or interposition graft maintains length.	Requires bone graft when soft tissue coverage stable. Maintain long term fixation for avascular fragments. If stable fixation start immediate range of motion.
Multiple fractures: More than one phalangeal or metacarpal fracture in same hand (Fig. 2*J*).	Difficult to control deformity and stabilize without internal fixation. Kirschner wires, plates, or screws needed.	Early motion of all joints after fixation. Control edema.
Pathologic fracture: Fractures through area of bone weakened by tumor, disease, or disuse (Fig. 2*K*).	Requires little force to fracture. Usually stable. Fixation depends on cause of fracture.	If stable begin immediate motion. Avoid stress to adjacent weakened areas.

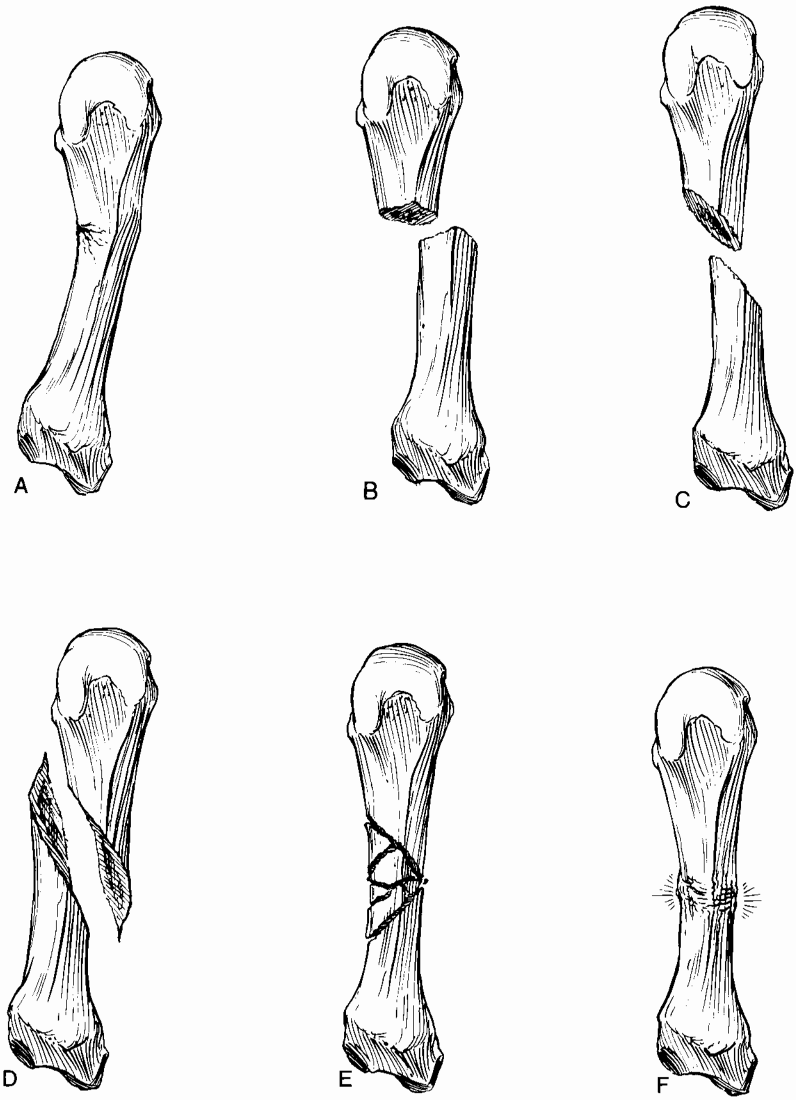

Figure 2. The configuration of fractures in the hand is shown. *A*, Greenstick fracture. *B*, Transverse fracture. *C*, Oblique fracture. *D*, Spiral fracture. *E*, Comminuted fracture. *F*, Impacted fracture.

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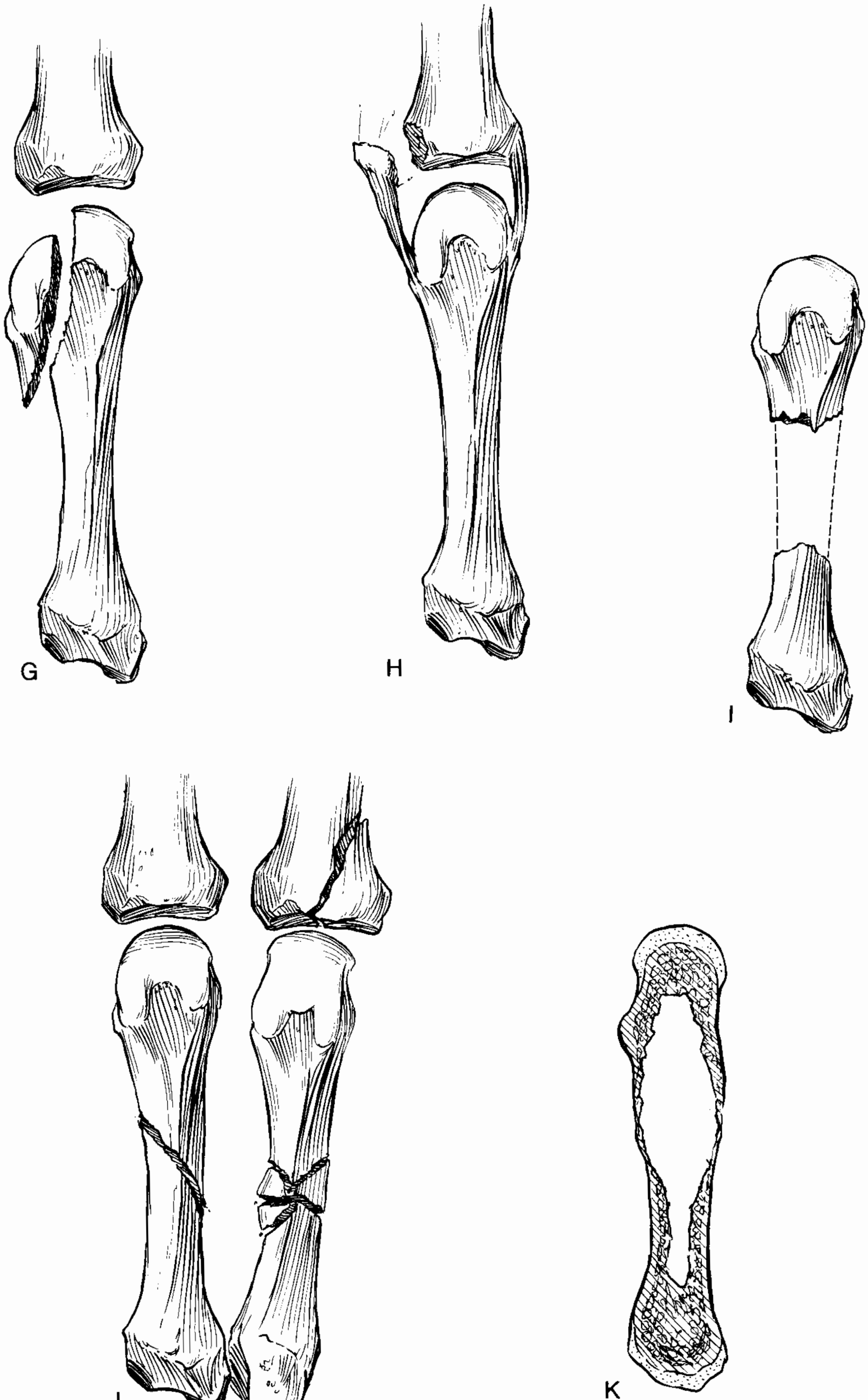

Figure 2 (*Continued*). *G*, Intra-articular fracture. *H*, Avulsion fracture. *I*, Segmental loss. *J*, Multiple fractures. *K*, Pathologic fracture.

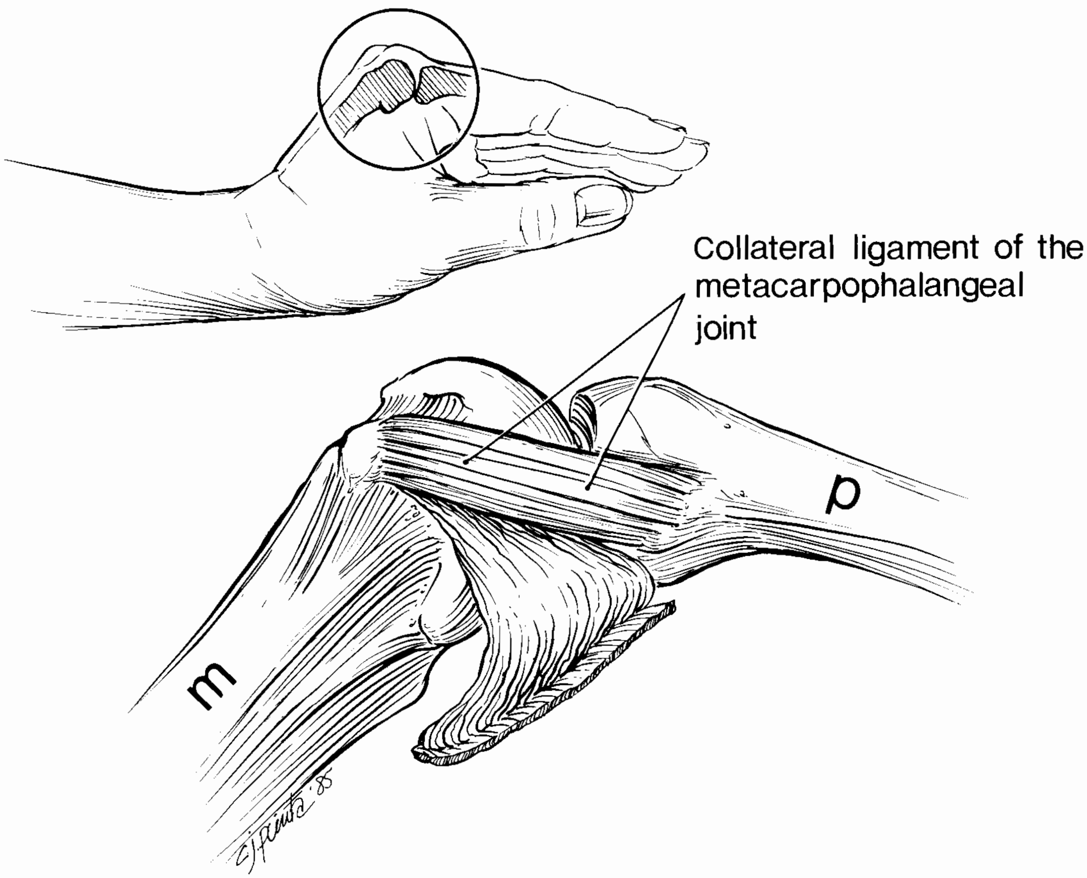

Figure 3. Positioning the wrist and interphalangeal joints in extension while holding the metacarpophalangeal joints flexed maintains all collateral ligaments at their maximum length. (M = metacarpal; P = phalanx)

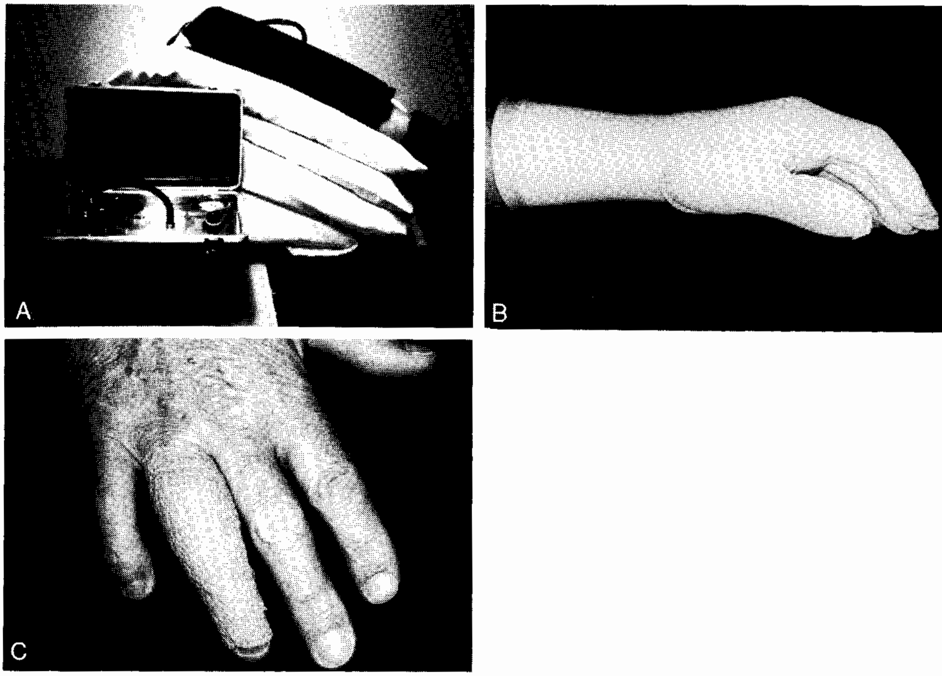

Figure 4. The Jobst pump *(A)*, elastic gloves *(B)*, and Coban wraps *(C)* are useful tools in controlling edema.

idly and thus tolerating immobilization without complications better than older adults. Associated arthritic problems which already inhibit normal joint mobility are exacerbated by unnecessary immobilization. The patient with thick palmar fascia, whether or not they have documented Dupuytren's contracture, will have a tendency to develop stiffer joints and thus need earlier than usual mobilization.

Patients must be properly motivated to be willing to work through the initial periods of weakness and stiffness. Rehabilitation is often hindered by persons receiving secondary gain from the increased attention and care they discover as a result of their injury or from monetary gains while disabled or out of work.

REHABILITATION TECHNIQUE

Early Motion

Early motion is that motion which is encouraged in the joints adjacent to a fracture as soon as one can achieve reasonable fixation or healing of the fracture, allowing the motion through the joint rather than the fracture site. In the hand this can usually begin by 3 weeks, or earlier if the fracture is quite stable. Fractures at this time cannot tolerate the stress of normal activity but can tolerate the compressive forces of active contraction of the flexor and extensor tendons. Protective splinting or a cast brace is continued at all times except when this specific exercising is being done. If the fracture has questionable stability it is advisable for active range of motion to be done only while the therapist or patient is manually stabilizing the fracture site (Fig. 5). Early motion of an improperly stabilized fracture creates unnecessary stimulation of edema, which results in increased stiffness. Frequently this early motion of an unstable fracture results in malunion or nonunion.

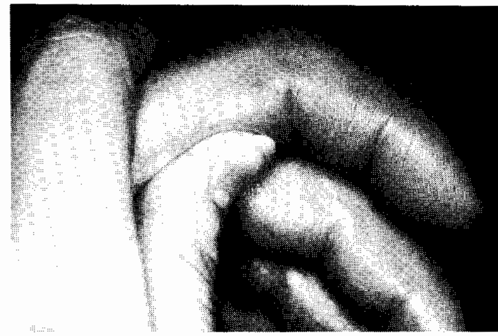

Figure 5. Early active motion may be performed with manual stabilization of the fracture.

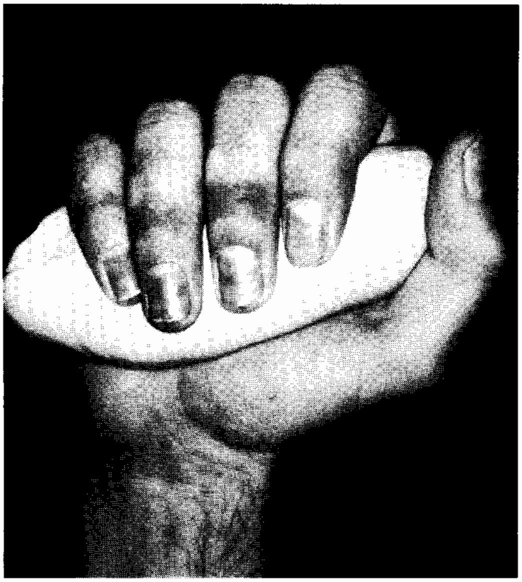

Figure 6. Use of soft putty facilitates early finger flexion after fracture immobilization is discontinued.

Weakness secondary to the immobilization impedes the gain of full tissue glide. Early range of motion helps maintain the muscle tone. Although no forceful passive range of motion should be done, it is acceptable to block proximal joints to gain better distal range of motion by demanding glide of the tendons across the fracture site. When bony union is present and protective immobilization is discontinued, one may begin extremely gentle passive range of motion beyond the range easily accomplished actively.

Soft putty or similar light resistive material may be used when immobilization is discontinued (Fig. 6). Activities requiring some resistance at the end of the available active range are encouraged to assist the patient in gaining increased motion. Heavy resistance and more vigorous passive motion are not appropriate until bone healing is mature. Obtaining full joint range of motion always supercedes strength and endurance activities.

Splinting to Gain Range of Motion

In simple fractures that are properly immobilized, full motion is usually regained by an active and passive range of motion program. In many fractures, however, splinting is necessary to achieve full joint motion. During early motion programs the protective static splint can be altered to assist in gaining a position of full extension or flexion. Static splints are used to hold the joint in a specific position and serially changed to gently move the joint position before the fracture can tolerate any force. Aluminum foam splints are good for this use. Protective extension splinting with intermittent active flexion exercises is a good method to minimize joint contractures in digital injuries.

If the patient is having difficulty gaining full passive motion after the immobilization has been discontinued for approximately 2 weeks or progress is extremely slow or not improving, then a dynamic splint can stretch the capsular structures into either flexion or extension. A spring wire splint for proximal interphalangeal joint extension, a dynamic proximal interphalangeal joint flexion splint with metacarpophalangeal block, and a metacarpophalangeal flexion splint are frequently used (Fig. 7).

Serial casting is often more effective if the joint contracture is unyielding to dynamic splinting, is of a long standing nature with distinct resistance to stretch, or the injury has associated soft tissue involvement. Cylinder casts for the proximal interphalangeal flexion contractures are well accepted (Fig. 8). Serial casts can also be effective in gaining wrist extension, metacarpophalangeal flexion, or thumb abduction/extension. These casts are not recommended for gaining finger flexion because constant maximum flexion is too constrictive to the digit, causing pressure necrosis.

Any splinting program should focus on gaining the motion most difficult to gain actively, but periods in the splint must be balanced with a program of active and active resistive motion so the glide of tendons follows the gains made in passive joint range of motion.

SPECIFIC FRACTURES

Distal Phalanx

Most fractures of the distal phalanx are of the stellate type at the terminal end of the phalanx and usually heal without great difficulty. The fractures in the midshaft diaphyseal portion frequently result in nonunion or delayed union. It is important that the immobilization of the distal phalanx fracture allows full range of the proximal interphalangeal joint. Accompanying soft tissue injuries resulting in scar of the distal tuft or deformity of the nail bed are common problems. Massage and direct use of the pulp for pinching activities will help mobilize the soft tissue pulp.

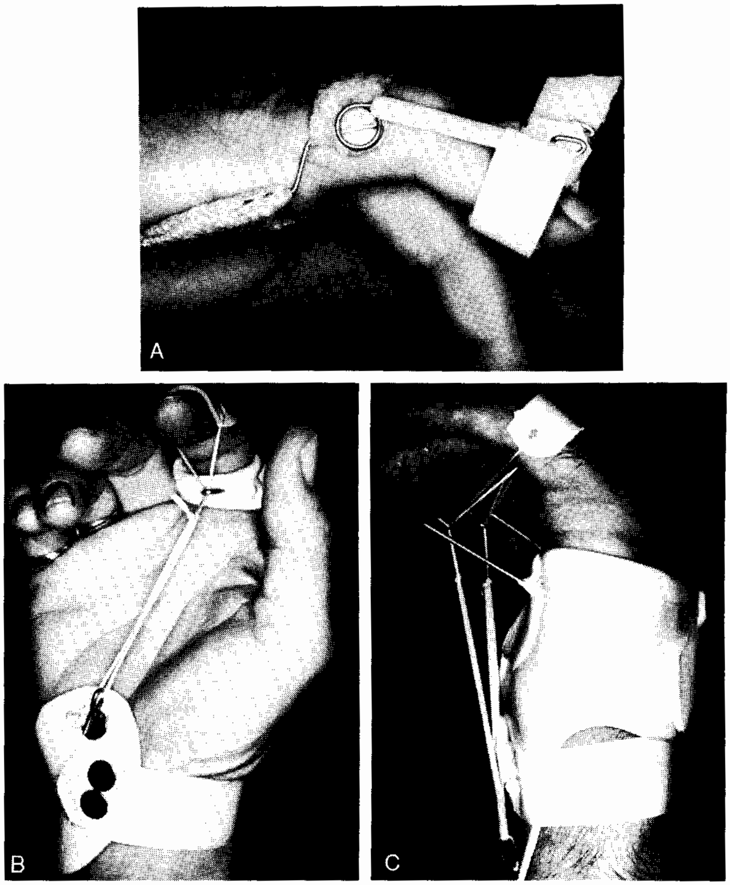

Figure 7. Splint's to gain increased range of motion following fractures are as follows: Spring wire extension splint for proximal interphalangeal extension *(A)*, dynamic proximal interphalangeal flexion splint with metacarpophalangeal block *(B)*, and dynamic metacarpophalangeal flexion splint *(C)*.

Middle and Proximal Phalanx

Anatomic reduction is important in fractures of both the middle and proximal phalanges due to their proximity to the articular surfaces and the gliding flexor and extensor tendons. Whenever possible these fractures are reduced by closed means. Unstable fractures, however, require open reduction or percutaneous fixation to restore stability and allow early motion. Care must be taken to minimize the additional scar created by the surgery.

Long-term problems from fractures of the middle phalanx are usually adherence of the extensor tendon over the fracture site preventing full flexion of the distal interphalangeal joint (Fig. 9). The most common late complication of the proximal phalanx fracture is a residual flexion contracture of the proximal interphalangeal joint.

If a stable reduction of a proximal phalanx fracture can be accomplished, the metacarpophalangeal joint should be held in 70° of flexion and the involved finger buddy-taped to the adjacent finger to prevent malrotation. Maintaining this position in a cast or splint allows early proximal interphalangeal joint motion, preventing adherence of the flexor and extensor tendons to the underlying periosteal disruption at the fracture site.

Metacarpal Fractures

Stable metacarpal fractures without malrotation can usually be treated by external splinting and edema control. Unstable fractures or multiple metacarpal fractures require fixation to allow early motion.

Metacarpal fractures are frequently associated with a dorsal crushing blow and thus result in significant dorsal edema. The most common complications are adherence of the extensor tendons and contracture of the metacarpopha-

Figure 8. Serial cylinder casting is used for residual flexion contractures of the proximal interphalangeal joints.

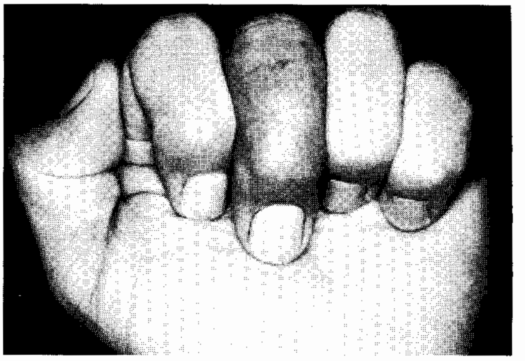

Figure 9. A frequent complication of a fracture of the middle phalanx is tenodesis of the extensor tendon, which prevents full distal interphalangeal flexion.

langeal joints in extension. Early motion prevents tendon adherence. Intrinsic muscle tightness is frequently seen with these injuries because of the direct trauma and intramuscular swelling. One should be aware of the possibility of a compartment syndrome and the need for a fasciotomy.

Malrotation and shortening of the metacarpal fractures is common. Although shortening of the metacarpal can be tolerated and still maintain full function, a 5° to 10° rotational deformity will cause overlapping of the fingers. Comparison of the rotation of the nail beds and individual finger flexion pointing toward the tuberosity of the scaphoid should always be observed to prevent this problem.

Fracture of the Thumb

Fractures of the thumb phalanges closely follow the principles of fracture management in the fingers. The thumb is more forgiving of a decreased range of motion due to the motion of the carpometacarpal joint and the priorities are maintenance of a good articular surface and full motion of this joint.

Fractures of the Carpals

Fractures of the carpals are the most difficult area for correct diagnosis due to the small bones and the difficulty seeing fracture lines on radiographs. Scaphoid fractures are the most common injury. Delayed union or nonunion are common complications, requiring electrical stimulation or bone grafting to stimulate healing.

Distal Radial Fractures

Common distal radial fractures, such as the Colles fracture, may be considered a hand in-

Figure 10. Activities requiring finger flexion with wrist extension facilitate return of function to the hand following a wrist fracture.

jury because edema and decreased motion of the hand are frequent complications. Appropriate fracture reduction requires maintenance of the wrist in a flexed position, thus preventing the normal tenodesis pattern of the hand. With the wrist flexed it is difficult to achieve full finger flexion and thus edema cannot adequately be pumped by active finger flexion.

Significantly displaced fractures of the distal radius are associated with excessive soft tissue swelling and compression of the median nerve. Joint stiffness complications are more common in these patients. Early edema control is mandatory. It is appropriate for patients to be referred to therapy while still in the cast to work on edema reduction of the digits and full motion of the joints not immobilized by the cast.

As early as can safely be accomplished, the wrist should be brought out of its flexed position to facilitate finger motion. The cast holding the wrist fracture should allow full metacarpophalangeal flexion, and the patient should be instructed in exercise for full finger flexion.

A common problem after removal of the cast is the substitution of the finger extensors for the action of the wrist extensors, as these have been unable to function in the cast. Activities that require finger flexion concurrent with wrist extension are recommended to reestablish the normal tenodesis pattern (Fig. 10). Edema control and finger range of motion are immediate priorities before a specific range of motion program for the wrist is begun.

SUMMARY

Solid bony union with full range of painless motion is accomplished by correct early diagnosis, adequate reduction, stable fixation, prevention of edema, and institution of early motion programs. The degree of bony injury and involvement of multiple tissues will dictate the type of fixation and length of immobilization. Restoration of a stable skeleton with a functional range of joint motion must always be accomplished.

REFERENCES

1. Bell, J. A.: Plaster cylinder casting for contractures of the interphalangeal joints. *In* Hunter, J. M., Schneider, L. H., Mackin, E. J., et al. (eds.): Rehabilitation of the Hand. St. Louis, C. V. Mosby, 1984.
2. Cailliet, R.: Fractures and dislocations of the fingers and hand. *In* Cailliet, R. (ed.): Hand Pain and Impairment. Edition 3. Philadelphia, F. A. Davis Co., 1982.
3. Colditz, J. C.: Dynamic splinting of the stiff hand. *In* Hunter, J. M., Schneider, L. H., Mackin, E. J., et al. (eds.): Rehabilitation of the Hand. St. Louis, C. V. Mosby, 1984.
4. Colditz, J. C.: Spring-wire splinting of the proximal interphalangeal joint. *In* Hunter, J. M., Schneider, L. H., Mackin, E. J., et al. (eds.): Rehabilitation of the Hand. St. Louis, C. V. Mosby, 1984.
5. Eaton, R. G., and Malerich, M. M.: Volar plate arthroplasty of the proximal interphalangeal joint: A review of ten year's experience. J. Hand Surg., *5*:260–268, 1980.
6. Green, D. P., and Rowland, S. A.: Fractures and dislocations in the hand. *In* Rockwood, C. A., and Green, D. P. (eds.): Fractures. Philadelphia, J. B. Lippincott Co., 1984.
7. Huffaker, W. H., Wray, R. C., and Weeks, P. M.: Factors influencing final range of motion in the fingers after fractures of the hand. Plast. Reconstr. Surg., *6*:82–87, 1979.
8. Milford, L.: The hand. *In* Edmonson, A. S., and Crenshaw, A. H. (eds.): Campbell's Operative Orthopaedics. Edition 6. St. Louis, C. V. Mosby Co., 1980.
9. O'Brien, E. T.: Fractures of the metacarpals and phalanges. *In* Green, D. P. (ed.): Operative Hand Surgery. New York, Churchill Livingstone, 1982.
10. Opgrande, J. D., and Westphal, S. A.: Fractures of the hand. Orthop. Clin. North Am., *14*:770–791, 1983.
11. Reynolds, C. C.: The stiff hand. *In* Malick, M. M., and Kasch, M. C. (eds.): Manual on Management of Specific Hand Problems. Pittsburgh, AREN Publications, 1984.
12. Weeks, P. M.: Acute Bone and Joint Injuries of the Hand and Wrist. St. Louis, C. V. Mosby Co., 1981.
13. Wilson, R. L., and Carter, M. S.: Management of hand fractures. *In* Hunter, J. M., Schneider, L. H., Mackin, E. J., et al. (eds.): Rehabilitation of the Hand. St. Lonis, C. V. Mosby Co., 1984.

Raleigh Orthopaedic Clinic, P. A.
P. O. Box 10707
Raleigh, North Carolina 27605