Metacarpal Fractures

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The majority of metacarpal fractures are closed injuries amenable to conservative treatment with external immobilization and subsequent rehabilitation. Internal fixation is favored for unstable fracture patterns and patients who require early motion. Percutaneous pinning usually is successful for metacarpal neck fractures and comminuted head fractures. Shaft and base fractures can be treated with pinning or open reduction and internal fixation; the latter, being more rigid, allows early rehabilitation. External fixation has a limited yet defined role for metacarpal fractures with complex soft-tissue injury and/or segmental bone loss. The recent development of bioabsorbable implants holds promise for skeletal rigidity with minimal soft-tissue morbidity, but long-term in vivo data supporting the use of these implants is not currently available.

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Early treatment of metacarpal fractures was limited to the only tools available: manipulation and casting. The discovery of percutaneous fracture fixation near the turn of the century opened up a new world of possibilities. It was 25 years after Bennett's original manuscript that Lambotte described the first surgical stabilization of a basilar thumb fracture by using a thin carpenter's nail.1 By 1913, Lambotte had authored a fracture text with multiple examples of pinning, wiring, and plating of hand fractures. Tennant2 published encouraging results of metacarpal fixation with smooth steel phonograph needles in 1924. Shortly thereafter, Kirschner developed a set of wires in variable diameters to address the fixation needs of small bones in the hand.1 Surgical techniques rapidly expanded to include retrograde fracture pinning, intramedullary pinning, and transfixed pinning. Many of the K-wires in use today have the same diamond-shaped tip and sizing specifications as the original design.

The first plate and screw set for the hand was introduced in the late 1930s. By today's standards, the Hermann Metacarpal Bone Set was quite lean; it included 3 longitudinal plates of 2, 3, and 4 holes, a drill, screwdriver, and 9 screws.1 Improvements in design and metallurgy have led to lower profile implants and choices for plate size, shape, and composition. Application of rigid internal fixation principles and meticulous soft-tissue handling techniques has produced superior clinical and biomechanical results for plate and screw fixation of metacarpal fractures.3,4 Pins, screws, and plates could not conquer all metacarpal fractures. The first reports of homemade external fixators surfaced in the 1970s when Crockett5 used K-wires connected by an acrylic resin to span segmental metacarpal defects. Lessons learned from external fixation in other parts of the bony skeleton were subsequently borrowed for the design and application of miniframes for the hand. Current models provide
the rigidity, modularity, and versatility necessary for managing difficult hand fractures.

Techniques for intraosseous wiring of fractures were drawn from oral-maxillofacial surgery experience. Lister popularized these methods as an alternative to plate and screw fixation in the 1970s. Biomechanical studies have shown that the strength of a composite K-wire extraosseous tension band or intraosseous wiring alone can equal that of a dorsal plate and screws. This simple, readily available material remains a useful tool in the surgeon’s armamentarium.

The most recent chapter in metacarpal history involves the introduction of bioabsorbable implants. Much like the Hermann set, early options are limited. However, the audience is eager to learn more. Clinical trials are needed to test this new product line against established techniques of pinning, plating, and wiring for metacarpal fractures.

**Surgical Considerations**

Many metacarpal fractures can be treated adequately by closed methods. Initial immobilization in the intrinsic plus position (80° metacarpophalangeal flexion and full interphalangeal extension) is recommended to avoid tightening of the collateral ligaments and digital stiffness. Conversion to a short cast with the metacarpophalangeal (MCP) and interphalangeal joints free is contingent on fracture location, stability, and patient compliance.

Recognition of the extent of associated soft-tissue injury is fundamental to metacarpal fracture management. Open wounds, traumatic arthrotomy, and tendon lacerations may necessitate access for wound care or early mobilization. Treatment methods should be selected to manage both the fracture and the less-forgiving soft-tissue envelope. The more extensive the soft-tissue injury, the more rigid should be the fixation.

**Metacarpal Head Fractures**

Metacarpal head fractures are uncommon and can be challenging to treat. Several patterns have been described: epiphyseal (Salter Harris type III), osteochondral, collateral ligament avulsion, coronal/sagittal/transverse split, and comminuted head fracture. Among these, the comminuted head fracture is the most prevalent. A Brewerton view is useful for detecting subtle articular fractures; for this projection, the patient’s fingers lie flat on the cassettes, the MCP joints are flexed to 65°, and the beam is angled 15° ulnar to radial. Nonsurgical treatment is indicated for closed fractures with articular congruency, demonstrated MCP stability by stress testing, and less than 20% articular surface involvement. Surgical treatment is recommended for fractures with greater than 1 mm of articular step-off; closed reduction is insufficient to maintain alignment in these cases. When fixation is required, the decision between pins, screws, and plates depends on the size and number of fracture fragments. Large, 2-part fractures are amenable to fixation with small (less than 2.0 mm) screws. A minicondylar plate is useful in sagittal and coronal patterns and head fractures with proximal metaphyseal extension. Highly comminuted head fractures fare better with percutaneous pinning than open reduction because of the risk for avascular necrosis. In rare circumstances, external fixation is required for wound management or treatment of segmental bone loss. Primary silicone arthroplasty has been described for comminuted metacarpal head fractures with the caveat that it be limited to the long and ring finger and avoided in the thumb, index, and small finger where stability is paramount.

**Metacarpal Neck Fractures**

Fractures to the metacarpal neck (boxer’s fractures) result from axial loads applied to a clenched fist. Closed fractures typically angulated to an apex dorsal position owing to the deforming force of the interosseous muscles. Criteria for acceptable reduction vary in proportion to the compensatory mobility at the carpometacarpal (CMC) level. The index and middle fingers have minimal CMC motion and can accommodate less than 15° of flexion deformity. The ring finger can tolerate less than 30° of flexion deformity, and the small finger less than 50° of flexion deformity. Lesser amounts of flexion are permissible with more proximal neck/shaft fractures because the distal displacement is increased with proximal fractures. Anatomic rotational alignment must be restored to avoid digital overlap. Closed reduction can yield satisfactory results; however, secondary displacement is common. Sage advice comes from Hunter and Cowen who recommend that if a patient can fully extend the small finger without any tendency to lag then the patient is best treated closed. Irreducible fractures can be treated by open reduction with pin-
Open fractures to the metacarpal head/neck area, especially those resulting from fist fights, mandate exploration to exclude involvement of the MCP joint and/or extensor mechanism. Delayed presentation of metacarpal neck fractures occurs commonly; the one study that specifically addresses this issue points out the futility of manipulative reductions if the fracture is more than 7 to 10 days old.

Metacarpal Shaft Fractures
Fractures of the metacarpal shaft can be spiral, oblique, transverse, or comminuted. Closed reduction and casting yields satisfactory results when length, rotation, and alignment can be maintained. Spiral fractures in the border digits (index, small) often shorten and rotate, necessitating fixation. Shortening in excess of 3 mm alters the length-tension relationship of the intrinsics sufficiently to affect function; reduction and fixation is recommended. As described with metacarpal neck fractures, correct rotation is necessary to prevent digital scissoring. Freeland et al point out that 10° of rotation is equal to 1.5 cm of digit overlap in a clenched fist. Acceptable angulation has been noted to be less than 10° in the index and middle fingers, less than 20° in the ring and small fingers, however, this may be too liberal in proximal shaft fractures in which increased limb length leads to greater prominence of the metacarpal head in the palm of the hand. Several options exist for fracture fixation: percutaneous pins, intramedullary pins, crossed wires, lag screws, and external fixation. Percutaneous pinning is useful when early mobilization is not essential. Open reduction is recommended in cases of multiple metacarpal fractures when the support of the intermetacarpal ligaments has been lost. Wires, screws, and plates require significant exposure but can produce rigid constructs to facilitate early motion. External fixation is reserved for fractures with segmental bone loss or exposed dorsal structures requiring access for wound care. Composite tissue loss (bone, tendon, neurovascular, or skin), so-called combined-complex injuries, can be managed either in a staged fashion or in a single setting dependent on the expertise and tenacity of the surgeon. Both approaches, when performed well, provide acceptable results.

Extra-Articular Metacarpal Base Fractures
Metacarpal base fractures can be subdivided into extra- and intra-articular types. Most extra-articular fractures are stabilized by the intermetacarpal ligament and are only minimally displaced. If rotational alignment is preserved, cast immobilization is sufficient. An extra-articular fracture of one metacarpal can be associated with a CMC dislocation of the adjacent digit. Percutaneous pinning is useful to maintain alignment at the fracture and the dislocation site after closed reduction. Many thumb metacarpal fractures occur at the proximal metaphyseal-diaphyseal junction, resulting in an apex dorsal pattern with distal adduction and flexion. Remarkably, up to 30° of angulation is acceptable. The deformity in this location is compensated well by the mobility of the thumb CMC joint. When deformity exceeds 30°, a hyperextension deformity can develop at the MCP level and therefore reduction is indicated. Percutaneous pinning is occasionally required to maintain reduction of an unstable thumb epibasilar fracture; open reduction rarely is required.

Intra-Articular Metacarpal Base Fractures
Intra-articular metacarpal base fractures are high-energy injuries. They are associated with CMC dislocations and occur most commonly in the ring and small fingers. In the small finger, the extensor carpi ulnaris, flexor carpi ulnaris, and abductor digiti minimi exert deforming forces on the fracture fragment. The obliquity of the hamate-ring metacarpal articulation facilitates proximal subluxation. Although occasionally successful, closed reduction is usually insufficient to maintain congruity at the CMC joint. Indications for surgical intervention include joint subluxation or incongruity. Percutaneous pinning is preferable to open reduction if the articular surface can be restored adequately.

Intra-articular metacarpal base fractures are uncommon at the index and middle fingers. Treatment principles are similar to those described for ulnar-sided injuries. In both cases the deforming force is dorsal and fixation usually is required for maintenance of reduction. Because of the proximity of the deep palmar arch and the motor branch of the ulnar nerve at the third metacarpal base, open reduction is preferable to closed reduction in this location. Percutaneous pins provide adequate fixation. In cases of comminuted fracture dislocations, 2 approaches have been champi-
tioned; the first is reduction, pin fixation, and, later, arthrodesis if pain persists; the second is primary arthrodesis of the index or middle CMC joints. The second approach allows aggressive mobilization of the extremity and an early return to unlimited activity.21,23 Intra-articular base fractures without dislocation also can occur after avulsions of the wrist extensors. For small fractures with preserved joint congruency, immobilization with the wrist extended at 20° to 30° is indicated. Although the percentage of intra-articular involvement associated with an unstable joint is not known, Stern25 suggests that avulsion fractures involving greater than 20% of the articular surface benefit from open reduction and internal fixa-

**Technical Aspects**

**Closed Reductions**

Jahss27 described a simple closed reduction maneuver for metacarpal neck fractures in 1938. Axial traction is used to disimpact the fracture, followed by digital flexion to 90° at the MCP and 90° at the proximal interphalangeal joint. The proximal phalanx then functions as a joystick for the fractured head because of the tightness of the MCP ligaments in flexion. Dorsally directed pressure combined with rotatory force (if necessary) allows reduction. Immobilization in the intrinsic plus position (MCP joint flexed 90°) with an ulnar gutter cast reduces the deforming forces of the interosseous muscles, maintains fracture rotation, and places the collateral ligaments under proper tension. The proximal interphalangeal joint is either left free or immobilized in extension. Commercially available braces are available but should be used with caution. Even when applied properly, pressure from these splints can break down the thin skin over the dorsum of the metacarpal head and neck and tend to immobilize the MCP joint in extension (Fig 1).

Closed reduction of metacarpal shaft fractures is performed with longitudinal traction, dorsal pressure at the fracture site, and rotation as needed. Three-point molding is useful for transverse patterns: dorsal pressure at the fracture site and palmar pressure proximally and distally. The counterpressure molds proximally and distally should be placed at a maximal distance from the fracture site for best results.

Metacarpal head and extra-articular base fractures typically require longitudinal traction only. Finger trap traction is simple, effective, and particularly helpful when no assistant is available. Although reduction closed maneuvers may reduce these fractures they usually require internal fixation.

Successful closed reduction of the intra-articular CMC base fractures of the central digits is possible with axial traction and dorsal pressure. The thumb and small finger intra-articular base fractures, lacking ligamentous support, are prone to subluxation. For Bennett’s fractures, the reduction maneuver involves a combination of traction, abduction, and pronation. In reverse Bennett’s fractures, the deforming force is the extensor carpi ulnaris tendon. Accordingly, the reduction maneuver involves traction, ulnar deviation, and radially directed pressure on the metacarpal shaft frag-
ment. Performing this reduction with the MCP joint assists proper rotational alignment of the 3 fingers. Even if the reduction is successful, cast immobilization should be pursued cautiously. The potential for secondary displacement is so high that weekly radiographs of the fracture should be taken for a minimum of 3 consecutive weeks. Any displacement should be treated with repeat reduction and percutaneous pinning for small fractures and lag screw fixation for larger fractures.

**Percutaneous Pin Fixation**

Many types of metacarpal fractures are amenable to percutaneous pinning. Smooth 0.9- to 1.1-mm (0.035- to 0.045-in) K-wires are appropriate for fixation of the metacarpal base, shaft, and neck levels. Smaller pins are needed in pediatric populations. Table 1 lists the conversion of English to metric K-wire diameters.

Pins with trocar and diamond-shaped tips have greater pullout strength immediately after drilling and at 3 weeks compared with manually cut pin tips. If retrograde pinning is planned, a set of double-ended K-wires should be available. In addition, experimental data supports higher pullout strength among pins inserted at low drill rpm compared with those inserted at high rpm. In sites where nerve injury is possible, a nick-and-spread technique is useful to clear soft tissues from the area. Drill guides and hypodermic needles work well as soft-tissue protectors and facilitate pin insertion, especially when the pin is directed at acute angles to the bone (Fig 2). A 14-gauge hypodermic needle accommodates a 0.9-mm (0.035-in) K-wire. Once placed, pins can be cut and capped above skin level or cut and buried beneath the skin. As a general rule, pins, which are intended to be in place longer than 6 weeks, are buried beneath the skin, all others are left out of the skin.

Several pinning techniques can be used for metacarpal head, neck, shaft, and base fractures (Fig 3). The easiest technique is transfixion pinning of the fractured metacarpal to an intact adjacent metacarpal.

**TABLE 1**

Conversion of English to Metric K-Wire Diameters

<table>
<thead>
<tr>
<th>English</th>
<th>Metric</th>
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<tbody>
<tr>
<td>0.028 in</td>
<td>0.7 mm</td>
</tr>
<tr>
<td>0.035 in</td>
<td>0.9 mm</td>
</tr>
<tr>
<td>0.045 in</td>
<td>1.1 mm</td>
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<tr>
<td>0.062 in</td>
<td>1.5 mm</td>
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**FIGURE 2.** A 14-gauge hypodermic needle serves as a tissue guard and helps direct the passage of 0.9-mm (0.035-inch) K-wires.
Instead of placing the hand flat with digits extended, as would be expected for an anteroposterior radiograph, we recommend bringing the fingers into a flexed position in the palm for pinning. This facilitates reduction and allows clinical correction of rotational alignment before and during pinning. In addition, this maneuver aids the surgeon in visualization of the transverse metacarpal arches for optimal pin targeting (Fig 4). Two transfixion pins are recommended distally and at least one proximally. Placing the distal pins out of plane can add rotational stability, and pin divergence can be used to reduce lateral translation of the distal fragment. The bending stiffness of transfixion constructs approaches that of plate and screw fixation.

A second pinning technique uses K-wires to cross near the fracture site (Fig 3B). These can be placed antegrade with an entry point on the dorsal metacarpal surface or retrograde from the MCP joint. By flexing the MCP joint to 90°, retrograde pins can enter near the origin of the collateral ligaments (dorsal, central, or volar) and avoid injury to the articular surface. The pins should cross each other proximal or distal to the fracture site for maximal stability. Several biomechanical studies have shown crossed pins to be inferior to other pin, wire, and plate constructs.

A third method for metacarpal pinning is the intramedullary approach (Figs 3C and 3D). Pins can be placed retrograde through the MCP joint at the origin of the collaterals or antegrade through a dorsal cortical window. Two to 5 pins are placed across the fracture site, spread distally, and impacted into subchondral bone. Metacarpal shortening, rotation, and pin migration are reported complications. This technique should be reserved for transverse or short oblique fractures without significant comminution. Supplementary buddy taping should be added to maintain rotational control.

A fourth pinning technique has been described for Bennett fractures: transarticular pinning. Placing one or 2 pins from the metacarpal shaft into the trapezium while maintaining reduction can counteract the deforming force of the abductor pollicis longus. In some cases, a combination of pinning techniques is useful. For Bennett and CMC base fractures, crossed pins are useful for securing fracture alignment while transfixation or transarticular pins are helpful to maintain reduction of a CMC dislocation (Fig 5).

Though less invasive than alternative methods of fixation, percutaneous pinning is not an entirely benign procedure. In a 1992 review of pinning for wrist and hand fractures, 5% of patients sustained major complications, 11% sustained minor complications, and an additional 2% of patients had both minor and major complications. Poor pin placement and poor patient compliance were identified as reasons for failure in many cases. The investigators recommended obtaining oblique radiographs to scrutinize pin placement (in addition to fracture reduction) before leaving the operating room. Similarly, an intraoperative test of tendon gliding will ensure that a flexor tendon has not been impaled. Pin tract infections should be managed aggressively to prevent stiffness and osteomyelitis.

**FIGURE 3.** Of the various pin fixation techniques described for the management of metacarpal fractures, transfixion pinning (A), cross k-wires (B), retrograde intramedullary fixation (C), and antegrade intramedullary fixation (D), the easiest method is the transfixion technique illustrated in 3A.

**FIGURE 4.** The arch of the metacarpal heads illustrates the colinear relationship between the small, ring, and middle finger angulated 35 to 40 degrees to a second line drawn between the index and middle metacarpal heads.
Aseptic loosening, pin tract infections, and non-union are the most frequent complications of pin fixation. One complication may lead to the other. Laboratory studies, which identify the failure mode of K-wires, noted that loosening at the bone-wire interface allowed the pin to slide and distract the fracture fragments. K-wire loosening is prevented by using trocar-tipped pins, delivered at low rpm, and avoiding repeat passes in and out of the same drill hole.

**Open Reduction Internal Fixation With Intraosseous and Tension Band Wiring**

Surgical exposure of the metacarpals is similar for base, shaft, and neck fractures. A direct dorsal incision is adequate for fixation of a single metacarpal. When 2 adjacent metacarpals require fixation, a dorsal incision between the bones provides access to the metadiaphyseal region. For adjacent metacarpal head fractures, the distal aspect of the straight dorsal incision is directed at 120° toward the respective metacarpal heads. These obliquely directed extensions decrease wound tension during early mobilization. A tendon-splitting approach allows deep exposure of the MCP articular surfaces and preserves the sagittal bands for capsular closure. Similar principles apply for surgical exposure of the thumb metacarpal. The skin incision runs along the base of the metacarpal at the junction between glabrous and hair-bearing skin. With subperiosteal elevation of the thenar muscles and longitudinal arthrotomy adequate visualization for open reduction of thumb metacarpal base fractures is provided.

Preparation of bone surfaces for intraosseous 90-90 wiring requires exposure (described earlier), debridement of the fracture site, and the determination that there is enough cortical contact between fracture fragments to accommodate compression. Parallel drill holes are made approximately 5 mm from the fracture edges in a dorsal-volar direction. Either a 0.9-mm (0.035-in) K-wire or a 20-gauge needle with the hub removed can be used to drill the holes. The latter has the advantage of facilitating passage of the 26-gauge wire. An analogous approach is used to prepare transverse holes slightly dorsal to the midline axis to generate a tension band effect. The 26-gauge wire is passed through the second set of holes, with attention to placing the wire ends on the noncontact side of the hand when possible. A single unicortical hole should be drilled approximately 3 mm from the wire holes; the wires are then twisted to apply compression, and the twist is impacted into cortical bone to prevent soft-tissue irritation.
Multiple investigators have shown that a single intraosseous wire with or without a supplementary K-wire is inferior to the fracture stability provided by dorsal plating.8,29,37 One biomechanical study has shown that 90-90 intraosseous wiring is similar to dorsal plating in 3-point bending tests.8 In a clinical study of 63 metacarpal and phalangeal fractures, a combination of K-wires and stainless steel wire provided rigid fixation and union in all cases (Fig 6).7

If comminution or segmental loss prohibits a congruous reduction, an alternative fixation technique should be selected. Fatigue failure will occur when intraosseous wiring is attempted with incongruous fracture edges.6 Similarly, wiring techniques can fail in osteoporotic bone by cutting out.36 Preventative strategies include appropriate patient selection and strict adherence to technical guidelines for a 5-mm bone bridge between wire holes and fracture edges.

Open Reduction Internal Fixation With Interfragmentary Screws

Interfragmentary screws are appropriate for fixation of large, noncomminuted, metacarpal head or base fractures and long, oblique, shaft fractures. The former is typified by Bennett fractures and the latter by spiral diaphyseal fractures. Lag screw technique is used for the approximation of 2 fracture fragments in which compression provides fracture stability without distorting normal anatomy. The near cortex is overdrilled to the diameter of the screw thread. The far cortex is drilled to the diameter of the screw core. The near hole is then deepened with a countersink and the depth gauge is inserted to measure length. When available, self-tapping screws are used, when not available, the far cortex is tapped to the size of the screw thread. As the screw glides through the near cortex and engages the far cortex, visible compression occurs. If bone loss or comminution exists, then lag screw fixation leads to distortion of anatomy, articular incongruity in joint fractures, and rotational deformity in shaft fractures. Comminuted articular fractures can be reduced and provisionally held with K-wires. The reduction is then secured with setscrews in which the near cortex is not overdrilled. Screw progression ends when the screw head reaches the near cortex. The fracture fragments are maintained but not compressed.

Bennett fractures are exposed through an incision along the line separating glabrous from hair-bearing skin. The proximal incision is extended ulnarly in a transverse direction parallel to the wrist crease. The thenar muscles are elevated from the proximal metacarpal and the fracture site is exposed. After irrigation and debridement of hematoma from the fracture site, a minimal amount of periosteal stripping is performed adjacent to the bone edges. The avulsed fragment is left attached to the anterior oblique ligament and stabilized with a dental pick while the remainder of the metacarpal fracture is reduced onto the articular fragment. Provisional fixation most easily is provided with K-wires and less so with reduction forceps. The trajectory of the K-wires is a helpful guide for definitive screw fixation. Usually a single 2.0- or 2.4-mm screw is used for definitive fixation (Fig 7A).

Long, oblique finger fractures are defined as those with a length greater than twice the width of the shaft. This length will accommodate 2 or more fixation screws. Placement of lag screws should be designed to resist torsional and compressive stress at the fracture site. Torsional stress is minimized with screws crossing at 90° to the fracture. Compressive stress is minimized by screw placement perpendicular to the long axis of the bone. Ideal screw placement would bisect these angles, which in the setting of spiral finger bone fractures is not a simple task.3 A more facile approach directs one screw perpendicular to the diaphysis and a second screw perpendicular to the fracture line (Fig 7B). Two- or 2.4-mm screws are appropriate for shaft fixation and 2.4- or 2.7-mm....
screws can be used for metacarpal head and base fractures.

Interfragmentary screw placement involves multiple steps, and minor technical faults at any point can result in inadequate fixation. An often-overlooked technical point is drilling a hole into an area of bone that is less than 3 times the diameter of the drill bit. The bone distal to the screw hole will break either as the fragment is drilled or as the fragment is engaged by the screw thread (Fig 7C). Unlike other fixation techniques, there are no second chances with lag screws. Recognition of improper screw placement is critical; a poorly placed screw should be supplemented with additional plate fixation if it cannot be replaced. Prolonged cast protection, and avoiding mobilization, is rarely a desirable adjunct.

Open Reduction Internal Fixation With Plate and Screws

Plate and screw fixation is used for metacarpal fractures that are short oblique, transverse, or comminuted. In comminuted fractures they act as a bridge, spanning the fracture site (Figs 8A and 8B). In simple 2-part fractures they function as a tension band to resist displacement from digital flexor activity (Fig 8C).

Plate design accommodates varied fracture configurations and anatomic locations. Periarticular fractures such as comminuted head and neck fractures or Rolando fractures are amenable to blade plate fixation or T, L, and Y plate fixation (Figs 8A, 8B, and 8D). When these devices are used the articular fragments are reduced first, provisionally fixed with K-wires, and the blade or the angled portion of the plate is introduced first. Plate position is confirmed and the stem of the plate is secured. Doing this in the opposite order is impossible with a blade plate and will lead to rational misalignment when using angled plates.

Because plate fixation is so rigid, alignment and rotation must be perfect before the plate is applied. Reduction maneuvers that place the digits in an intrinsic plus posture and take advantage of provisional K-wire fixation are helpful. In the setting of multiple
metacarpal fractures, all of the digits are flexed at the MCP joints and aligned relative to an uninjured digit. A 0.9-mm (0.035-in) K-wire is passed retrograde from the fracture site through the medullary canal and out the metacarpal head of the flexed MCP joint (Fig 9A). The fracture is reduced and the K-wire is delivered into the proximal medullary canal (Fig 9B). The maneuver is repeated for the other fractured metacarpals. Starting with the central-most rays, plates are affixed by placing one unicortical screw adjacent to the fracture site that creates an acute angle between the fracture and the plate, rotational alignment is rechecked, and a second unicortical screw is placed on the opposite side of the fracture (Fig 9C). If alignment and rotation are correct, the intramedullary K-wire is removed and the remainder of the screws are inserted. Addition of a lag screw, through or adjacent to the plate, enhances rigid fixation (Fig 9D).

Early editions of the AO manual (Arbeitsgemeinschaft Für Osteosynthesefragen) espouse that 2.7-mm plates engaging a minimum of 4 cortices on either side of the fracture are essential for the fixation of metacarpal fractures. Subsequent series have shown effective fixation with smaller implants. We routinely use 2.4-mm plates for border digits and multiple metacarpal fractures and 2.0-mm implants for smaller patients and those unstable fractures of the middle and ring finger not amenable to the K-wire techniques mentioned earlier. The use of fixed angle devices such as condylar blade plates provides rigid fixation in which fragment size accommodates only one screw (Figs 8A and 8B).

Smaller, lower profile implants may circumvent the most common complications associated with plate fixations. A retrospective study of morbidity after plate fixation identified complications in 29% of acute metacarpal fractures and 42% of metacarpal reconstructions. Complications were more common among fractures with associated soft-tissue injuries or bone loss. Stiffness and prominent hardware were the most common complication. Early motion postoperatively can help prevent the former but not the latter complication. Deliberate intraoperative interventions include selecting low-profile implants, confirming appropriate screw lengths and tendon excursion after fixation, and interposition of periosteum or soft tissue between the plate and the extensor mechanism.

External Fixation

External frames are used in the setting of combined bone/soft-tissue deficiencies and to span joints to prevent contractures. Two- and 2.5-mm pins are used in metacarpal fractures. Larger pins present a fracture risk. A single proximal and distal pin is adequate in many cases. Two sets of pins should be used when significant deforming forces are anticipated. Freeland recommends that when spanning a comminuted articular fracture, the joint should be set in a position of function in anticipation of a potential ankylosis during healing. Preventable complications from external fixation are attributable to soft-tissue injury during insertion, infection, and fracture through a pinhole after fixator removal. The use of drill sleeves and tissue protectors minimizes iatrogenic injury to nerves, tendons, and vessels. Regular follow-up visits and checking radiographs confirm maintenance of reduction and provides an opportunity
to reinforce simple pin tact care. Crust is removed from pin sites, cleaned with saline or mild soap, and dressed with dry gauze or left open depending on patient preference. Loose or chronically irritated pins are replaced when possible, or converted to some other form of fixation when essential. Activity restriction reduces but does not eliminate fracturing through an empty pinhole after fixator removal. Patients should be informed that it takes several weeks for the stress-concentrating effect from an empty hole to subside.42

**Alternate Procedures**

**Open Reduction Internal Fixation With Bioabsorbable Implants**

Bioabsorbable interference screws, anchors, tacks, and arrows have gained enormous popularity for knee meniscal and ligament repairs in recent years. However, relatively few investigators have reported the results of bioabsorbable plates and screws or pins for fracture fixation.10,43

One unique drawback of bioabsorbable implants is a small but significant number of late inflammatory reactions (ie, osteolysis, sterile sinus tracts, hypertrophic fibrous encapsulation, and synovitis).9 These have been attributed to implant degradation. Adverse tissue reactions generally have been reported in less than 5% of cases using polylactic acid implants, but in up to 50% of cases using polyglycolic acid implants.9,44,45 These tissue reactions have occurred as late as 4 years postoperatively.44

In the future, bioabsorbable implants may prevent secondary surgery to remove painful, prominent, or adherent implants. Presently, biomechanical and biologic long-term data are lacking to support the use of bioabsorbable material instead of conventional implants for metacarpal fracture fixation.

**Complications**

Identification and, importantly, prevention of surgical complications were reviewed under the Technical Aspects section. However, complications of metacarpal fractures can also arise from nonsurgical treatment and postoperative decision making.

Stiffness can develop after prolonged immobilization or delayed rehabilitation. In most cases, signs of clinical union will be present at 4 weeks after a closed metacarpal fracture. Although the fracture has not yet radiographically united, transitioning the patient to a removable splint and initiation of rehabilitation at this time can minimize stiffness. Patients with crush injuries or open surgical approaches also can form tendon adhesions. Recognition of these risk factors for stiffness should prompt the surgeon to choose the most rigid form of fixation and begin mobilization early. In cases with rigid internal fixation, mobilization should begin at the time of suture removal.

Malunion primarily manifests as malrotation or dorsal angulation. At each visit the surgeon should confirm that the patient’s fingertips point toward the scaphoid tuberosity in composite flexion. Five degrees of malrotation can produce 1.5 cm of digital overlap19 and diminish grip strength. Prominent palmar metacarpal heads from an apex dorsal malunion also can produce pain and secondary weakness. A compensatory hyperextension deformity at the MCP often accompanies a dorsal malunion. Corrective osteotomy is the treatment of choice for metacarpal shaft and neck malunions, whereas osteotomy or arthrodesis can be performed at the metacarpal base level.

Nonunion is an uncommon complication of metacarpal fractures. Bone grafting and rigid internal fixation are the recommended treatments in the absence of osteomyelitis or soft-tissue defects.

**Rehabilitation**

Joint mobilization is contingent on fracture location and stability. Fractures treated nonsurgically that involve the distal shaft, neck, and head have a greater tendency for secondary displacement; aggressive rehabilitation should be delayed for 3 to 4 weeks after injury. Metacarpal base and proximal shaft fractures are immobilized in an intrinsic plus splint with interphalangeal joints free to start active and passive motion. Gentle active motion at the MCP level is allowed in the most proximal stable fractures. Passive MCP mobilization is added when there are signs of clinical union, typically at 5 to 6 weeks after injury. Strengthening exercises are added at 8 weeks.

Surgically managed metacarpal fractures are immobilized for 2 weeks postoperatively in a bulky intrinsic plus splint until sutures are removed. The rehabilitation plan is individualized based on rigidity of internal fixation, patient compliance, and the complexity of associated soft-tissue injuries and repairs. Active MCP and active/passive interphalangeal motion is ini-
tiated within days of surgery in compliant patients with rigid internal fixation. Passive MCP motion is added at 4 weeks after surgery. Dynamic assist motion programs are started within 3 to 5 days of tendon reconstruction. Cast immobilization is used for 4 to 6 weeks in noncompliant patients with rigid fixation. Mobilization follows thereafter, according to the protocol described previously for nonsurgical fractures. Elastic wrapping is used for edema control and adjustments are made to manage concomitant soft-tissue injury as needed.

**CONCLUSION**

Most metacarpal fractures can be treated adequately with closed techniques. An awareness of anatomy and potential deforming forces of the intrinsic muscles of the hand are essential to determining fracture stability and to optimize splint/cast application. When surgical intervention is required for metacarpal fractures, several fixation techniques and implants are available. Percutaneous pinning is a convenient, minimally invasive technique but does not provide sufficient strength for early motion. It is the technique of choice for neck fractures and comminuted head fractures. Open reduction and internal fixation with lag screws or plate/screw constructs has the potential for greater morbidity but allows for earlier mobilization. These techniques are optimal for unstable shaft fractures and fractures associated with soft-tissue injuries. External fixation has a role in the management of metacarpal fractures with segmental bone loss and complex wounds. Bioabsorbable implants, though an exciting concept, have yet to supplant more traditional methods of fixation.

**REFERENCES**

2. Tennant CE. Use of steel phonograph needle as a retaining pin in certain irreducible fractures of the small bones. JAMA 1924;83:193.


