The Role of Locking Technology in the Hand

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KEYWORDS

• Locking plates • Metacarpal and phalanx fractures
• Hand trauma

Internal fixation of the hand and wrist has evolved in the last 4 decades. It is well accepted that stable internal fixation in the setting of combined musculoskeletal injuries involving the osseous skeleton and soft-tissue envelope facilitates early rehabilitation and promotes improved functional outcomes.[1–4] Plate and screw fixation systems in the hand and wrist were originally predicated on the larger long-bone fracture fixation systems. Locked plating establishes a fixed-angle construct (ie, functions as an internal-external fixator). Angular-stable fixation has begun to revolutionize the operative management of complex metadiaphyseal long-bone trauma, as well as periarticular and periprosthetic fractures, and has acquired a growing role in the hand as well.

With the growth of hand surgery as a subspecialty, and a better understanding of the structural requirements of the hand skeleton and periarticular soft tissues, an increasing number of commercially available hand fracture fixation systems that incorporate fixed-angle technology into plate and screw designs have emerged. The multiple hand fracture locking plate systems available reflect the growing trend amongst hand surgeons to use internal fixation for difficult acute fractures (ie, acute bone loss, periarticular and metaphyseal fractures, osteopenic bone) and complex reconstructions for malunion, nonunion, or posttraumatic deformities. Locked plates in the hand confer rigid or relative stability based on the clinical scenario being addressed.

In appropriately selected cases, locking plate technology may be helpful in addressing a variety of extraarticular and periarticular problems in the hand and wrist. Clinical experience with locking technology in hand trauma remains relatively limited compared with its application for fractures about the proximal humerus,[5–8] distal humerus,[9] distal radius,[10–14] distal femur,[15,16] periprosthetic femur,[17,18] tibial plateau,[19] proximal,[20] and distal tibia.[21] As hand surgeons become more familiar with locked plating, these plates may augment or replace the use of the technically demanding fixed-angle blade plates used to stabilize periarticular fractures and osteotomies.

The current indications and impetus for locked (fixed-angle) plating, along with the pearls and pitfalls of this technology are highlighted by anatomic region in the hand. Results following the application of locking plate technology in the management of distal radius acute fractures[10–14]

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and malunion[22,23] have been extensively reported. A discussion of locked plating in the distal radius is beyond the scope of this article. The application of locking technology in the distal ulna, metacarpals, and phalanges is discussed here.

BIOMECHANICS

Conventional Compression Plating

Conventional nonlocked plate/screw constructs rely on frictional force created between the plate and bone surface to neutralize the axial, torsional, and 3-point bending forces experienced by the plate/screw/bone construct.[24] Stability with standard plate/screw constructs is largely determined by screw torque generated. Osteopenia, metaphyseal bone, comminution, segmental bone loss, and/or pathologic bone all affect maximal screw-thread purchase and compromise the development of sufficient torque to establish absolute stability with compression plating.[24,25] However, the need to perform a more extensive soft-tissue dissection to maximize the plate-bone contact interface and coefficient of friction with conventional plating systems may adversely affect the fracture site and periosteal biology.

Locked Fixed-Angle Plating

Early attempts at improving fixation of conventional plates to compromised bone have included the use of bone cement to improve screw torque, Schuhli nuts,[26] and Zespol plates[27] to create a fixed-angle construct. Fixed-angle technology has been refined by the Arbeitsgemeinschaft fur Osteosynthesefragen (AO/ASIF) group.[28–32] In the Synthes (Paoli, PA, USA) fracture fixation system, the locking screw heads are conical with threads that lock into corresponding screw hole threads that are recessed within the body of the plate. A recent proliferation of locked plate designs by several manufacturers has followed. Locking technology aims to eliminate screw toggle and to create a fixed-angle single-beam construct.[33] Endosteal fibula allograft augmentation[34] has been described as a supplemental technique to locked plating in larger long bones.

Locked fixed-angle plate/screw constructs function as an internal-external fixator. Locked plates preserve periosteal vascularity while maintaining fixation by locking the fixation screws to the plate, which may be placed extraperiosteally. The angular stability of locked screws functions to distribute the applied load more evenly across the component screws, thus avoiding significant load concentration at a single screw-bone interface.[24,35,36] In a locked plate system, the overall strength equals the sum of fixation strengths of all screw-bone interfaces instead of that of a single component screw as in conventional plating. As a result, the fixed-angle construct leads to a mechanism of screw-purchase failure that is fundamentally different from that of conventional unlocked screws. Locked screws act together in parallel, whereas conventional screws act in series.[35] With 3-point bending load application, screw hole track deformation occurs. Unlocked screws toggle within the screw track and sequentially loosen. In contrast, with fixed-angle fixation, the plate/screw construct must fail as a unit.

Locked plates may be used in a bridging mode across an area of comminution and/or bone loss, thereby avoiding fracture site compression. Bridge plating helps to preserve the vascularity of the intercalary fracture fragments. Relative stability is achieved and allows enough strain at the fracture site to promote secondary bone healing with callus formation.[37] Alternatively, locked screws can be used to augment a standard compression plate/screw construct to create hybrid fixation (ie, nonlocked and locked screws). In a hybrid construct, it is therefore essential to apply compression across the fracture site using standard techniques before insertion of the locked screws. The use of hybrid fixation with bicortical locking screws is advantageous in osteopenic bone.

Indeed, current locked plate designs incorporate combination-hole technology, which allows surgeons to incorporate aspects of locked plating and compression plating into a single implant and at each screw hole site. Combination plates are helpful in select fracture patterns in which one aspect of the fracture would benefit from anatomic reduction and compression (ie, simple intraarticular component), whereas another fracture component would benefit from bridging fixation (ie, comminuted metadiaphyseal portion). If cortical contact can be achieved on the compression side, it is essential to complete maximal fracture compression before locked screws are inserted.

INDICATIONS

Current indications for locked plating in the hand include unstable distal ulna head/neck fractures associated with unstable fracture of the distal radius, periarticular metacarpal and phalangeal fractures, especially those with metaphyseal comminution, complex multifragmentary diaphyseal fractures with bone loss (ie, open, combined injuries of the hand), osteopenic/pathologic fractures, fixation for nonunions and corrective osteotomies in the hand, and arthrodeses of the small joints of the hand.

CONTRAINDICATIONS

There are no absolute contraindications to the use of locked plates in the hand and wrist. However, there are scenarios for which fixed-angle locked plating is not essential. If open reduction internal fixation is selected for simple, displaced, diaphyseal fractures of the short tubular bones in nonosteopenic patients, compression or neutralization with nonlocking plate fixation is all that is required. In addition, simple intraarticular split fractures do not require locked plating. With increasing emphasis on cost-effectiveness in the practice of medicine, the added cost associated with locking plates remains a concern.[38] We believe that locked fixation in the hand should be reserved for problematic fractures that are expected to have suboptimal outcomes using conventional plate/screw constructs.

Percutaneous insertion of fixed-angle plates is now performed routinely for distal femur, proximal and distal tibia, and pediatric diaphyseal fractures while adhering to AO principles of internal fixation. Cited advantages include percutaneous reduction, extraperiosteal plate placement, and bridging fixation. In the hand and wrist, the intricate association of the flexor and extensor tendons and neurovascular structures to the bones prohibit percutaneous insertion of percutaneous plate/screw constructs.

CONTEMPORARY ANGULAR-STABLE DESIGNS

Fixed-angle implants were introduced more than 20 years ago by Buchler and Fisher.[39] These investigators reported their initial experience with the minicondylar plate (Synthes, Paoli, PA, USA) for periarticular metacarpal and phalangeal fractures. The design of this fixed-angle implant was predicated on larger blade plates used extensively for periarticular fractures in other anatomic locations (ie, proximal and distal femur) (**Fig. 1**). The minicondylar plate was initially made of steel and available in 1.5-mm and 2.0-mm sizes. It is currently also available in titanium. Blade length is determined by predrilling the blade pathway. The blade is then inserted and acts as a derotation device and resists shear on the condylar fragments. Condylar fracture fragments can also be fixed and compressed with the supplemental condylar screw.

Proper insertion of this device remains technically challenging.[3,40] The evolution of small locking plates for hand applications may minimize the complications reported with minicondylar plates. Fixed-angle locking subarticular buttress pins are an alternative to the use of the minicondylar blade plate.

Novel plate/screw locking mechanisms continue to emerge. These advances have recently led to the introduction of polyaxial locking capabilities in addition to fixed monoaxial locking designs. Multiple factors are responsible for the proliferation of new locked plate designs by several manufacturers. These include improved biomaterials, the desire for anatomically precontoured plates, and the need to respect company-specific patents. Biomechanical analyses in cadaveric specimens have previously validated the use of these low-profile plates.[41–43] Studies reporting clinical and radiographic outcomes following dedicated use of the current systems are needed to further define their applications.

Synthes

The AO/ASIF group (Synthes, Paoli, PA, USA) has developed the minifragment and modular hand locking compression plate (LCP) fixation systems. Both modules are available in 316L stainless steel and titanium alloy. Self-tapping cortical and locking screws are available in the 2.7-mm, 2.4-mm, and 2.0-mm minifragment and modular hand trays.

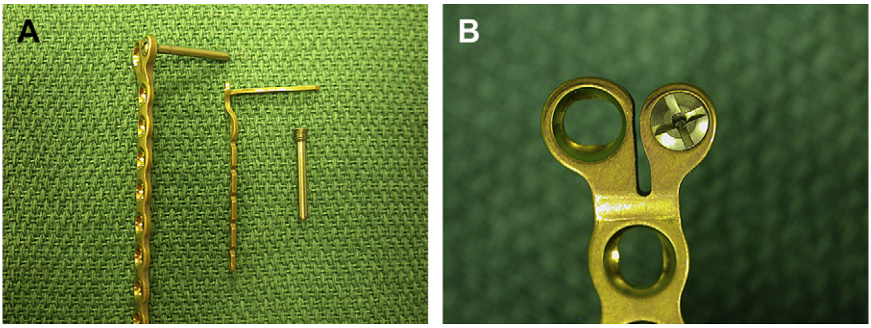

Fig. 1. Contemporary minicondylar locking plate (*right*) and blade plate (*middle*) (Synthes, Paoli, PA). The subarticular locking buttress screws have threaded heads (*left*) (*A*) which lock into the screw hole, creating a fixed-angle construct (*B*).

The LCP plates are unique in that they offer sequential combi-holes that afford either cortical or locking screw fixation through the same hole (Fig. 2). In this system, the locking screw heads are conical with threads that lock into the screw hole threads. The locking screw angle is monoaxial, and is dictated by the trajectory of the locking sleeve insert into the locking side of the combi-hole. The 2.4-mm condylar plate uses a 1.8-mm locking subarticular buttress pin. Additional nonlocking 1.5-mm and 1.3-mm plates are found in the modular hand fracture fixation system. Plates are available in straight, Y-, T-, and H-shaped configurations . Notched plates facilitate plate cutting and additional contouring. These low-profile plates (plate thickness range, 0.7–1.25 mm)[44] make periosteal closure around the implant easier.

Stryker

The Stryker VariAx Hand Locking Module (Stryker-Leibinger, Kalamazoo, MI, USA) builds on this company's Profyle Hand Standard Plating Module,[44] a nonlocking plate/screw system with 2.3-mm, 1.7-mm, and 1.2-mm implant options. The VariAx module offers polyaxial locking plate/screws in 2.3 mm and 1.7 mm (maximum plate thickness, 1.5 mm). Anatomically precontoured plates in variable shapes and lengths provide multiple fixation options in each region of the hand (Fig. 3). An oblong shaft hole allows proper positioning relative to the periarticular segment head and collateral ligament recesses.

This system offers polyaxial (ie, variable angle) locking interfaces. The lip on the drill guide allows for toggle within a 20° arc (±10° in each direction) when it engages the screw hole. Every angle in this angular cone results in locking of the screw. Polyaxial locking allows the surgeon to dictate the precise placement of the locking screws based on plate positioning, fracture characteristics, and proximity to the articular surface. Their locking mechanism is created as the stronger grade 5 titanium alloy in the screw head obtains purchase within the screw hole made of softer grade 2 titanium in these plates. The locking threads on the underside of the screw head also engage the circular lip in the screw hole. Rounded low-profile screw heads minimize soft-tissue irritation when the locking screw is inserted at the maximum allowable angle. Similar to the Synthes fixation system, all plate holes (with the exception of the oblong shaft screw holes) can be filled with either nonlocking or locking screws, and thus allows for creation of a hybrid fixation construct. As opposed to combi-holes, each hole is circular, and locking is created by use of a locking screw made of grade 5 titanium alloy. In osteopenic bone, locked screws can be inserted to augment standard nonlocking compression screws made of grade 2 titanium. Bicortical screws are used for improved torsional control, but unicortical locking screws can also be used to avoid screw tip prominence and irritation of tendons or periarticular structures.

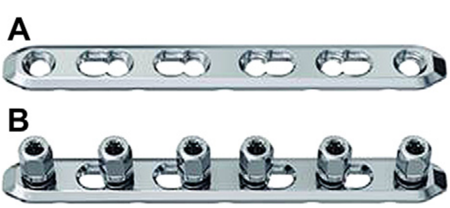

Fig. 2. LCP plates with sequential combi-holes that afford either cortical or locking screw fixation through the same hole. (Synthes, Paoli, PA, USA) *(Courtesy of* Jesse B. Jupiter, MD.)

Medartis

The Medartis (Basel, Switzerland) Aptus titanium system offers 2.0-mm and 2.3-mm plate and screw options for angular-stable fixation of metacarpal and phalangeal fractures (plate thicknesses,1.0 mm and 1.3 mm, respectively). Screw holes are offset to reduce screw collision and are also oriented in a nonlinear configuration to avoid fracture propagation with drilling. Locking is achieved through a TriLock radial 3-point wedge-locking mechanism (Fig. 4). TriLock locking screws can be re-locked in the same hole under individual angles up to 3 times. This system also offers polyaxial locking capabilities within a 15° cone. The 1.2-mm and 1.5-mm phalangeal plates do not offer a locking option.

DePuy

DePuy (Warsaw, IN, USA) has recently introduced its 1.5-mm and 2.5-mm titanium ALPS for hand reconstruction (plate thicknesses, 1.1 mm and 1.6 mm, respectively). Plate styles include straight, T, Y, web, and T/Y options (Fig. 5). Nonlocking as well as monoaxial and polyaxial locking interfaces are available at each screw hole in the 1.5-mm and 2.5-mm plates. Preloaded fixed-angle screw targeting (FAST) guides facilitate rapid insertion of nonlocking cortical screws and monoaxial locking screws. 2.5-mm and 1.5-mm polyaxial (20° locking cone; ±10° in each direction off center) locking screws are also available and are predrilled after removing the FAST guides. These multidirectional locking screws are made of cobalt-chrome and the threaded screw heads create a new thread path in the plate (see Fig. 5). In addition, 1.5-mm nonlocking screws placed eccentrically or 2.5-mm

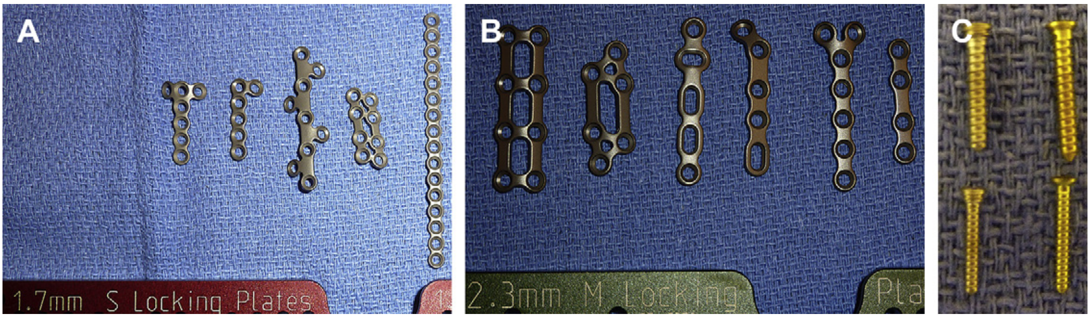

Fig. 3. Stryker VariAx hand locking module (Stryker-Leibinger, Kalamazoo, MI, USA) with (*A*) 1.7 mm and (*B*) 2.3 mm anatomically precontoured locking plates. (*C*) Locking (*left*) and nonlocking (*right*) screws are available for each screw hole: 2.3 mm (*top*), 1.7 mm (*bottom*). The grade 5 titanium alloy in the screw head obtains purchase within the screw hole made of softer grade 2 titanium to create the locking mechanism.

locking screws with compression washers can be placed through the compression hole to create axial compression (0.75 mm of compression per hole).

FIXATION BY ANATOMIC REGION

Distal Ulna

Unstable metaphyseal fractures of the distal ulna may be seen in up to 6% of patients with unstable fractures of the distal radius.[45] Optimal management of distal ulna articular head and/or metaphyseal neck fractures sustained in conjunction with an unstable distal radius fracture requiring operative fixation is not well established, and series reporting outcomes following operative treatment of these injuries remain limited.[45–50] Failure to achieve congruent anatomic reduction through stable fixation at the sigmoid notch and distal radioulnar joint (DRUJ) compromises the ability to reestablish ulnar variance and DRUJ stability, and thus increases the risk of distal ulna nonunion,[51–53] DRUJ dysfunction, ulnar-sided wrist pain, and posttraumatic arthrosis.[54]

Fixation of comminuted distal ulna head/neck fractures remains technically challenging (**Fig. 6**). Only 2 series have been published reporting results with angular-stable implants (2.0-mm, 2.4-mm, or 2.7-mm minicondylar blade plates,[49] or minifragment Y-, T-, or L-shaped locked plates)[46] for obtaining fixation within small, osteopenic, metaphyseal fragments and the short nonarticular arc of the ulnar head. Ring and colleagues.[49] reported good-to-excellent results in most of their cohort at a mean of 26 months following operative fixation of unstable distal ulna fractures with a minicondylar blade plate construct. Dennison[46] reported good-to-excellent radiographic alignment and clinical results in 5 patients following locked plating of an unstable distal ulna fracture at the time of operative fixation of a concomitant distal radius fracture.

In the distal ulna, exposure is achieved through the extensor carpi ulnaris–flexor carpi ulnaris interval, and the dorsal sensory branch of the ulnar nerve is identified and protected. When applying an angular-stable implant to the distal ulna, it is

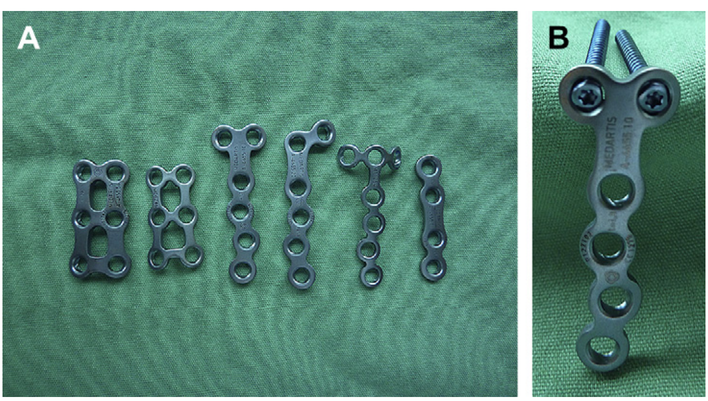

Fig. 4. The Medartis (Basel, Switzerland) Aptus titanium system: (*A*) screw holes are offset to reduce screw collision during polyaxial locking within a 15° cone and to avoid fracture propagation with drilling. (*B*) Locking is achieved through a TriLock radial 3-point wedge-locking mechanism.

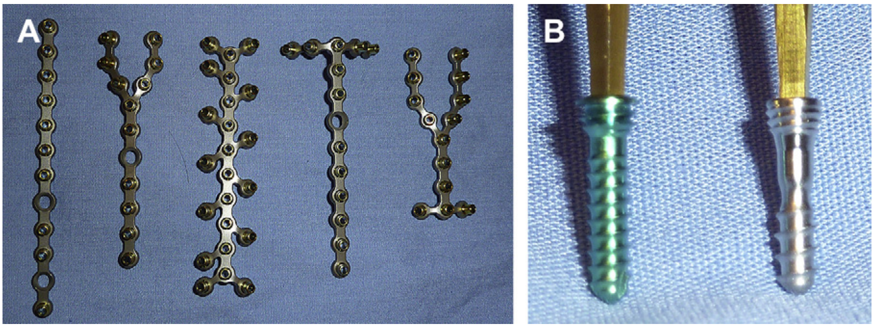

Fig. 5. (*A*) DePuy (Warsaw, IN, USA) titanium anatomic locked plating system (ALPS) with precontoured plating options. (*B*) Cobalt-chrome locking screws have polyaxial locking capabilities in this system.

helpful to identify the distal end of the ulna head under fluoroscopy to avoid plate or screw impingement on the triangular fibrocartilaginous complex. A Kirschner wire can be inserted from ulnar to radial deep to the triangular fibrocartilaginous complex to mark the distal extent that the plate may be applied. A 2.0-mm plate is appropriate in most patients, but a 2.4-mm or 2.7-mm plate may be selected in larger patients. The T-, Y-, or L-shaped terminal ends

Fig. 6. (*A*) Posteroanterior and (*B*) lateral injury radiographs of a distal radius metadiaphyseal fracture with concomitant ulna neck and styloid fractures. (*C*, *D*) Corresponding images from the preoperative sagittal plane computed tomography reconstructions. (*E*) Postoperative posteroanterior and (*F*) lateral radiographs following plating of both fractures. (*Courtesy of* Chaitanya S. Mudgal, MD.)

of the locking plate are contoured with plate benders to anatomically fit the ulnar head segment. Contouring the plate to wrap around the ulnar head also helps to create orthogonal fixation, wherein the screws interlock in multiple planes to increase construct stability. Cannulated locking guides should be seated within the locking plate holes to prevent disruption of the locking mechanism as the plate is contoured. In the Synthes system (Paoli, PA, USA), the plate bending irons actually lock into the plate, thereby mimicking the locking guide and avoiding screw hole deformation.

The plate is secured to the distal ulna in an extraperiosteal fashion. Alternatively, if a minicondylar blade plate is selected, the track for the blade is drilled under fluoroscopic guidance. The blade length is determined and the blade is then cut to the measured length. Following insertion of the blade, the screw adjacent to the blade is inserted to compress the plate to the bone. The proximal screw holes are then filled.

If the metaphyseal neck is highly comminuted, nonlocking screws are placed in neutral positions to avoid compression through the zone of comminution. Unicortical locking screws are advantageous in the ulna head segment given its short nonarticular arc. Unicortical screws help to avoid articular penetration and subsequent impingement on the sigmoid notch during forearm rotation. In addition, supplemental locked screws along the construct help prevent loosening in osteoporotic bone.

Despite the availability of angular-stable locked plating fixation constructs[46,49] for distal ulnar articular/metaphyseal fractures, nonanatomic reduction,[45,46] loss of fixation in multifragmentary fractures, and symptomatic hardware necessitating additional surgery[49] remain significant problems with these fracture patterns.

Metacarpal and Phalangeal Shaft Fractures

Diaphyseal fractures of the metacarpals and phalanges may be multifragmentary, associated with significant cortical comminution, and show intercalary bone loss (**Fig. 7**). These fractures may occur in combined volar and/or dorsal skeletal and soft-tissue injuries. In addition, multiple ipsilateral consecutive metacarpal[55]or phalangeal fractures may be seen following significant trauma and necessitate rigid plate fixation. Goals of operative fixation include stable restoration of length, alignment, and axial rotation so that mobilization of injured structures can be initiated in the early postoperative period to maximize outcomes in patients with these complex combined injuries.

In these settings, locking plates appropriately sized for the injured region may be used to obtain stable fixation. Angular-stable plates applied with a bridging technique across the comminuted area avoid periosteal stripping and preserve vascularity. If corticocancellous bone graft is indicated, additional screw fixation can be placed to secure the graft. In the metacarpals, a paratendinous or extensor splitting exposure is used. In the border metacarpals, plate application may be dorsal or lateral. A dorsal or midaxial approach may be used in phalanges for lateral plate application. Biomechanical analyses[56,57] in cadaveric specimens have suggested that midlateral plate positioning may have superior biomechanical properties.

Periarticular Fractures

Phalangeal condylar fractures are typically unstable fracture patterns. The collateral ligament origin rotates the condylar fragment creating articular incongruity and angular deformity. Unicondylar fractures that are comminuted in the phalangeal neck region as well as bicondylar fractures may not be amendable to lag screw or Kirschner wire fixation techniques. For open reduction internal fixation, the interval between the central slip and lateral band or reflection of the central slip[58] is used. For these injuries a 1.5-mm minicondylar locking plate or blade plate[39,40] provides angular-stable fixation and subchondral support and allows for early postoperative rehabilitation. Combi-holes additionally allow for lag screw fixation of condylar fragments through the plate. These plates may be applied dorsally or laterally for juxtaarticular fractures.[39,40,59] The collateral ligament should be avoided when possible with lateral plate application to preserve the vascular supply to the condylar fragment and avoid mechanical impingement. Freeland and colleagues[60] have suggested that unilateral excision of the lateral band and oblique retinacular fibers of the metacarpophalangeal joint extensor expansion may decrease the risk of postoperative adhesions, tissue irritation, and intrinsic tightness when minicondylar plates are inserted on the lateral aspect of the proximal phalanx.

Injuries occurring at the base of the phalanx may be epibasilar/extraarticular or intraarticular. Exposure is performed through a paratendinous or tendon-splitting approach. When there is articular impaction, the articular surface is elevated by working through an adjacent fracture line. Provisional articular reduction is secured with Kirschner wires. T- or Y-shaped locking plates may be applied dorsally. The angular-stable screws

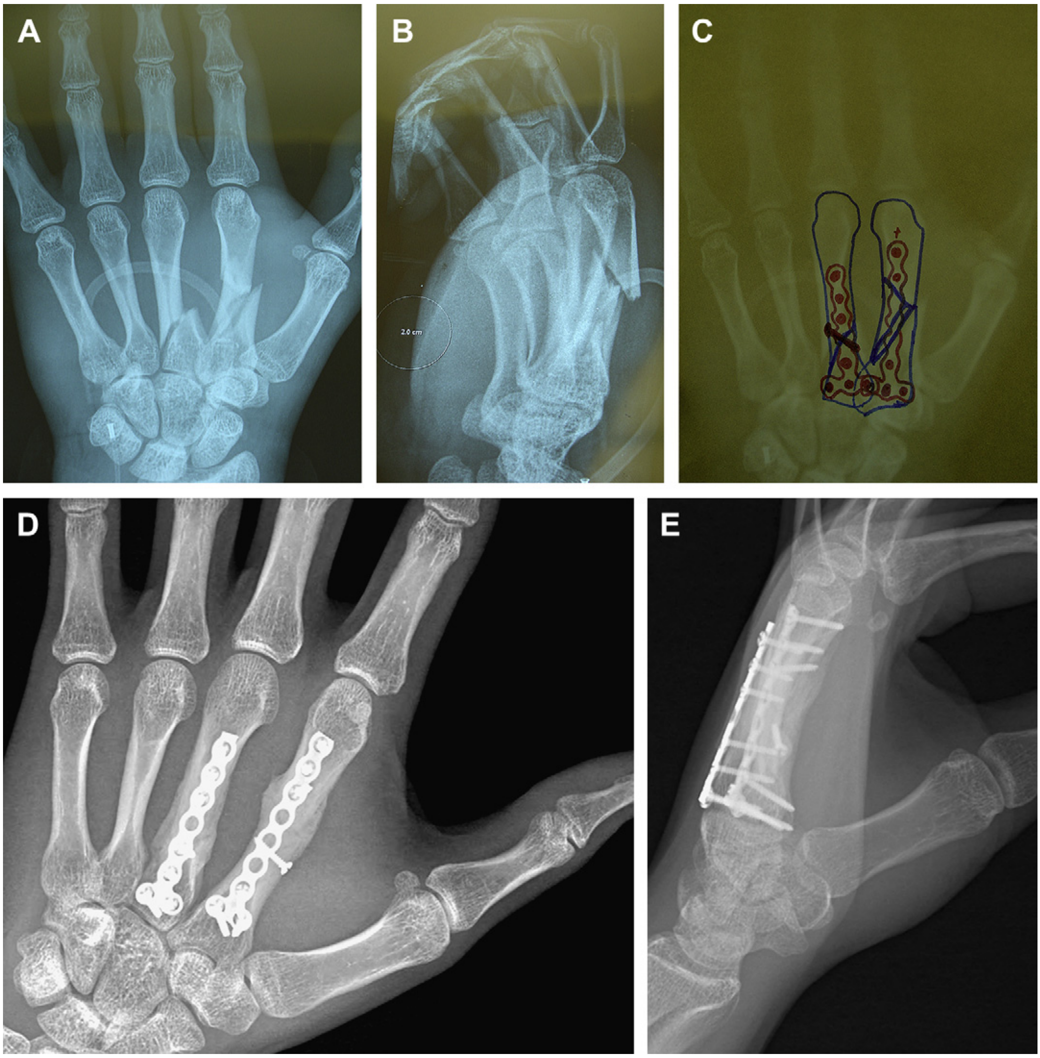

Fig. 7. (*A*) Posteroanterior and (*B*) lateral injury radiographs of high-energy ipsilateral index and long-finger metacarpal fractures. The index metacarpal fracture shows multifragmentary metadiaphyseal comminution and the long-finger metacarpal is epibasilar. (*C*) Preoperative template showing a 2.0-mm plate applied in a bridging mode across the area of comminution in the index metacarpal. In the long-finger metacarpal, the 2.0-mm plate is used as a neutralization plate following application of a 2.0-mm cortical lag screw. (*D*) Postoperative posteroanterior and (*E*) lateral radiographs at latest follow-up show anatomic alignment and fracture union. (*Courtesy of* Chaitanya S. Mudgal, MD.)

through the periarticular position of the plate serve to optimize metaphyseal fixation (**Fig. 8**) and buttress the elevated articular surface when there has been joint impaction. As with nonlocked plates, malrotation and malalignment may occur if only a single screw is placed in the periarticular portion of the plate and a shaft screw is placed with the plate eccentrically placed on the diaphysis.

In select cases, intraarticular fractures at the base of the thumb (ie, epibasilar, Bennett, and Rolando fractures) and the fifth metacarpal may be treated with open reduction and internal fixation. Dorsally applied angular-stable implants resist flexion deformity at the fracture site created by comminution on the volar cortex. In addition, improved metaphyseal fixation is achieved. For 3-part articular fractures (ie, Rolando fractures), the site of plate application is selected after careful analysis of the fracture pattern in the coronal and sagittal planes. Articular restoration is attempted with lag screw fixation. Alternatively, nonlocked

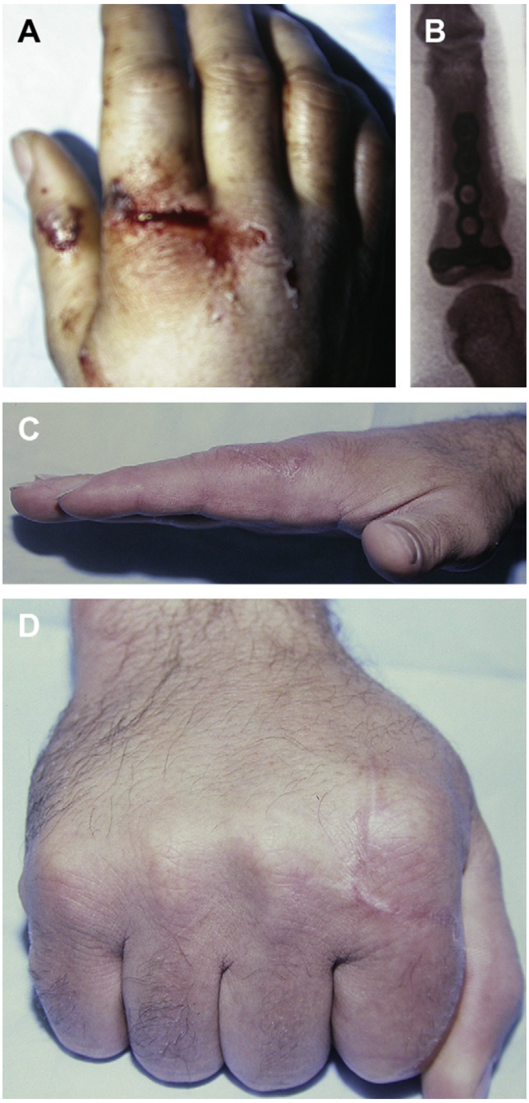

Fig. 8. (*A*) Combined injury to index finger which included an open fracture of the proximal phalanx at the metadiaphyseal junction. (*B*) Dorsal plating of the proximal phalanx fracture allowed for early range of motion following this combined injury and osseous union. (*C*, *D*) Functional range of motion was achieved at latest follow-up. (*Courtesy of* Chaitanya S. Mudgal, MD.)

screws may be placed eccentrically in the condylar segment of the plate to create compression of the articular fracture line. These can then be replaced with locked screws.

Delayed Reconstruction: Nonunion, Osteotomy, and Arthrodesis in the Hand

Nonunions and malunions of the metacarpals and phalanges continue to represent unique challenges for the hand surgeon. Angular and rotational deformity with functional deficits are indications for surgical correction. Previous scars and tendon adhesions may make exposure challenging, and the presence of soft-tissue contractures may increase the stress on the fixation. In the setting of these complex non- and malunions, angular-stable fixation may allow early functional rehabilitation following concomitant tenolysis, arthrolysis, and capsulectomy.

Nonunions of the tubular bones of the hand are uncommon. There are limited reports of the results of treatment of metacarpal and phalangeal non- and malunions.[61,62] Jupiter and colleagues,[61] in a series of 25 nonunions/delayed unions, found plate and screw fixation achieved a more functional digit compared with several other techniques. Implant selection depends on the location and direction of the non-/malunion within the longitudinal axis of the involved bone. Diaphyseal corrections are amenable to straight plates or extended H-plates. In transverse nonunions, cortical screws can be used to achieve compression across the nonunion site before placing locking screws (**Fig. 9**). Minicondylar plates are used for metaphyseal, juxtarticular, or combined metadiaphyseal reconstructions. As a general rule, in the setting of these reconstructions, implants one size larger than would be required for an acute fracture at the same level should be considered (ie, 2.4-mm plates in the metacarpal and 2.0-mm plates in the proximal phalanx). The need for intercalary structural corticocancellous grafting is determined preoperatively. Additional locking screws can be used to stabilize the graft at the nonunion or osteotomy site.

When corrective osteotomy is performed at the site of the original fracture, a complex multiplanar deformity can be completely addressed while simultaneously performing tenolysis and arthrolysis. Buchler and colleagues[63] reported good-to-excellent results in 96% of patients following corrective osteotomy for isolated posttraumatic phalangeal malunions; however, this rate dropped to 64% when soft-tissue structures were also involved. In this setting, rigid fixation is required to allow for early postoperative rehabilitation to optimize outcome.

Arthrodesis represents a salvage option for the stiff painful joint adjacent to a periarticular nonunion. Various fixation techniques have been described for arthrodesis in the hand. Use of angular-stable fixation allows the surgeon to use a single construct to address the nonunion site (ie, debridement, bone grafting, and fixation) while concomitantly providing for stability at the involved joint to achieve solid fusion.

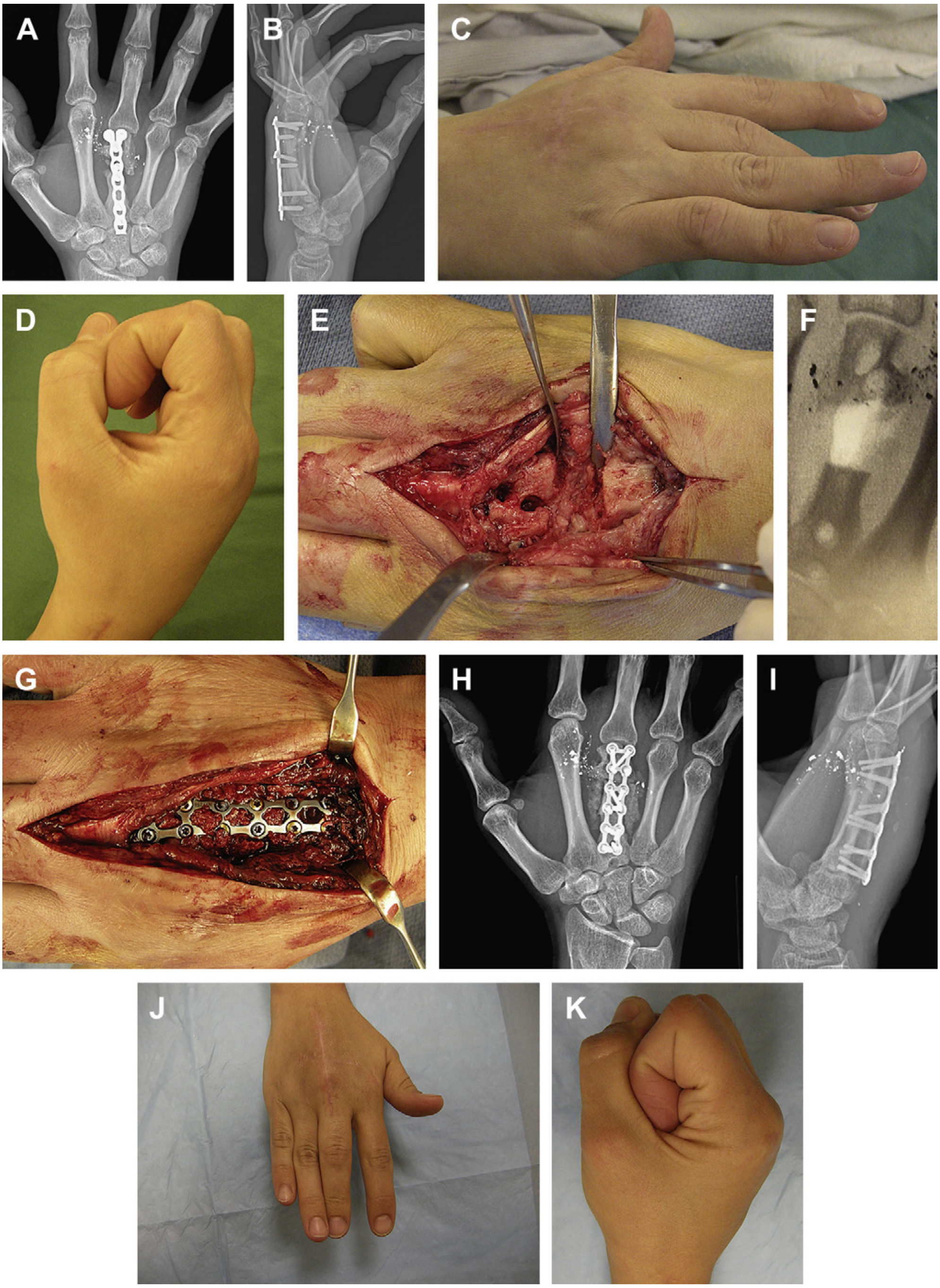

Fig. 9. (*A*) Posteroanterior and (*B*) lateral radiographs showing long-finger metacarpal nonunion in a patient who suffered a low velocity gun shot wound, followed by multiple unsuccessful attempts at achieving union. (*C, D*) Preoperative clinical examination demonstrated digital stiffness and extrinsic tightness. (*E*) Intraoperative image following removal of hardware and debridement of the nonunion site. (*F*) Corresponding intraoperative fluoroscopic image of the segmental bone gap following debridement of the nonunion site. (*G*) Intraoperative image following iliac crest autograft and hybrid fixation using a combination of locked and nonlocked screws. Maximal fixation was obtained by using an extended H-plate. (*H*) Posteroanterior and (*I*) lateral radiographs following nonunion repair. (*J, K*) An excellent clinical outcome was achieved. (*Courtesy of* Chaitanya S. Mudgal, MD.)

COMPLICATIONS

The complications reported following plating of metacarpal and phalangeal fractures[3,40] are also seen following the use of locked plates in the hand. However, several complications are unique to locking technology. The locked screws can disengage from the plate secondary to failure of the screw to seat into the plate properly because of cross-threading (where the screw threads and the plate threads are not collinear) or when insufficient screw torque is used to engage the screw head into the plate in systems relying on alternate methods of locking. The screws can break or disengage from the plate under excessive cyclical loading. Despite an excellent feel intraoperatively, locked plates may cease providing fragment fixation as a result of exceedingly poor bone quality, excessive comminution, or suboptimal plate length to working length ratio.

Nonunion and malunion can still occur with the use of locked plates if anatomic contouring is imprecisely performed. The locking sleeves provided in select systems should be secured within the locking screw holes when plate contouring is required to prevent disruption of the locking mechanism. In addition, locked screws should only be placed after a direct anatomic reduction is achieved. Placement of locked screws before reduction confers malreduction that is not correctable.

When a hybrid construct is used with locked screws placed to augment compression plating, it is essential to achieve maximal compression across the fracture site with standard cortical nonlocking screws before the insertion of locked screws. When locked screws are placed on both sides of the fracture before fracture compression, fracture gap will result. This scenario increases fracture site strain and implant stresses, and may lead to nonunion and/or hardware failure.

SUMMARY

Locked fixed-angle plating in the hand and wrist will continue to evolve. This technology is most appropriate in acute fractures or reconstructions with long plate working lengths, short periarticular segments, and the absence of bony support on the contralateral cortex from the side of plate application. Clinical experience with locking technology in hand trauma remains relatively limited compared with its application in larger extremity long bones. A thorough understanding of the biomechanics and fracture personality are required to apply fixed-angle plates correctly, optimize outcomes, and avoid iatrogenic nonunion and malunion.

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