CURRENT CONCEPTS REVIEW

Fixation of Hand Fractures with Intramedullary Headless Compression Screws

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Abstract

Metacarpal and phalangeal fractures remain among the most frequently encountered orthopedic injuries, accounting for 10% of all fractures. For operative fractures, there is an array of treatment options with percutaneous kirschner wire stabilization and screw and plate fixation strategies predominating. Recently, a new fixation method was introduced, intramedullary (IM) fixation with headless screws, which has advantages of a percutaneous technique and buried hardware. The purpose of this review is to highlight the indications and surgical techniques of IM screw fixation of metacarpal and phalangeal fractures. Although more research is needed, IM fixation represents a potentially reliable alternative to Kirschner-wire and plate fixation.

Level of evidence: V

Keywords: Indications, Intramedullary compression, Metacarpal fracture, Phalanx fracture, Technique

Introduction

Metacarpal and phalangeal fractures are among the most frequently encountered orthopedic injuries, accounting for 40% of upper extremity fractures, and 10% of all fractures.[1,2] They occur mostly in children and young adults between the ages 10 and 40, and tend to peak in the third decade in men and second decade in women.[3,4] The mechanism of injury varies and will influence the presenting fracture pattern and deformity.[5] Often occurring as a result of accidental falls or direct blows, any mechanism resulting in an axial load directed across the finger or hand can cause these injuries.[6] Referred to as a "boxer's fracture," the direct blow mechanism classically results in a transverse fracture through the metacarpal neck - a commonly seen fracture pattern.[3,5] Other common metacarpal and phalangeal fracture types include transverse or oblique shaft fractures, and extra- and intra-articular base fractures.

A thorough assessment, including history, physical examination, and imaging is necessary to guide diagnosis and treatment. Common examination findings include swelling, tenderness and ecchymosis about the fracture. Also, crepitus, shortening of the involved digit(s), loss of knuckle contour, rotational malalignment, and angulation of the digit(s) can be seen. Basic radiography, including posteroanterior, lateral, and oblique views are generally sufficient to assess the injury pattern.[5] Regarding treatment, the literature supports a variety of options given the variability of fracture patterns and other associated variables.[3]

The vast majority of metacarpal and phalangeal fractures can be treated nonoperatively (cast, splint, brace) with or without closed reduction, and early protected motion. In these cases, the fracture is non- or minimally displaced, inherently stable, and the finger cascade and overall alignment is maintained. Non-operative treatment strategies for stable and well aligned fractures have been found to provide equivalent functional and patient reported outcomes when compared to cases managed operatively.[7,8] However, for displaced and unstable fractures with altered cascade and finger alignment, operative intervention may be indicated. There are a wide array of options to reduce and stabilize metacarpal and phalangeal fractures including external fixation, cerclage wiring, percutaneous kirschner wires (K-wires),

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lag screws, intramedullary (IM) screws, and screw/plate fixation. In this paper we will focus specifically on IM fixation of metacarpal and phalangeal fractures using headless compression screws and we will review the different indications, operative techniques, and available evidence.

Indications and Contraindications for Intramedullary Fixation

First described in 1957 by Dr. Richard Lord, a military surgeon, the IM fixation technique using K-wires for metacarpal fractures was originally applied in an attempt to return active duty military personnel to action as quickly as possible[9,10] Foucher et al. later built upon this technique in 1975 with a "bouquet" method that introduced three k-wires into the medullary canal which diverged at the head for added stability.9 Similarly, IM fixation of phalangeal fractures is not a new concept. Thevenin et al. was one of the first to describe using K- wires in 1972.[11,12] Now, with the growth and popularity of headless compression screws employed throughout orthopedics, this alternative fixation method is beginning to emerge as an option for both metacarpal and phalangeal fractures.

The current indications for IM screw fixation of metacarpal or phalangeal fractures include extra-articular fractures that are diaphyseal or metaphyseal, transverse or short oblique and minimally comminuted. [Table 1] However, there is a need to better define the indications outside of these fracture patterns. Recent studies suggest that IM screw fixation is reliable in the treatment of unstable extra-articular fractures of the metacarpals, and middle and proximal phalanges.[12–20] However, given the risk of shortening the metacarpal/phalanx, increasing degrees of fracture comminution raises the technical difficulty and can limit the effectiveness of this technique. The same can be said for long oblique (fracture line is more than twice the width of the bone at the center of the fracture) fractures where collapse can occur upon insertion of the screw.[13,21] In particular, when cortical continuity cannot be re-established in diaphyseal fractures, excessive collapse and / or rotation instability may persist with IM screw fixation. Therefore, relative contraindications include fractures with near or complete intra-articular extension and / or very distal or proximal extra-articular fractures where there may be insufficient bone remaining for screw purchase.[13] Long oblique fractures or cases when at least partial cortical continuity cannot be re-established are less stable with IM screw fixation compared with other techniques. And lastly, absolute contraindications to this technique include infection and fractures involving an open physis.[20]

Despite these limitations relative to fracture type, IM screw fixation has a number of advantages common to other long bone fractures stabilized by intramedullary technique. These advantages include a minimally invasive technique with less soft tissue dissection, less periosteal stripping and bone devascularization, a load-sharing versus load-bearing construct, immediate fracture dynamization, and earlier return to motion and function. It is also a more cost effective option and involves minimal reliance on unreliable patients.[13,22]

Implant Selection for Intramedullary Fixation of Metacarpal & Phalangeal Fractures

A number of considerations should be given when selecting a screw for intramedullary fixation of metacarpal and phalangeal fractures. These include screw width, length, cannulation, and compression features. Smaller diameter screws may have limitations in length and cannulation. Generally, screws smaller than 2.0 mm in diameter are not cannulated due to biomechanical weakness. Moreover, smaller screw sizes are typically manufactured at short lengths. Generally, IM screws under 3.0 mm in diameter do not exceed 50 or 60mm in length due to biomechanical weakness beyond those lengths. Lastly, most IM screws available on the market provide compression by thread design. These thread designs are not non compression and thus do not risk shortening. However, in certain scenarios, such as fracture comminution, bone loss, and significant obliquity, compression may not be desirable due to risk of shortening and/or collapse. In these cases, IM screws without compression may be more desirable. [Figure 1]

Surgical Technique for Metacarpal Fractures

IM screw fixation of metacarpal fractures can be performed through a retrograde approach. This technique is best facilitated with the use of intraoperative fluoroscopy and is recommended by the authors for its technical efficiency and versatility. The surgery can be performed under all forms of anesthesia including general sedation with local block, or wide-awake technique. Various screw options are available however, the authors recommend using a cannulated headless screw without compression and with a minimum width of 3.0mm, but also sized appropriately to the inner diameter of the intramedullary canal. [Table 2]

Retrograde Technique

Traditionally, this technique involves performing an arthrotomy after splitting either the extensor tendon or

Table 1. Current Indications and Contraindications for Intramedullary Compression Screw Fixation of Metacarpal and Phalangeal Fractures

Intramedullary Fixation of Metacarpal and Phalangeal Fractures Using Compression Screws	
Indications	**Contraindications**
Extra-articular fractures that are diaphyseal or metaphyseal	Infection
Transverse fractures	Fractures involving an open epiphysis
Short oblique fractures	Fractures with near or complete intra-articular extension
Minimally comminuted fractures	Cases when at least partial cortical continuity cannot be re-established

Figure 1. Top: Example of an intramedullary screw under 3.0mm in diameter that does not exceed 50 or 60mm in length due to biomechanical weakness beyond those lengths. Bottom: Intramedullary screws without compression.

sagittal band. Alternatively, the guidewire and screw can be placed percutaneously without a formal arthrotomy. To achieve the best access to the metacarpal head, the metacarpophalangeal (MCP) joint is flexed to 90°. With the fracture held reduced after appropriate closed reduction, a guidewire is introduced retrograde under fluoroscopic guidance from the midline of the metacarpal head and at the junction of the dorsal 1/3 and volar 2/3, which aligns with the central IM canal. The wire is advanced across the fracture into the proximal metaphysis of the metacarpal. The screw length is measured, usually subtracting at least 5 mm to allow the screw to be countersunk in the head. The head and intramedullary canal are subsequently drilled with a cannulated drill followed by IM screw placement. Ideally, following the principles of intramedullary fixation of long bones, maximum fill of the metacarpal canal is preferable, relative to length and width, providing maximum strength and bony fixation.[23–29] [Figure 2]

Surgical Technique for Phalangeal Fractures

IM screw fixation of phalangeal fractures can be performed either retrograde and antegrade. All techniques are best facilitated with the use of intraoperative fluoroscopy. The surgery can be performed under all forms of anesthesia including general sedation with local hematoma block, or using a wide-awake technique. Again, various screw options are available including cannulated or non-cannulated, compression versus non-compression, and different screw widths and lengths. The authors recommend using a cannulated headless screw with a minimum width of 2.0 mm whenever possible, but also sized appropriately to the inner diameter of the intramedullary canal. [Table 3]

Retrograde Technique

The retrograde approach to phalangeal fractures is similar to that of the metacarpals and can be applied to all of the phalanges – proximal, middle, and distal. With the fracture reduced by closed or open manipulation as needed, the interphalangeal joint is maximally flexed, and the guidewire is introduced percutaneously through the center/center position of the head of the phalanx and advanced across the fracture into the phalanx base. The guidewire is then measured, over-drilled with a cannulated drill, and then the fracture secured with an IM screw placed across the guidewire. If necessary, except in cases of distal phalanx fixation, the entry point within the interphalangeal joint can be opened with a longitudinal incision through the skin and the extensor mechanism. But potential injury to the extensor mechanism must be taken into account.[20] [Figures 3-8]

Table 2. Tips and tricks for the retrograde approach to metacarpal fractures

Surgical Technique for Intramedullary Compression of Metacarpal Fracture Tips and Tricks
Retrograde Technique
Confirm adequate closed reduction before guidewire placement. If not possible, consider open reduction.
Consider percutaneous approach to minimize extensor mechanism manipulation.
Maximize screw diameter fit within intramedullary canal, a minimum of 3.0mm is recommended to maximize rotational stability and construct rigidity.
Maximize screw length across the fracture while making sure to be adequately countersunk distally across the metacarpal head while not violating the metacarpal base proximally.

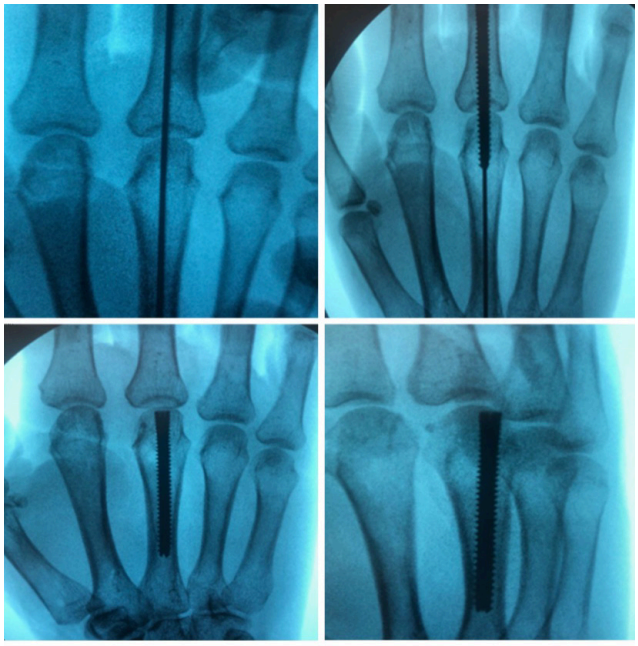

Figure 2. Top left: AP radiograph of pin placement using retrograde approach to metacarpal. Top right: AP radiograph showing introduction of screw using retrograde approach to metacarpal. Bottom left: AP radiograph showing final screw position after retrograde approach to metacarpal. Bottom right: Oblique view of final screw position using retrograde approach to metacarpal.

Anterograde Technique

The anterograde approach begins with a small incision on the dorsum of a 90-degree flexed MCP, PIP, or DIP joint for proximal phalanx, middle phalanx, or distal phalanx fixation; respectively. Next, a guidewire is driven from the dorsal base of the bone, into the IM canal, and into the distal metaphysis. Care is taken to position the guidewire as volar as possible to not disrupt, or "blow out" the dorsal cortex when drilling and placing the screw. The screw length is measured, a drill is advanced over the guide wire, and the screw is placed ensuring that it is driven beneath the cartilage of the phalanx base. With this approach, there are several considerations. First, there is potential for cartilage damage to both sides of the joint, specifically the phalangeal head which is not at risk of injury in the retrograde approach.[20] Second, the wire can be easily bent or broken in the joint if the finger is inadvertently extended, so care should be taken to keep the joint flexed once the wire is inserted. [Figures 9-11]

Table 3. Tips and Tricks for Both the Antegrade and Retrograde Approaches to Phalangeal Fracture

Surgical Technique for Intramedullary Compression of Proximal Phalangeal Fracture Tips and Tricks	
Retrograde Technique	**Antegrade Technique**
Enter the PIP joint percutaneous without surgical exposure of the central slip to minimize extensor mechanism injury. Hyperflex the PIP joint to facilitate access to the proximal phalangeal shaft. Keep PIP and MCP joints flex to maintain rotational alignment of the phalanx during IM fixation.	With the MCP joint slightly flexed, place a dorsal stress across the proximal phalanx base to deliver it for guidewire access. Enter the base of the proximal phalanx with a guidewire through its dorsal half.

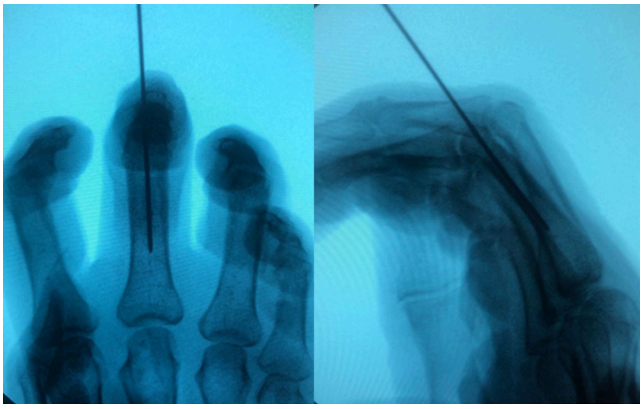

Figure 3. AP and lateral radiographs showing introduction of guide wire using retrograde approach to proximal phalanx.

Complications

Chondral Damage

With respect to articular injury, this has been well

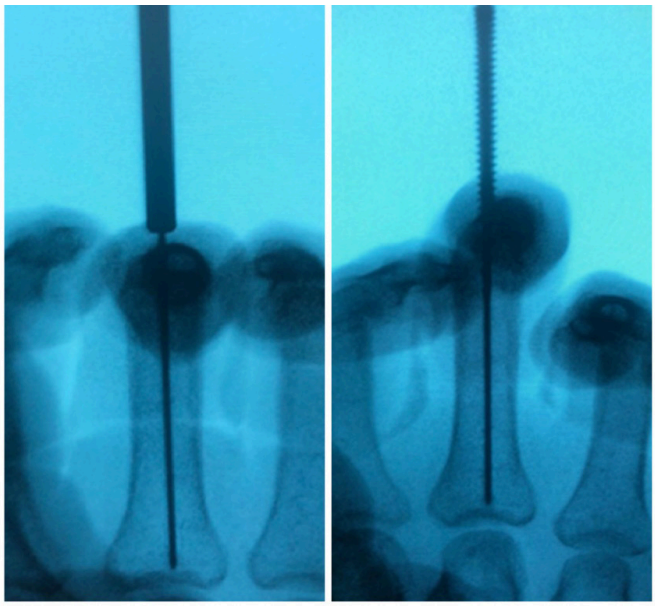

Figure 4. Left: AP image showing measurement tool used to determine screw length. Right: AP image showing introduction of screw using retrograde approach to proximal phalanx.

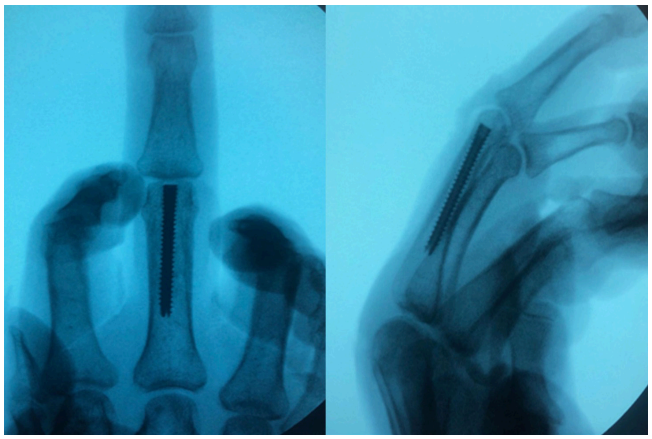

Figure 5. AP and lateral view of final screw placement for retrograde approach to proximal phalanx.

studied in many orthopedic applications including retrograde femoral IM nails, antegrade humeral IM nails, and scaphoid screw fixation. Violating a small proportion of an articular surface to place a buried implant is generally well tolerated without any long-term degenerative changes or joint dysfunction.[30,31]

Starting with the proximal phalanx, the theoretical advantage to the antegrade approach is avoiding any violation of the PIP joint, and thus reducing potential risk to postoperative arthritis. The downside to this approach is the challenging guidewire placement, risk of bending or breaking the guidewire, and potential injury to the metacarpal head. A cadaveric study performed by Borbas et al was aimed at quantifying the extent of the damage comparing a trans-articular to an intra-articular approach to the proximal phalanx. The study showed that the average defect to the articular surface for the trans-articular and intra-articular approaches were similar at 4.2% and 4.6%, respectively. Notably however, with the intra-articular approach, the defect is located dorsally on the base of the proximal phalanx whereas it is centrally located with the transarticular approach. This is important to highlight because with grasping movements

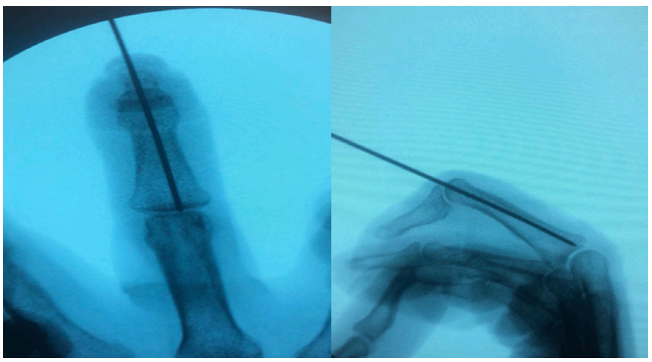

Figure 6. AP and lateral image of guide wire placement using the retrograde approach to the middle phalanx.

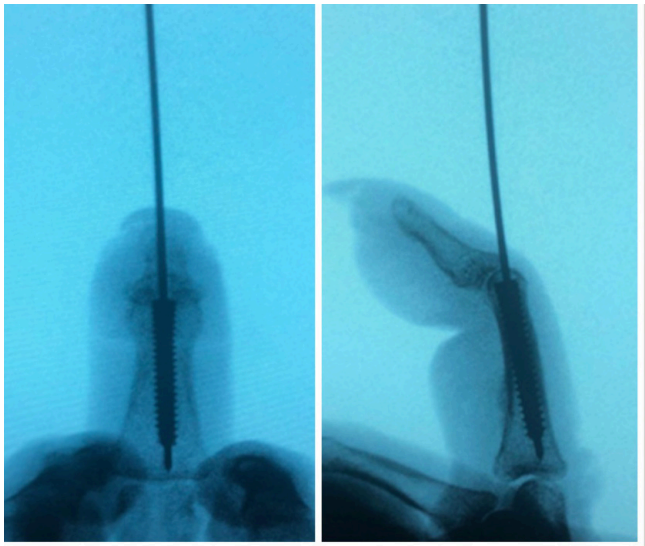

Figure 7. AP and lateral views of screw insertion using retrograde approach to the middle phalanx.

the MCP joint is flexed and the dorsal proximal phalanx base does not see as much joint reaction force as the central region. Thus, the trans-articular approach could perceivably lead to pain with gripping.[12,20] Still, there are no reports of osteoarthritic degeneration after fixation with IM screws in the early literature, but for this reason the authors recommend intra-articular guidewire placement.[20] In a similar study performed by Urbanschitz et al., the damage to the articular surface of the metacarpal head after transcutaneous screw insertion was compared to a mini-open approach. The median size defect using the transcutaneous approach was 7mm^2 whereas with the mini-open approach the median size defect was 8mm^2. This represented a small portion of the articular surface at 5% and 6%, respectively. This minute difference is likely clinically irrelevant. Collectively, these 2 studies show very little of the joint surface is drilled in placing IM screws, supporting the belief that drilling the articular surface is unlikely to cause any long-term

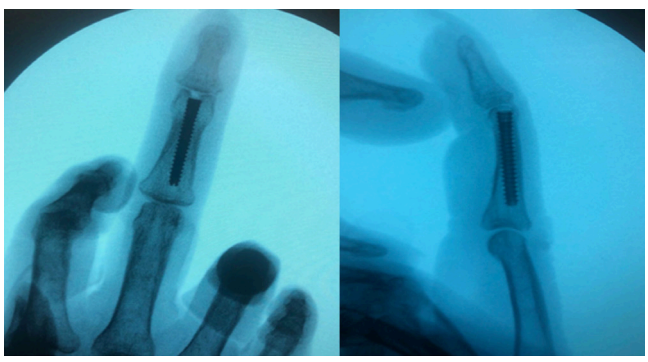

Figure 8. AP and lateral view of final screw placement after retrograde approach to middle phalanx.

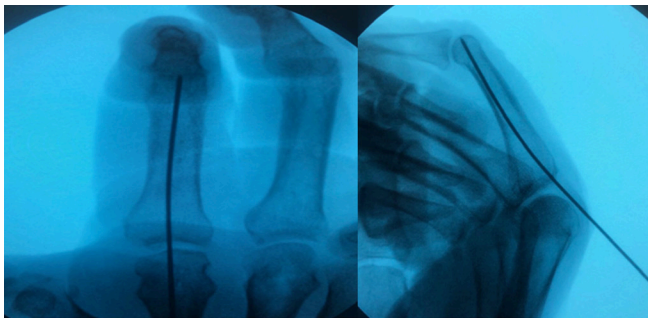

Figure 9. AP and lateral view of guide wire insertion using antegrade approach to proximal phalanx.

degenerative change.[32]

Tendon Injuries

With the retrograde technique to both the metacarpal and phalanges requiring either the sagittal band or extensor tendon to be split, damage to the extensor mechanism of the digit can occur. Multiple studies however, have demonstrated that this complication is rare and often self limited. In one such study performed by Ruchelsman et al., evaluating a series of 39 patients, 50% had an extensor lag immediately post-operatively; however, by 3 weeks after surgery all had resolved[25,26] In another study by Pinal et al., evaluating 69 fractures in 59 patients, only two had extensor lag >30 degrees.[13,20]

Screw Bending, Breakage and Removal

There are some hardware specific concerns with IM screw fixation of metacarpal and phalangeal fractures.[23–27] They include the difficulty of removing

Figure 10. AP view showing introduction of screw to proximal phalanx using antegrade approach.

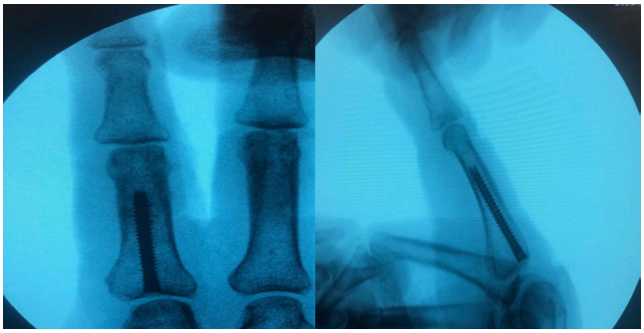

Figure 11. AP and lateral view of final screw placement using antegrade approach to proximal phalanx.

IM hardware, particularly if bent or broken due to new injury or fatigue failure. [Figure 12] In addition, IM screw fixation does not have the benefit of proximal and distal interlocks employed with other long bone fracture nails, thereby providing little rotational stability. To maximize rotational stability and overall strength of the construct, the surgeon should place the longest screw possible with a snug fit in the IM canal which provides friction resistance to rotation. Though one must be careful to not over-drill the canal, weakening the bone, making it susceptible to iatrogenic fracture with screw insertion. Conversely, passing a screw through an under-drilled IM canal, particularly in young patients with dense cortical bone, could lead to screw breakage or fracture. One helpful pointer is to measure the IM canal diameter on

Figure 12. Example of bent screw due to biomechanical weakness.

Table 4. Pros and Cons of Intramedullary Fixation with Headless Compression Screw for Metacarpal and Phalangeal Fractures

Pros	Cons
Reduced operative times	Difficult removing hardware
Minimally invasive technique	Rotational instability
More cost effective	
Lower complication rate	
Allows for early post-operative motion	
Improved postoperative outcomes when compared to k-wiring and plates.	

radiograph pre-op or visually check the canal/screw fit fluoroscopically, intra-op, to help choose the proper screw size.

Post Operative Outcomes

As a newer fixation technique, a full understanding of the risks and benefits of this procedure are not known. However, early studies have shown that it is associated with reduced operative time, lower complication rates and quicker recovery.[24,33,34] In a systematic review by Genoveffa et al. analyzing outcomes of retrograde IM screw fixation of metacarpal fractures, the complication rate was 2.8%. This was significantly lower than alternative operative treatments such as k-wires and plates where reported complications range from 26-35%, and 16-22%, respectively [Table 4].[24,35,36]

Post Operative Management

Important post-operative considerations for this procedure include reducing rotational instability and allowing for protected early range of motion. Along with using the longest screw possible with a snug fit in the IM canal to provide friction resistance to rotation, the operative finger can be buddy taped to an adjacent finger for increased rotational stability postoperatively.[20] Early post operative motion can be encouraged through use of a removal splint and utilization of hand therapy. These patients should then return to clinic in four to six weeks for radiographic evaluation to ensure fracture union.

Regardless of the technique utilized by the surgeon, there seems to be a general agreement that IM screw fixation should be reserved for transverse or oblique fractures of the metacarpals and phalanges whereas fixation with plates and screws is recommended for long oblique, spiral, and/or highly comminuted fractures.[6,23,38,39]

Disclosures: The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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