Intramedullary Headless Screw Fixation for Phalanx Fractures: Technique and Review of Current Literature

Rajeev N. Herekar, DO, Mitchell P. John II, MD,†*
Michael C. Doarn, MD,† and Jason A. Nydick, DO†

Abstract: Fractures of the phalanges can often be managed nonoperatively, but displaced phalangeal fracture patterns, including malrotation, are more amenable to operative treatment. There are several described methods for surgical management of phalanx fractures, but there remains no consensus on a clearly superior method of fixation. Percutaneous Kirschner wires, interfragmentary screws, plate and screw constructs, intramedullary nails, and cannulated intramedullary headless screws are all utilized in the treatment of these fractures. Intramedullary headless screws for phalanx fractures may provide suitable fixation allowing early motion and recovery. Here, we describe a technique for antegrade and retrograde intramedullary headless screw fixation for phalanx fractures.

Key Words: phalanx, fracture, headless screw, intramedullary, fixation

(*Tech Hand Surg* 2022;26: 218–228)

Phalanx fractures are common injuries, making up 6% of all fractures to the musculoskeletal system,[1] 26% of all hand and forearm injuries,[2] and along with metacarpal fractures, an estimated 41% of all fractures of the upper extremity.[3] Most proximal and middle phalanx fractures presenting with simple extra-articular fracture patterns may be successfully treated nonoperatively, however, those with significant rotational deformity, shortening or open fractures warrant surgical intervention.[4] There are a multitude of techniques described, including percutaneous Kirschner wire fixation, open reduction and internal fixation with interfragmentary screws or plate-screw constructs, and cannulated intramedullary headless screws.[4,5] Surgical techniques and patient outcomes using intramedullary headless screw have been described with good early and mid-term results for phalangeal and metacarpal fractures.[6–9] In this article, we present our surgical technique for intramedullary headless screw fixation in the proximal and middle phalanx and review the current outcomes literature using this technique.

From the *Florida Orthopaedic Institute/Foundation for Orthopaedic Research and Education; and †Florida Orthopaedic Institute/Department of Orthopaedic Surgery, University of South Florida, Tampa, FL.

Conflicts of Interest and Source of Funding: J.A.N. is a paid consultant and paid presenter or speaker for Axogen and for Depuy (A Johnson & Johnson Company); paid presenter or speaker for Checkpoint Surgical; editorial or governing board for *Journal of Hand Surgery American* and *Techniques in Hand & Upper Extremity Surgery*; paid consultant for Mission Surgical, Trimed, and Conmed. For the remaining authors none were declared.

Address correspondence and reprint requests to Rajeev N. Herekar, DO, Foundation for Orthopaedic Research and Education (FORE), 13020 Telecom Parkway North, Tampa, FL 33637. E-mail: rherekar@foreonline.org.

Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website, www.techhandsurg.com.

INDICATIONS/CONTRAINDICATIONS

Phalangeal fractures can often be managed nonoperatively with closed reduction and immobilization. Patterns that are nondisplaced or stable following closed reduction with minimal angulation, shortening, or malrotation can be managed with a short period of immobilization in the intrinsic plus position followed by a range of motion (ROM).[4,10] Surgical indications include open fractures, those with rotational deformity disrupting the digit cascade, unstable patterns, significantly displaced, shortened, or angulated fractures, and patients with multiple phalangeal or metacarpal fractures.[11] The technique of intramedullary screw fixation is best utilized for transverse or short oblique extra-articular fractures of the proximal or middle phalangeal neck or shaft in the index, long, ring, or small digits.[6,10] Certain fractures with partial articular involvement or some degree of metaphyseal or diaphyseal comminution may also be amenable to intramedullary headless screw fixation.[12] This technique also works well in the setting of a phalangeal nonunion (Figs. 1–13).[13]

Contraindications include those involving open physes, length unstable (long oblique or very comminuted) fractures or those with significant bone loss, active infection, and complex intra-articular fractures patterns.[6] Significant intra-articular comminution or a subchondral fracture pattern can compromise the secure fixation of the screw head increasing the risk for failure.[6]

FIGURE 1. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Preoperative and postoperative imaging following initial injury and management with percutaneous, crossed Kirschner wire fixation.

FIGURE 2. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Preoperative and postoperative imaging following initial injury and management with percutaneous, crossed Kirschner wire fixation.

FIGURE 3. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Preoperative and postoperative imaging following initial injury and management with percutaneous, crossed Kirschner wire fixation.

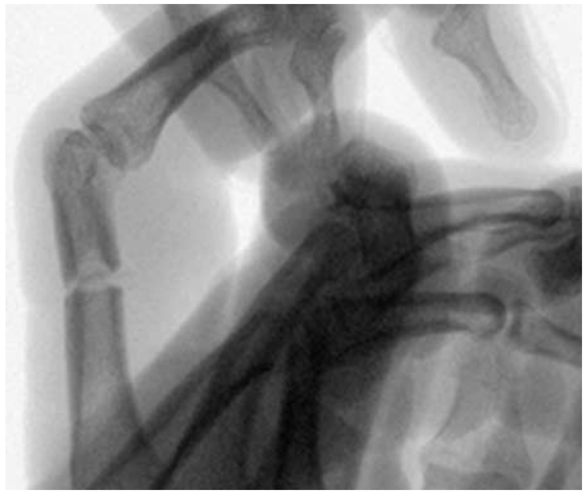

FIGURE 4. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Oligotrophic nonunion treated with revision fixation using headless intramedullary screws.

Anatomy and Surgical Considerations in Proximal and Middle Phalanx Fractures

The decision to proceed with surgical management warrants an operative plan. A retrograde or antegrade approach can be used depending on the personality of the fracture (location and pattern), presence of adjacent metacarpal or phalanx fractures (potential to use a single incision), and soft tissue integrity. Local anatomic considerations must also be considered, including violating the central slip approaching through the

FIGURE 5. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Oligotrophic nonunion treated with revision fixation using headless intramedullary screws.

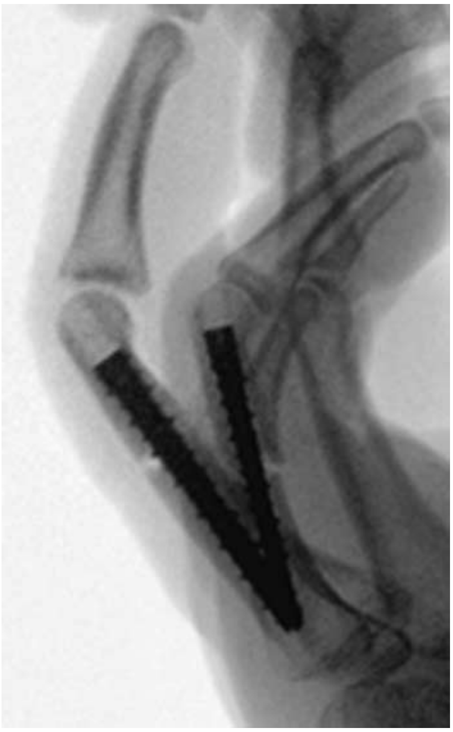

FIGURE 6. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Oligotrophic nonunion treated with revision fixation using headless intramedullary screws.

FIGURE 8. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Posteroanterior, oblique, and lateral radiographs at 3 weeks postoperatively showing interval healing following revision open reduction internal fixation with intramedullary headless screw fixation.

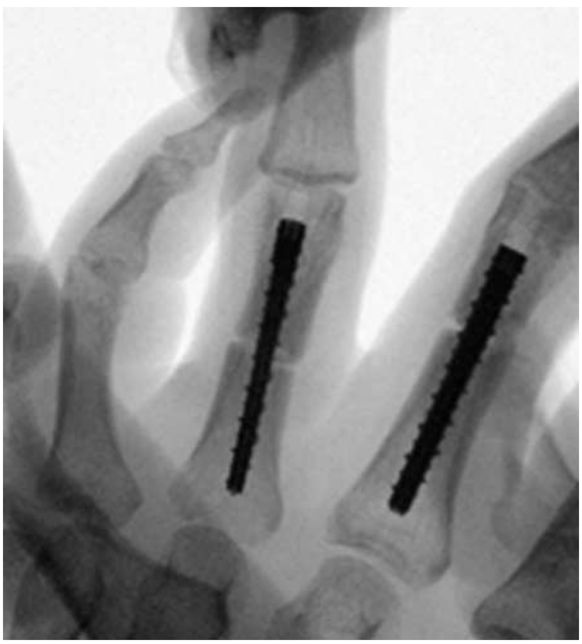

FIGURE 7. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Oligotrophic nonunion treated with revision fixation using headless intramedullary screws.

FIGURE 9. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Posteroanterior, oblique, and lateral radiographs at 3 weeks postoperatively showing interval healing following revision open reduction internal fixation with intramedullary headless screw fixation.

FIGURE 10. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Posteroanterior, oblique, and lateral radiographs at 3 weeks postoperatively showing interval healing following revision open reduction internal fixation with intramedullary headless screw fixation.

FIGURE 11. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Posteroanterior, oblique, and lateral radiographs at 5 months postoperatively showing interval healing following revision open reduction internal fixation with intramedullary headless screw fixation.

proximal interphalangeal joint (PIPJ) or the sagittal band complex when accessing through the metacarpophalangeal joint (MCPJ).

For length, stable fracture patterns reduction and adequate fixation can reliably be achieved with this method via an intra-articular or transarticular approach (Figs. 14, 15). The intra-articular technique is described in detail below. In certain circumstances, a transarticular technique can be helpful, with the caveat that violation of the metacarpal or proximal phalanx head occurs. For example, in a phalanx fracture with a short segment proximally, an antegrade transarticular technique permits access to the starting point without requiring excessive flexion or translation through the fracture which can contribute to malreduction (Figs. 14, 15).[8] The transarticular approach is rarely needed.

The retrograde technique is well described in metacarpal fractures and less so in proximal phalanx fractures.[6,7,9,14] The steps are analogous to those described here for the antegrade technique, except for a few considerations. When violating the PIPJ, it is important to monitor the integrity of the central slip during exposure and hardware insertion, and it is prudent to insert the guidewire using an oscillatory function and insert the screw by hand (Figs. 16, 17). The percentage of the joint surface violated with this approach to the proximal phalanx is slightly greater compared with the antegrade pathway due to the relative size of the PIPJ compared with the MCPJ, but this is unlikely to be clinically significant (Fig. 18).[6,13,15] In circumstances where either a proximal/middle phalanx or proximal phalanx/metacarpal fracture involve the same digit, this is an

FIGURE 12. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Posteroanterior, oblique, and lateral radiographs at 5 months postoperatively showing interval healing following revision open reduction internal fixation with intramedullary headless screw fixation.

Copyright © 2022 Wolters Kluwer Health, Inc. All rights reserved.

FIGURE 13. Nonunion of long and ring finger proximal phalanges initially treated with crossed Kirschner wires and revised with retrograde intramedullary screws: Posteroanterior, oblique, and lateral radiographs at 5 months postoperatively showing interval healing following revision open reduction internal fixation with intramedullary headless screw fixation.

excellent technique to be completed in both directions through a single percutaneous incision.

Technique (Proximal Phalanx–Antegrade) Exposure

Before incision, ensure that adequate fluoroscopic imaging can be obtained. Closed reduction can typically be achieved with gentle axial traction and direct pressure near the apex. Oblique patterns may be amenable to reduction aid with the use of a percutaneous clamp (Fig. 19). Fractures not reducible by closed means should be open reduced and can be held with a reduction clamp or adjuvant Kirschner wires to assist in reduction. Rotation and digit cascade should be closely monitored both clinically and fluoroscopically at this stage and throughout the duration of wire placement and fixation. With the MCPJ flexed from 70 to 90 degrees, a guidewire is percutaneously placed centrally in the sagittal and coronal planes and oscillated down

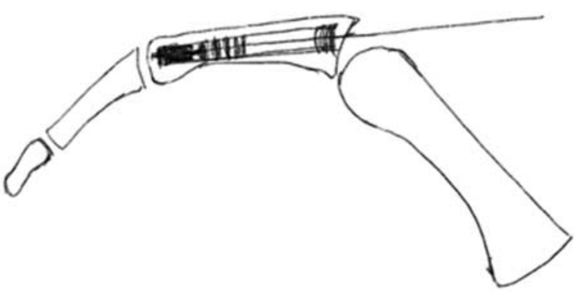

FIGURE 14. Intra-articular and transarticular illustrations: Drawing demonstrating intra-articular approach.

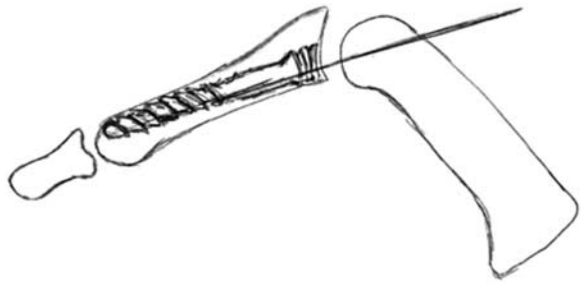

FIGURE 15. Intra-articular and transarticular illustrations: Drawing demonstrating transarticular (right) approach.

the entire length of the reduced proximal phalanx in an antegrade (or retrograde) direction under fluoroscopic guidance. Placement is then confirmed on both anteroposterior and lateral views (Figs. 22, 23). A small incision, just large enough to pass the screw, is made at the site of the guidewire just over the head of the phalanx through the skin to the extensor hood complex. Surgeon preference dictates the size of the incision. A longitudinal split is made in the middle of the central tendon to directly visualize the guidewire entering the proximal phalanx.

Fixation

With the skin and extensor complex retracted in either direction with 2 Ragnell retractors, slide the cannulated gauge down the wire placing it flush to the bone and determine screw length. We prefer to use the longest screw possible that can be maintained within the bone for maximal stability, although using too long a screw can distract the fracture site. Screw core diameter size should be determined based on the size of the medullary canal, and depending on the manufacturer, these are usually 2 to 3 mm in diameter. We routinely use 2.3 mm screws in the proximal and middle phalanx. Using a screw with too large a diameter may cause fracture displacement as it engages the isthmus. Next, ensure the guidewire is completely advanced to limit the possibility of incidental extraction during drilling or screw insertion. Alternatively, the guidewire can be driven through the distal end of the digit and clamped with a hemostat to prevent incidental extraction while reaming and countersinking. A hand-driven countersink is then placed over the guidewire to facilitate complete insertion of the screw head beneath the cartilage. Using the cannulated hand drill, carefully drill to the fracture site with the digit held in the reduced position. Utilization of the hand drill limits the risk of injury to adjacent soft tissues. Drilling the entire length of the bone may

FIGURE 16. Retrograde technique modifications: Cadaver demonstration of starting incision over the head of the proximal phalanx at the level of the proximal interphalangeal joint.

FIGURE 17. Retrograde technique modifications: Cadaver demonstration of appropriate retraction of the central extensor mechanism with 2 small, sharp, hooked retractors while carefully passing the guidewire in a retrograde manner.

be necessary in patients with very narrow intramedullary canals to pass the screw.

Cannulated headless screws set typically come in partially or fully threaded options. We generally use the partially threaded option as it usually provides adequate fracture fixation while limiting the risk of bone or screw head breakage as these generate a significant amount of torque upon insertion. The appropriately sized screw is then placed by hand under fluoroscopic guidance while carefully monitoring rotation, cascade, and for evidence of fracture distraction. Visually and tactically confirm that the screw head is buried beneath the articular surface into the subchondral bone to avoid iatrogenic joint arthrosis or block to motion. After confirming the placement of the screw on orthogonal fluoroscopic views, the guidewire may be removed (Figs. 24, 25). Bring the digit through the full passive ROM including flexion, extension, radial and ulnar deviation to confirm the fracture is stable and there is no obstruction to motion. Check digit cascade to assess for any malrotation.

Modifications should be made as described above when approaching via the PIPJ with antegrade fixation of a middle phalanx (Supplemental Figs. 1–5, Supplemental Digital Contents 1–5, http://links.lww.com/BTH/A159, http://links.lww.com/BTH/A160, http://links.lww.com/BTH/A161, http://links.lww.com/BTH/A162, http://links.lww.com/BTH/A163) or retrograde fixation of a proximal phalanx (Supplemental Figs. 6–11, Supplemental Digital Contents 6–11, http://links.lww.com/BTH/A164, http://links.lww.com/BTH/A165, http://links.lww.com/BTH/A166, http://links.lww.com/BTH/A167, http://links.lww.com/BTH/A168, http://links.lww.com/BTH/A169) (Figs. 20–30).

FIGURE 18. Retrograde technique modifications: Limited articular surface defect in the proximal phalangeal head following insertion of the retrograde headless screw using the intra-articular technique.

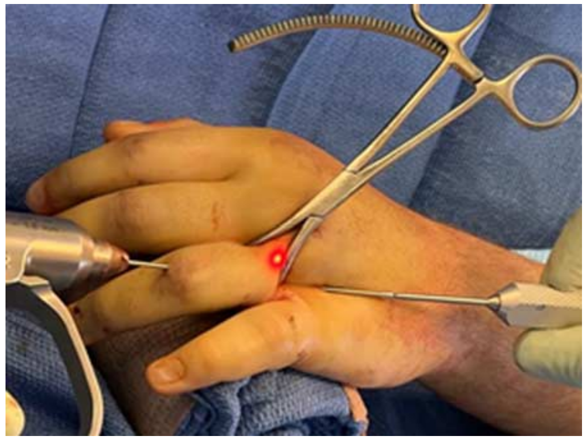

FIGURE 19. Percutaneous clamp-assisted reduction: Guidewire placement across the ring finger proximal phalanx fracture site. A percutaneous clamp is used as a reduction aid across the fracture site.

Closure

Irrigate the incision site with sterile saline. Due to the minute size of the dorsal defect required to obtain the starting position, repair of the capsule or extensor mechanism is not routinely performed. In the setting where a larger entry point is required for fixation, repair is carried out using 4-0 braided absorbable suture. We have not encountered problems omitting routine

FIGURE 20. Antegrade technique in proximal phalanx fracture: Initial injury films demonstrating a displaced transverse fracture of the base of the small finger proximal phalanx.

FIGURE 21. Antegrade technique in proximal phalanx fracture: Initial injury films demonstrating a displaced transverse fracture of the base of the small finger proximal phalanx.

FIGURE 22. Antegrade technique in proximal phalanx fracture: Intraoperative fluoroscopy is used to obtain the proper starting point following closed reduction. Note the central starting point in both the sagittal and coronal planes.

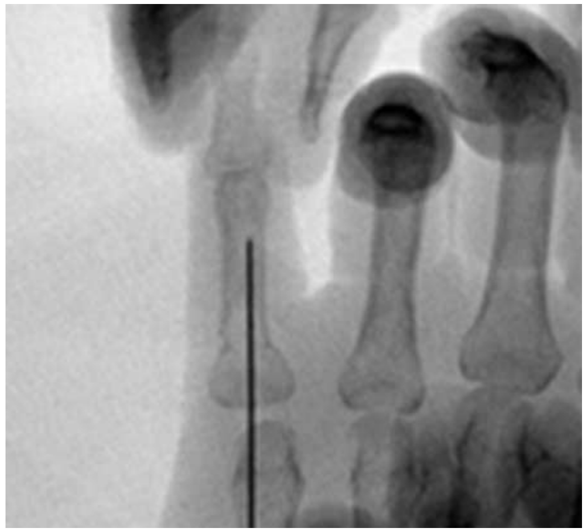

FIGURE 23. Antegrade technique in proximal phalanx fracture: Intraoperative fluoroscopy is used to obtain the proper starting point following closed reduction. Note the central starting point in both the sagittal and coronal planes.

closure of the capsule and small extensor defect. The skin should be closed with 4-0 monofilament interrupted sutures. Plaster may be used as needed in patients with questionable compliance, multiple fractures, or in the setting of complex soft tissue injury.

Rehabilitation

Following the procedure, those with isolated phalanx fractures and no significant associated soft tissue trauma are placed in a custom volar resting orthosis at 3 to 5 days postsurgery by hand therapy to wear during sleep and heavy activity. They are encouraged to come out of the orthosis and begin active and passive ROM as soon as postoperative pain and soft tissues allow. Patients with multiple fractures or soft tissue concerns

FIGURE 24. Antegrade technique in proximal phalanx fracture: Intraoperative fluoroscopy demonstrating the final construct with placement of a single 2.3-mm fully threaded headless screw. Note the compression across the fracture site.

Copyright © 2022 Wolters Kluwer Health, Inc. All rights reserved.

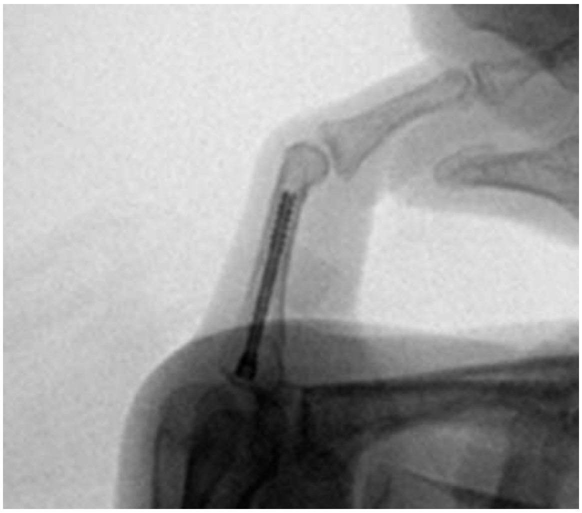

FIGURE 25. Antegrade technique in proximal phalanx fracture: Intraoperative fluoroscopy demonstrating the final construct with placement of a single 2.3-mm fully threaded headless screw. Note the compression across the fracture site.

FIGURE 26. Antegrade technique in proximal phalanx fracture: Postoperative images at 6 weeks showing evidence of bony healing with near full consolidation of the fracture line and maintained alignment.

FIGURE 27. Antegrade technique in proximal phalanx fracture: Postoperative images at 6 weeks showing evidence of bony healing with near full consolidation of the fracture line and maintained alignment.

may be treated with splinting or increased immobilization time as needed to facilitate soft tissue recovery.

Technical Modifications

In addition to the standard technique described above, there have been fracture specific modifications described by del Piñal et al[6] and Gaspar et al,[14] axial strutting and Y-strutting.

Axial strutting is a technique used in settings of significant dorsal cortical comminution leading to a lack of cortical support. In axial strutting, the screw is inserted as dorsally as possible within the phalanx at a shorter length than the standard technique so that the screw head is buried deep within the medullary canal once the leading tip of the screw engages the distal subchondral bone. According to del Piñal et al,[6] this allows the screw to act as a girder because of its proximal fixation within the isthmus of the medullary canal, providing a dorsal cortical substitution. An example from our own series is seen in small finger P1 fixation in Supplemental Figure 8 (Supplemental Digital Content 8, http://links.lww.com/BTH/A166).

Y-strutting is used in cases of significant comminution or subchondral fractures. In these circumstances, fractures often lack circumferential cortical support and seating the screw can lead to shortening or loss of reduction. In this technique, following reduction, first one long screw and then one shorter oblique screw are inserted sequentially in a Y configuration, with the apices of the screws converging distally. Using the

FIGURE 28. Antegrade technique in proximal phalanx fracture: Postoperative images at 6 weeks showing evidence of bony healing with near full consolidation of the fracture line and maintained alignment.

architectural concept of strutting, this construct has increased resistance to longitudinal shortening. This technique was originally described in metacarpal head fractures (del Piñal and colleagues). A small series by Gaspar et al[14] successfully described an expansion of this technique using an antegrade approach in comminuted proximal phalanx fractures. Supplemental Figures

FIGURE 29. Antegrade technique in proximal phalanx fracture: Postoperative clinical images at 6 weeks showing a range of motion assessment with full uninhibited flexion at the small finger metacarpophalangeal joint and proximal interphalangeal joint and near full extension with the small finger proximal interphalangeal joint.

FIGURE 30. Antegrade technique in proximal phalanx fracture: Postoperative clinical images at 6 weeks showing a range of motion assessment with full uninhibited flexion at the small finger metacarpophalangeal joint and proximal interphalangeal joint and near full extension with the small finger proximal interphalangeal joint.

12 and 13 (Supplemental Digital Contents 12, 13, http://links.lww.com/BTH/A170, http://links.lww.com/BTH/A171) are examples of this technique from our own series.

Expected Outcomes

To date, 3 small series report on outcomes following intramedullary headless screw fixation for phalangeal fractures. The series by del Piñal and colleagues reported on 19 proximal phalanx fractures treated with an average final ROM of 83 degrees at the PIPJ and total active motion (TAM) of 243 degrees (range: 0 to 270 degrees), and all fractures healed at final follow-up, with a median return to full activity at 54 days.[6]

A small series of 10 proximal phalanx fractures treated with antegrade Y-strutting demonstrated a final TAM of 258 degrees and a mean postoperative grip strength of 97% of the contralateral side. Importantly, all fractures healed without complication, and the average return to full activity was 6.4 weeks, with 2 high-level athletes returning to competition within 1.5 weeks wearing a protective cast.[14]

A recent study by Giesen et al[8] included 31 proximal and middle phalanges. This series included open fractures, patients with multiple hand fractures, and associated soft tissue tendon injuries making it more generalizable to a trauma population. All patients healed radiographically at a mean of 31 days, except for 1 that went onto early failure. Their series reported a mean TAM of 222 degrees, with an average final extension lag of 2 and 8 degrees at the MCPJ and PIPJ, respectively.[8]

Complications

The potential complications with this technique are similar to those described in other methods of operative fixation of phalanx fractures including infection, stiffness and loss of motion, screw failure, fracture displacement, joint arthrosis, and symptomatic hardware.

The risk of stiffness, loss of motion, or extensor lag is less common but not absent with this technique. Given the minimal soft tissue dissection and stability allowing immediate ROM, we believe the risk is quite small, and evidence so far has demonstrated this. The cohort of patients treated by del Piñal and colleagues showed TAM of 243 and 249 in the proximal phalanx and metacarpal fracture groups, respectively. Only 2 patients in their study required secondary surgery for stiffness with tenolysis or capsulotomy, and these patients had additional hand injuries. Notably, their postoperative protocol involves wearing an extension orthosis at night to help prevent PIPJ extensor lag.[6] In a retrospective analysis of 31 patients that underwent intramedullary headless screw fixation of the

Copyright © 2022 Wolters Kluwer Health, Inc. All rights reserved.

metacarpals, proximal, or middle phalanges, only 1 patient required an extensor tendon tenolysis for PIPJ extensor lag of 25 degrees, improving to 5 degrees after tenolysis.[8]

Secondary displacement is rare but can occur if patients are not carefully selected based on fracture characteristics, patient factors, and additional injuries. Some degree of shortening or angulation are better tolerated than rotational deformities. Malrotation can occur intraoperatively or postoperatively. Should it occur in the operating room, the screw should be backed out and alignment adjusted before reinserting the screws, with open reduction performed as necessary. So far, we have not encountered any known secondary displacement in the postoperative setting. del Piñal et al[6] noted that fractures involving the subchondral surface, those with unrecognized intra-articular extension, and with significant comminution are at risk for later displacement or shortening and may require adjuvant modalities, including pins or lag screws, to confer appropriate mechanical stability. In the retrospective review by Giesen et al[8] including 31 fractures treated with headless screw, a single patient with a long oblique proximal phalanx fracture required revision with screw removal and lag screw fixation due to displacement at 9 days postoperatively.

A unique concern for this method of fixation is the theoretical risk for MCPJ or PIPJ iatrogenic arthrosis. There are several factors that contribute to the general consensus that the articular surface violation is likely inconsequential when this technique is performed properly. Multiple studies have quantified the small amount of articular surface involved when inserting these screws with estimates ranging from 4% to 5% in the metacarpal head[16] and 13% to 25% of the proximal phalanx head[6] and 4.2% to 8.5% of the proximal phalanx base.[15] Unlike joints of the lower extremities, the PIPJ and MCPJ are not significant load-bearing joints, and the change in force distribution across the joint due to the small change in the articular surface area following screw insertion is likely insignificant.[16] Furthermore, we believe that the defect likely fills in with fibrocartilage over time, similar to that seen in common microfracture techniques. We have not seen any significant examples of iatrogenic arthrosis or persistent joint pain in our early follow-up of either proximal phalanx or metacarpal fractures treated with headless intramedullary screw, but there are no studies at this time evaluating long-term follow-up.[6,7]

Although hardware complications related to intramedullary headless compression screw fixation appear to be rare compared with plate or pin fixation, they are a potential risk.[14,17,18] Common screw and intramedullary implant complications including head stripping, implant failure, or intra-articular prominence, can occur. Of the case series in the literature at this time, only a single screw was removed for perceived implant prominence in the MCPJ at 1 month postoperatively, which was asymptomatic.[8] Although a more extensive open approach and arthrotomy may be needed for hardware removal to isolate the screw below potential fibrocartilage overgrowth, the cannulated screw and driver design can help to ease screw removal.

DISCUSSION

Intramedullary fixation with headless screws in the management of proximal and middle phalanx fractures allows for minimal soft tissue disruption, rapid and safe ROM, high union rates, and lower complication rates compared with other common modes of fixation, especially for simple unstable fracture patterns.[7] Although there is conflicting evidence regarding the overall biomechanical strength with intramedullary headless screws compared with plating, they have been shown to be biomechanically sufficient to tolerate the typical digit forces seen with immediate ROM, a welcome advantage for early return to work and prevention of contractures.[19–21] This article demonstrates the broad range of simple techniques and tricks that make intramedullary screw fixation an easily applicable, reliable, and ideal method for the treatment of proximal and middle phalanx fractures.

REFERENCES

1. Emmett JE, Breck LW. A review and analysis of 11,000 fractures seen in a private practice of orthopaedic surgery 1937-1956. *J Bone Joint Surg*. 1958;40:1169–1175.
2. Chung KC, Spilson SV. The frequency and epidemiology of hand and forearm fractures in the United States. *J Hand Surg [Am]*. 2001;26:908–915.
3. Bernstein ML, Chung KC. Hand fractures and their management: an international view. *Injury*. 2006;37:1043–1048.
4. Henry MH. Fractures of the proximal phalanx and metacarpals in the hand: preferred methods of stabilization. *J Am Acad Orthop Surg*. 2008;16:586–595.
5. Liodaki E, Kisch T, Wenzel E, et al. Percutaneous cannulated compression screw osteosynthesis in phalanx fractures: the surgical technique, the indications, and the results. *Eplasty*. 2017;17:e8.
6. del Piñal F, Moraleda E, Rúas JS, et al. Minimally invasive fixation of fractures of the phalanges and metacarpals with intramedullary cannulated headless compression screws. *J Hand Surg Am*. 2015;40:692–700.
7. Sellers TR, Lewis JT, Smith C, et al. Intramedullary headless screw fixation for metacarpal fractures. *Tech Hand Up Extrem Surg*. 2021;25:45–51.
8. Giesen T, Gazzola R, Poggetti A, et al. Intramedullary headless screw fixation for fractures of the proximal and middle phalanges in the digits of the hand: a review of 31 consecutive fractures. *J Hand Surg Eur Vol*. 2016;41:688–694.
9. Doarn MC, Nydick JA, Williams BD, et al. Retrograde headless intramedullary screw fixation for displaced fifth metacarpal neck and shaft fractures: short term results. *Hand (N Y)*. 2015;10:314–318.
10. Guidi M, Frueh FS, Besmens I, et al. Intramedullary compression screw fixation of metacarpal and phalangeal fractures. *EFORT Open Rev*. 2020;5:624–629.
11. Kozin SH, Thoder JJ, Lieberman G. Operative treatment of metacarpal and phalangeal shaft fractures. *J Am Acad Orthop Surg*. 2000;8:111–121.
12. Gaston RG. Football commentary: phalangeal fractures—displaced/nondisplaced. *Hand Clin*. 2012;28:407–408.
13. Weiss AP. Intramedullary Herbert screws for treatment of phalangeal nonunion. *Tech Hand Up Extrem Surg*. 1997;1:41–47.
14. Gaspar MP, Gandhi SD, Culp RW, et al. Dual antegrade intramedullary headless screw fixation for treatment of unstable proximal phalanx fractures. *Hand (N Y)*. 2019;14:494–499.
15. Borbas P, Dreu M, Poggetti A, et al. Treatment of proximal phalangeal fractures with an antegrade intramedullary screw: a cadaver study. *J Hand Surg Eur Vol*. 2016;41:683–687.
16. ten Berg PW, Mudgal CS, Leibman MI, et al. Quantitative 3-dimensional CT analyses of intramedullary headless screw fixation for metacarpal neck fractures. *J Hand Surg Am*. 2013;38:322.e2–330.e2.
17. Robinson LP, Gaspar MP, Strohl AB, et al. Dorsal versus lateral plate fixation of finger proximal phalangeal fractures: a retrospective study. *Arch Orthop Trauma Surg*. 2017;137:567–572.

18. Eberlin KR, Babushkina A, Neira JR, et al. Outcomes of closed reduction and periarticular pinning of base and shaft fractures of the proximal phalanx. *J Hand Surg Am*. 2014;39:1524–1528.

19. Labèr R, Jann D, Behm P, et al. Intramedullary screw fixation for metacarpal shaft fractures: a biomechanical human cadaver study. *J Hand Surg Eur Vol*. 2020;45:595–600.

20. Lögters TT, Lee HH, Gehrmann S, et al. Proximal phalanx fracture management. *Hand (N Y)*. 2018;13:376–383.

21. Miles MR, Krul KP, Abbasi P, et al. Minimally invasive intramedullary screw versus plate fixation for proximal phalanx fractures: a biomechanical study. *J Hand Surg [Am]*. 2021;46: 518.e1–518.e8.

Copyright © 2022 Wolters Kluwer Health, Inc. All rights reserved.