

# Minimally Invasive Fixation of Fractures of the Phalanges and Metacarpals With Intramedullary Cannulated Headless Compression Screws

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**Purpose** To present the technique, indications, and outcomes of metacarpal and phalangeal fractures fixed with intramedullary cannulated headless screws (CHS).

**Methods** We retrospectively reviewed all charts of patients whose metacarpal and phalangeal fractures had been treated with intramedullary CHS in our practice. A total of 69 fractures (48 metacarpal and 21 phalangeal) were identified in 59 patients. Seventeen were open fractures. Eleven patients had multiple fractures (29 in total); of those, 21 were managed with CHS. In 4 other fractures the method was abandoned intraoperatively. The defect created by the entrance of the screw in the proximal phalanx was identified by computed tomography in 20 patients.

**Results** In 63 fractures a single screw was used; in 6 fractures 2 screws were used to provide stronger fixation. All patients returned to full duties or sport activities at an average of 76 days (range, 3 wk to 15 mo). At the latest follow-up (range, 5–54 mo; average, 19 mo) total active motion was on average 247° (range, 150° to 270°) for all fractures, 249° (range, 210° to 270°) for metacarpal, and 243° (range, 150° to 270°) for proximal phalangeal fractures. All fractures were healed and within acceptable radiological parameters. A comminuted basilar phalangeal fracture displaced secondarily yielding a poor functional result. Two patients required tenolysis and further procedures before the final result was achieved. The screw hole represents around 20% of the proximal phalanx distal articular surface.

**Conclusions** Unstable transverse fractures in the phalanx and metacarpal are amenable to single intramedullary CHS fixation. Comminuted fractures require more complex configurations. (*J Hand Surg Am.* 2015;40(4):692–700. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)

**Type of study/level of evidence** Therapeutic IV.

**Key words** Metacarpal fractures, phalangeal fractures, open digital fractures, intramedullary fixation, cannulated screws.

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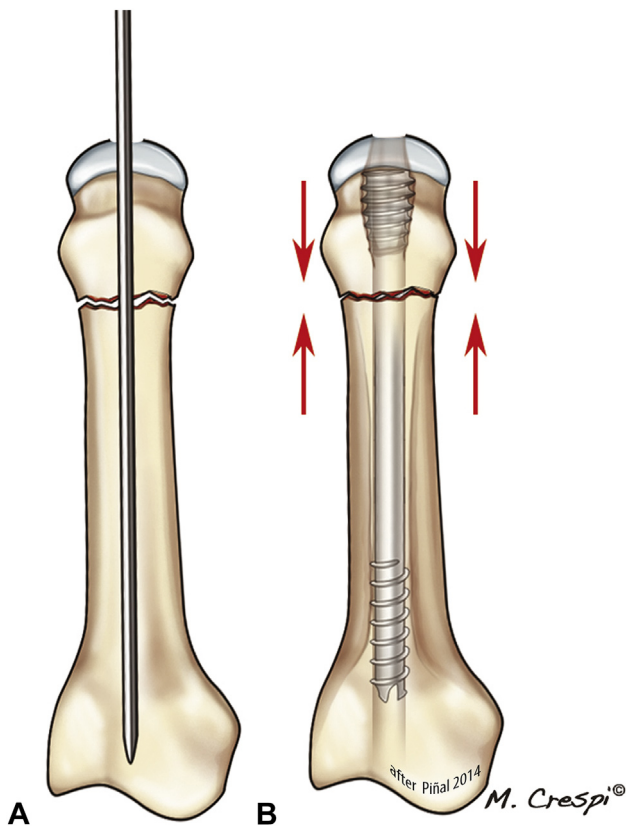
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MULTIPLE APPROACHES EXIST for treating metacarpal and phalangeal fractures.<sup>1,2</sup> Stable fractures can be managed successfully with orthoses or early-protected mobilization.<sup>3–5</sup> Unstable fractures are ideally treated with one of the various described operative techniques. The results are sometimes disappointing, particularly when treating open fractures or those associated with more severe trauma.<sup>3,6–10</sup>



**FIGURE 1:** In **A** the typical neck fracture without comminution, minimal countersinking in the head is needed because **B** the cortex will resist compression.

The aim of this report was to present the technique and outcomes of intramedullary cannulated headless screws (CHS) fixation of metacarpal and phalangeal fractures. In addition, technical refinements for dealing with the more complex fractures (comminuted and multiple) are described.

## MATERIALS AND METHODS

We retrospectively reviewed the clinical and radiological data of the cohort of prospectively collected patients who had had intramedullary fixation with CHS in our practice. The study period included patients from January 2008 (when we started to apply this method) to December 2013. This series includes all patients without dropouts or exclusions. We treated a total of 69 fractures in 59 patients. There were 58 men and 1 woman, mean age 36 years. Thirty-seven fractures were work-related injuries. All surgeries were performed within 14 days of the injury (average, 5 d). There were 48 fractures of the metacarpals, 19 of the proximal phalanges, and 2 of the middle phalanges. Thirty-three were transverse, 23 were short oblique, and 13 had localized comminution. In the latter group,

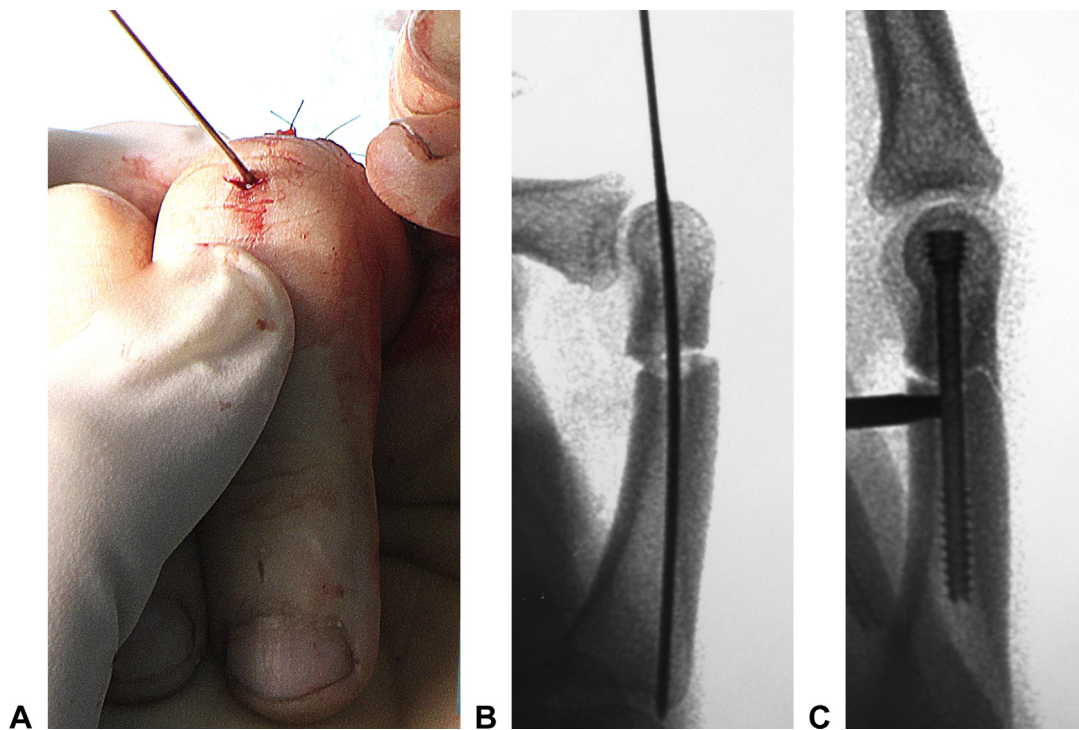
despite the comminution, cortical continuity could be restored in some parts of the diaphysis after the reduction. A total of 17 open fractures were all treated in one stage. Five patients had 2 fractures, 5 had 3, and 1 had 4. Of these 29 fractures, 8 received a different method of fixation for the fractures that were not amenable to treatment with CHS. In 4 additional fractures (not included in the series but discussed) the intramedullary technique was abandoned intraoperatively and another method of fixation was used. Both our indications and understanding of the limitations of the technique evolved over the course of the study. However, no cases have been excluded from the data presented here.

Our institution does not require institutional review board approval; however, all patients were aware of the treatment aims and understood the risks and benefits of the procedure. Informed consent was obtained for each patient.

## Surgical technique

**Transverse fracture with minimal or no comminution:** In the case of a metacarpal (neck or diaphysis) fracture, reduction was achieved manually. The proximal phalanx was maximally flexed to expose the head of the metacarpal. A 0.5- to 1-cm transverse incision was made and the extensor tendon opened longitudinally in the midline. Under fluoroscopic guidance, we inserted a 1.0-mm guidewire along the longitudinal axis of the metacarpal. To avoid cortical penetration and to favor gliding in the medullary canal, the tip of the guidewire was blunted. Once the position of the guidewire was confirmed with fluoroscopy, only the subchondral bone plate was countersunk with the cannulated countersink. Appropriate screw length was calculated based on preoperative imaging. In most metacarpal fractures except for the fifth, we used 3.0-mm-diameter screws. We used AutoFIX headless cannulated screws (Small Bone Innovations, Morrisville, PA). The maximum available length for the 3.0-mm screws is 40 mm. This is shorter than the average length of a metacarpal (around 6.0 cm) but long enough to engage the leading threads in the endosteal canal where the screw gains secure fixation. The diameter of the medullary canal of the fifth metacarpal is usually larger and here we used the 4.0-mm screws, which are available up to 50 mm. At the end of the operation, we ensured that the trailing threads were completely buried below the cartilage line. Conversely, over-insertion of the implant was avoided, particularly in neck fractures. Frequent fluoroscopic checks prevented both of these complications (Fig. 1).

The procedure was similar for transverse fracture<sup>2</sup> in the proximal phalanx (Fig. 2). We made a 0.5-cm



**FIGURE 2:** **A** Intraoperative view of a transverse phalangeal case. A small transverse incision allows for the introduction of a 1-mm guidewire following the longitudinal axis of the proximal phalanx. **B** With the guidewire in place, the reduction may be fine-tuned and any rotation corrected. **C** A 2.5-mm CHS has been inserted and buried into the head. Owing to the peculiar shape of the phalanx, compression may cause some distraction in the volar cortex. (Same patient as in Fig. 8.)

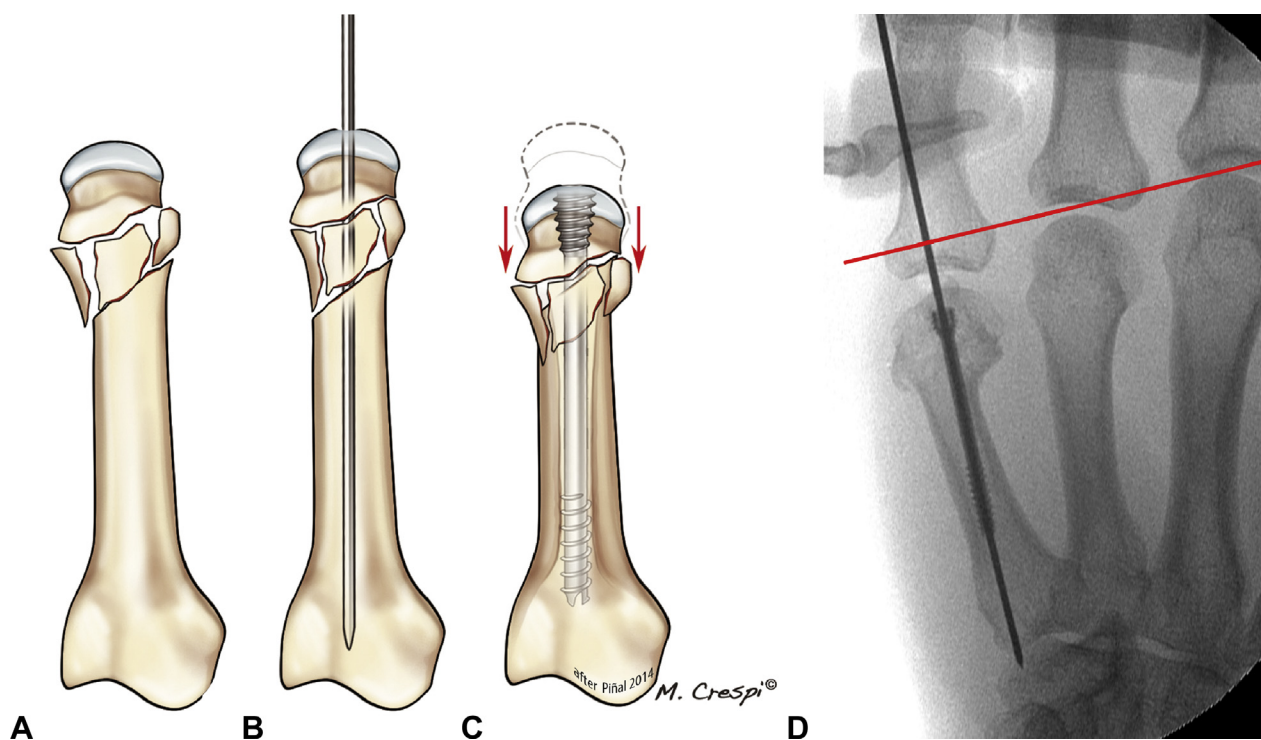
transverse incision over the head of the proximal phalanx while we maximally flexed the proximal interphalangeal joint. The central band was split longitudinally and retracted to expose the head of the proximal phalanx. In most proximal phalanx fractures we used 2.5-mm screws, except for larger phalanges, for which 3.0-mm screws were used. The maximum length available of the 2.5-mm CHS currently used is 30 mm. We took care not to over-insert the screw. Because the screws are self-drilling and tapping, they may penetrate the base of the phalanx with minimal torsional resistance. A similar technique was undertaken for middle phalangeal fractures, with an incision starting over the head of the middle phalanx for retrograde screw placement.

**Comminuted fractures:** Compression without support will result in shortening in metacarpals and phalanges alike when inserting the CHS (Fig. 3). Thus, although in principle the use of CHS is contraindicated in such circumstances, we found a solution for 2 of the most common situations that we faced.

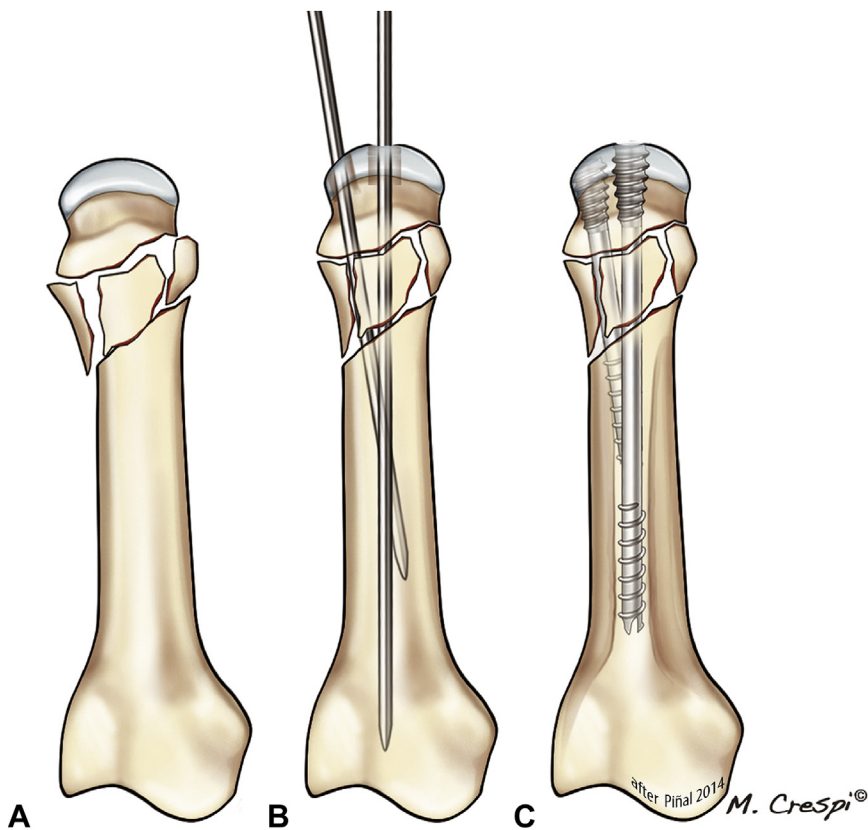
For subcapital metacarpal fractures, we used a modification of the technique based on the architectural concept of strutting (ie, a structural element used to brace or strengthen a framework by resisting

longitudinal compression and hence shortening). By creating a “Y” with 2 screws, the head of the metacarpal cannot collapse; we named it “Y-strutting.”

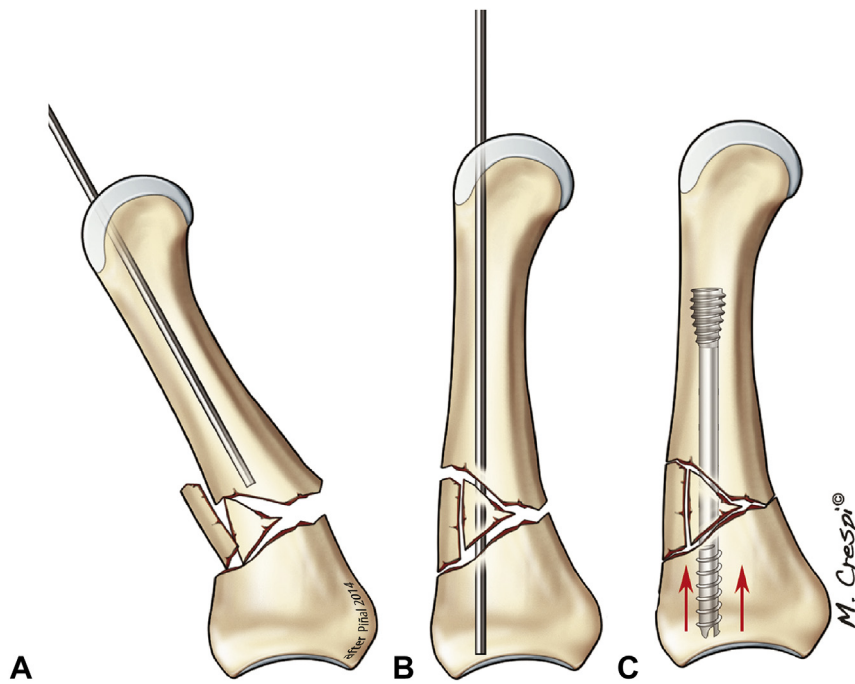
A longitudinal 1.0-mm guidewire with a blunted tip was inserted as in the previous method. While the correct metacarpal length was maintained, an additional guidewire was introduced but offset to the first one, thus creating a triangular construct. Both guidewires were countersunk with a guided countersink. For the axial screw and the oblique screw, we usually used a 3.0-mm and a 2.5-mm-diameter screw, respectively. First the axial screw was inserted until the trailing thread was level with the cartilage. The appropriate length offset screw was then inserted. Because there was insufficient room in the medullary canal for both screws, the length of the oblique screw needed to be carefully calculated to meet the axial screw only after it was sufficiently buried in the head of the metacarpal to ensure adequate stability without screw prominence. The first screw was then advanced farther until completely buried. This can be performed without fear of axial shortening of the metacarpal and collapse of the head, which is prevented by the oblique screw. We carried out frequent fluoroscopic checks to ensure no collapse occurred and that the screws locked into each other in the medullary canal (Fig. 4).



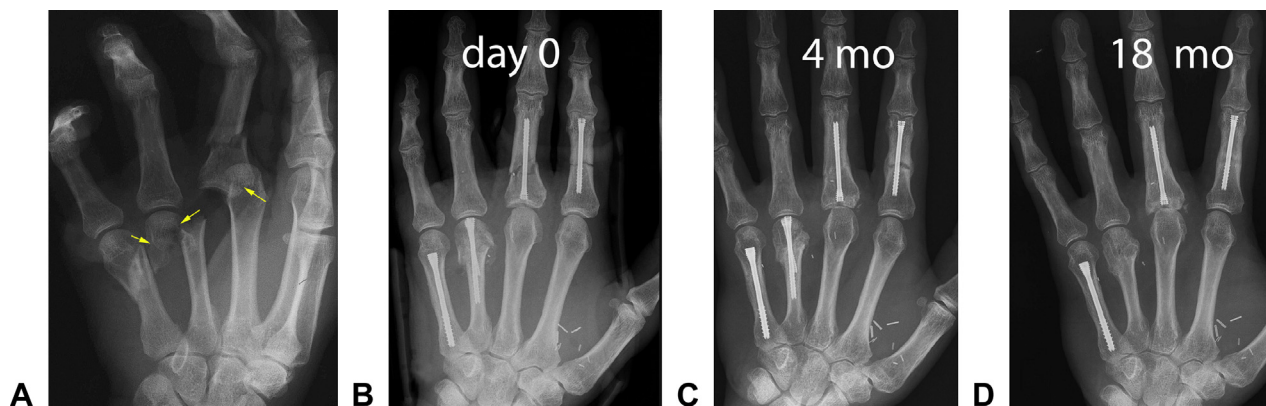
**FIGURE 3:** **A–C** If the fracture has no cortical support, despite perfect reduction, tightening of the screw will cause fracture collapse. **D** Paradigmatic example in the authors' series corresponding to the case with maximal shortening (5 mm). The red line corresponds to the metacarpal line.



**FIGURE 4:** **A–C** Technique of Y-strutting.



**FIGURE 5: A–C** Technique of axial strutting.



**FIGURE 6:** Different fixation methods in a patient who sustained a crush injury. **A** Severe subcapital comminution in the ring finger metacarpal and compound dislocation on the base of the middle finger (yellow arrows point to area of comminution). **B** The injury was managed by a standard 3.0-mm CHS for the index finger, a 3.0-mm antegrade for the comminuted middle finger, Y-strutting for the ring finger (and primary bone grafting of the defect), and a 4.0-mm CHS for the little finger. A free flap was used for soft tissue coverage. **C** Radiographs at 4 months. There is primary bone healing of the little finger metacarpal. Some callus has formed in the others, suggesting secondary fracture healing. **D** One year after the accident the flap was debulked; although it was asymptomatic, the screws on the ring finger metacarpal were removed for suspected intra-articular penetrance. At the last visit excellent results (greater than 240° TAM) were obtained in each finger. Changes in the middle finger metacarpophalangeal joint were evident at 18 months.

We have devised a modification for when the comminution affects the dorsal cortex of the base of the proximal phalanx; we named it *axial strutting* because the screw acts as a girder inside the phalanx. After reduction of the proximal phalanx, an axial guidewire was introduced into the medullary canal as dorsally as possible. A CHS (2.5 or 3.0 mm) slightly shorter than the total length of the phalanx was then inserted until its

leading tip abutted in the subchondral plate at the base of the phalanx. At this point, the trailing thread of the screw was locked inside the medullary canal, thus acting as an internal strut and supporting the base of the phalanx. Frequent fluoroscopic checks were taken to prevent joint penetration (Fig. 5). Other combinations of screws or internal fixation devices may be required based on the fracture pattern (Fig. 6).

**TABLE 1. Range of Motion of Series and Breakdowns**

|                           | Fractures, n | TAM<br>(average [range])<br>(degrees) |
|---------------------------|--------------|---------------------------------------|
| <b>All fractures</b>      | 69           | 247° (150° to 270°)                   |
| Metacarpal                | 48           | 249° (210° to 270°)                   |
| Phalanx                   | 19           | 243° (150° to 270°)*                  |
| Standard technique        | 56           | 248° (210° to 270°)                   |
| Y-strutting               | 5            | 260° (245° to 270°)                   |
| Axial strutting           | 8            | 238° (150° to 270°)                   |
| <b>Multiple fractures</b> | 21           | 245° (210° to 270°)                   |
| <b>Open fractures</b>     | 17           | 240° (210° to 260°)                   |
| Metacarpal                | 48           | 84° (60° to 100°)†                    |
| Proximal phalanx          | 19           | 83° (40° to 100°)‡                    |
| Middle phalanx            | 2            | 60° (50° to 70°)§                     |

\*The TAM of the 2 middle phalanx was not included.

†The range of active motion of the metacarpophalangeal joint only is reported here.

‡The range of active motion of the proximal interphalangeal joint only is reported here.

§The range of active motion of the distal interphalangeal joint only is reported here (2 cases).

After surgery, patients started range of motion immediately and were guided during the follow-up visits according to their progress. No simple fractures required formal therapy. Digits containing fractures of the proximal phalanx that had some comminution were buddy-taped for additional protection, but active motion and passive assisted exercises were encouraged. Lack of tenderness over the fracture suggested fracture healing, and unprotected motion was allowed at that point. Night extension with aluminum orthoses was prescribed to prevent proximal interphalangeal joint extensor lag. Cases in which fractures were open or there were additional soft tissue injuries, including tendon lacerations, required formal hand therapy. The protocol was modified depending on the needs of the concomitant injuries.

Patients were followed up an average of 19 months (range, 5–54 mo) after injury. Total active motion (TAM; active flexion of the metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints minus the extension deficits in these joints) was recorded with a handheld goniometer by one of the operating surgeons. Plain radiographs were taken until the fracture had healed and at the latest visit. Radiological results were considered good when acceptable standards set by Pun et al<sup>3</sup> were met for phalanges. These included less than 10° angulation in the sagittal

**TABLE 2. Mean Surface Area Measurements**

|        | Articular<br>Surface Area<br>(range), mm <sup>2</sup> | Percent Joint<br>Occupied by Screw |              |
|--------|-------------------------------------------------------|------------------------------------|--------------|
|        |                                                       | 2.5-mm Screw                       | 3.0-mm Screw |
| Index  | 126 (117–135)                                         | 16                                 | 22           |
| Middle | 150 (143–159)                                         | 13                                 | 19           |
| Ring   | 120 (111–126)                                         | 16                                 | 24*          |
| Little | 111 (104–117)                                         | 18                                 | 25*          |

\*Screws with a 3.0-mm diameter were not used in the ring or little finger.

and/or coronal planes except in the metaphysis, where up to 20° was accepted in the sagittal plane. No rotation was accepted. In the metacarpals no angulation of the head was allowed and shortening was measured by transposing the metacarpal line<sup>11</sup> on the middle, ring, and little finger metacarpals. Any shortening more than 6 mm<sup>12</sup> was considered unacceptable whether or not it caused a functional deficit.

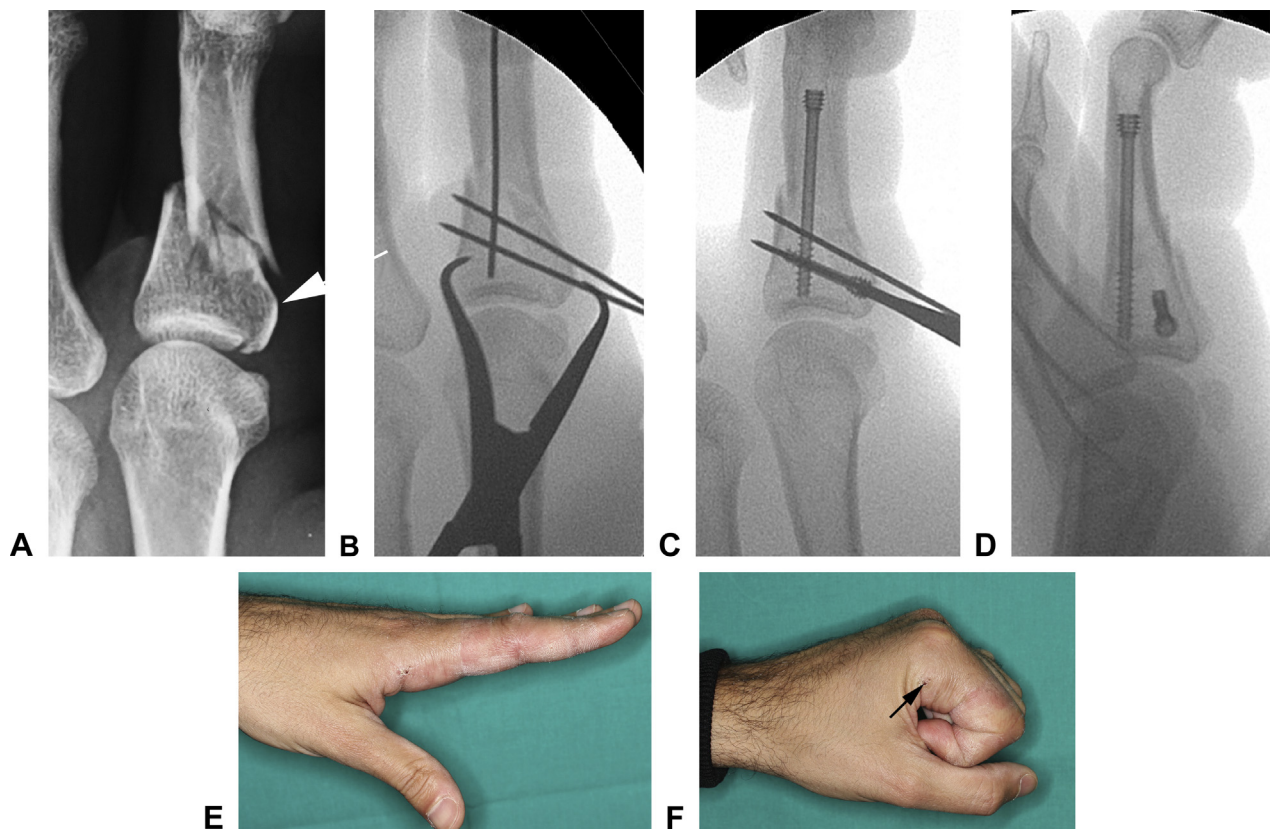
### Computed tomographic studies of the head of the proximal phalanx

To estimate the impact of the CHS on the articular surface of the head of the proximal phalanx, we performed articular surface measurements on multi-slice computed tomography studies. We selected retrospectively 20 multi-slice computed tomography studies from our database (10 men and 10 women) unrelated to this group of patients. Inclusion criteria were young patients with age distribution similar to that of the study population (range, 19–37 y). Exclusion criteria included phalangeal fractures, arthritis, bone dimensional deformity, and neoplasm. We performed 3-dimensional reconstructions and articular surface measurements (in square millimeters) of the second to fifth fingers with OsiriX software (Pixmeo SARL, Bernex, Switzerland).

Subsequently, we calculated the percentage of the joint area of the head of the proximal phalanx of the second to fifth digits occupied by CHS 2.5 and 3.0 mm in diameter.

### RESULTS

All workers resumed full duties and non-workers returned to unlimited leisure activities at an average of 76 days (range, 24 d to 15 mo; median, 54 d). The TAM of the series reported in Table 1 corresponds to the final TAM without additional procedures except in 2 patients. The first patient, who had lacerations of all flexor tendons and phalangeal fractures, had a



**FIGURE 7:** **A** A fracture in the index finger with intra-articular extension (arrow) was transformed into a simpler configuration by **B** stabilizing the articular component temporarily with K-wires. **C** This created a stable base where a supporting longitudinal screw was inserted. **D** After fixation, the construct was judged stable and immediate active motion was permitted. **E, F** Range of motion at 3 weeks (arrow marks the entrance point of the basilar screw).

TAM of 230°, 150°, and 200° in the middle, ring, and little fingers, respectively, before tenolysis of the ring and little fingers. After achieving nearly full active range of motion, the ring finger flexor tendon ruptured 5 weeks after surgery while the patient was exercising. This was followed by several procedures for tendon reconstruction until the end result was achieved (250°, 210°, and 230° TAM in the middle, ring, and little fingers, respectively). The second patient (shown in Fig. 6) had had a free flap for coverage and then at one year had flap debulking and hardware removal in the ring metacarpal because of radiological suspicion of metacarpal head subsidence and intra-articular screw penetration. During surgery, no screw prominence was noted but the screws were removed. After the procedure, range of motion improved in the little finger by 40° (to 250° final TAM). No other surgery was required or scheduled in any patient.

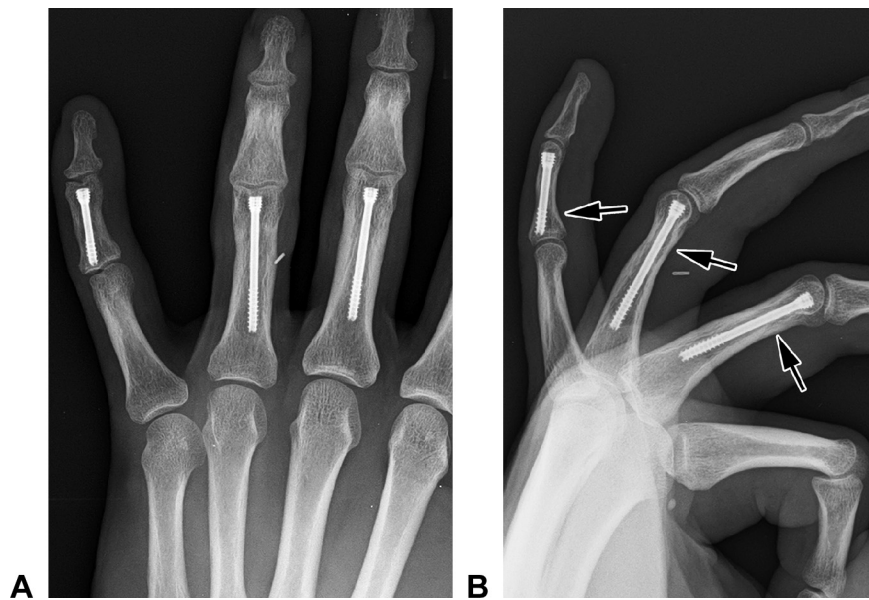
All fractures were healed at the latest follow-up on plain radiographs. Some had exuberant callus; in others it was minimally apparent (Fig. 6C). All fractures except one were within the acceptable

radiological parameters.<sup>3,12</sup> The exception was a comminuted fracture in a proximal phalanx treated with the axial strutting method, which had an unrecognized articular extension and underwent secondary displacement, with a poor result (TAM, 150°). Another patient treated before development of the Y-strutting method ended with 5 mm shortening (Fig. 3D) but the TAM (245°) was acceptable. One patient (middle finger metacarpophalangeal joint shown in Fig. 6D) had narrowing of the joint space on the latest radiograms. Because of the severity of the original injury it is difficult to know whether the screw or the trauma was responsible for the joint changes.

In 4 metacarpal fractures in 2 patients (not included in the series) the method was abandoned during surgery for excessive comminution that could not be controlled with screws. The screws were removed and the fractures were fixed with plates.

#### Computed tomography studies of the head of the proximal phalanx

Table 2 lists the mean surface area of the head of the proximal phalanx and the percentage affected by the



**FIGURE 8:** **A** Posteroanterior and **B** lateral radiographs of a patient whose 3 transverse fractures (arrows) were treated with 2.5-mm cannulated screws. At 2 years no changes were noticeable in the interphalangeal joints. (Same patient as in Fig. 2.)

screw. The mean articular surface area used by cannulated screws amounted to 13% to 18% for the 2.5-mm screw and 19% to 25% for the 3.0-mm screw.

## DISCUSSION

Herbert and Fisher<sup>13</sup> popularized cannulated headless compression screws in the wrist. More recently, the same concept has been applied for intra-articular fractures of the hand.<sup>14,15</sup> Intramedullary devices have long been used in the metacarpals<sup>16,17</sup> and phalanges.<sup>18,19</sup> Boulton et al<sup>20</sup> in a case report combined both concepts in a subcapital fracture of the metacarpal of a little finger. The fracture had some comminution in the neck, which led to some shortening. Despite this, the technique had the advantage of not stripping periosteum, which allowed minimal devascularization and the possibility of immediate motion.

Similar to Boulton et al,<sup>20</sup> we applied the same principles for fractures of the phalanges and the metacarpals. Taking into account our experience, including our failures and abandoned cases, we believe the method presented here to be the most effective for dealing with transverse and short oblique diaphyseal or metaphyseal fractures of metacarpals and phalanges. In transverse fractures reduction and fixation can be carried out in a matter of minutes and we have experienced minimal complications. Increasing degrees of comminution or obliquity of the fracture raise

the level of technical difficulties and thus place more demands on the surgeon's ingenuity to achieve the goal of stable fixation (Fig. 7).

Absolute contraindications to using the CHS include fractures in the presence of an open epiphysis or infection. This method is not recommended for long oblique fractures or when partial cortical continuity cannot be reestablished in diaphyseal fractures. In both instances collapse will occur when inserting the screw. Furthermore, recently (not included in the series) we had another failure in a marginal (subchondral) fracture in a middle phalanx that split into 2 fragments. As a precaution, we advise not using the method in any marginal (subchondral) fractures. In such cases, the amount of bone remaining may not allow purchase for the leading screw, and risk of splitting exists.

We have insufficient data to determine whether the fixation afforded by the CHS is rigid, provided by the thread purchase in the endosteal canal, or whether it is dynamic, with the implant acting as an elastic Ender-type device.<sup>21</sup> There is likely a mixture of both because callus formation was prominent in some fractures, which indicated secondary bone healing, and minimal in others, implying primary healing (Fig. 6C–D). In any case, the fixation was stable enough in all fractures to start immediate active range of motion with little pain. Secondary displacement occurred in one basilar proximal phalanx fracture, which was in retrospect an error in judgment.

Several articles show excellent results in metacarpal and phalanx fractures with varied methods.<sup>1,2</sup> We believe this technique compares favorably with others and has some unique advantages. When comparing fractures that are most likely to result in a poor outcome (ie, severe open type III-B and IIIC<sup>8</sup>/Chow's type III fractures<sup>7</sup>), virtually all patients had a poor result (less than 180° TAM) in other studies.<sup>7-9</sup> In our series, 1 of 6 fractures had a poor result, whereas the rest had good or excellent results (TAM greater than 210°) before the tenolysis, and all eventually achieved excellent results.

We acknowledge there are weaknesses in this study, which presents a relatively new and incompletely proven technique. The TAM measurements were not performed by an independent observer. Furthermore, the entrance of the screw was through cartilage, thus creating a defect in the metacarpal/phalanx head, which may be considered a major drawback. At the level of the head of the metacarpal no midterm changes were noticed using intramedullary devices up to 5 mm in diameter.<sup>16</sup> This is not surprising because the cartilage defect created by a single screw represents a minor portion of the total surface of the head of the metacarpal.<sup>22</sup> Because more screws were used in some cases, it is difficult to know how much impact this may have had on the long-term result. Our radiological measurements in the head of the proximal phalanx also show that the surface involved was around 20% for a single screw. Furthermore, as for the metacarpal, the hole is located dorsally, in a relatively non-load-bearing area of the proximal phalanx as most of our activities are performed with the fingers in flexion. Besides, in other instances in which direct load occurs through a screw hole, no midterm problems have been published.<sup>23,24</sup> Nevertheless, our follow-up was relatively short and later long-term arthritic changes cannot be ruled out (Fig. 8). Despite violation of the extensor tendon, only 2 patients had a major extension lag (greater than 30°) at the proximal interphalangeal joint. One had a concomitant flexor tendon injury; in the other, the fracture re-displaced. The use of a night orthosis may have prevented this complication. Although we believe that patients experienced less pain during early rehabilitation compared with techniques we previously used, quantitative or qualitative data to confirm this assumption were not available for this group of patients. Infection may be a major problem with an intramedullary device should infection occur.<sup>7</sup>

To further evaluate the efficacy of this technique, we recommend a controlled, prospective study.

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