

## RETROSPECTIVE ANALYSIS OF END-TO-END DIGITAL ARTHRODESIS

*Michelle L. Butterworth, DPM*

*Michael S. Downey, DPM*

Digital deformities are one of the most common entities we face as foot and ankle specialists (1). A hammertoe is a complex deformity and throughout the years, various surgical procedures have been advocated for its correction. The authors believe that the proximal interphalangeal joint arthrodesis has stood the test of time and has been shown, when performed properly, that it produces a stable construct and affords for good long term correction, high success rates, and a happy, satisfied patient. The question remains however, what proof do we have that this really is a true statement? We as surgeons know that this procedure produces good results but there is lack of documentation of its success rate. Today, the most common digital arthrodesis technique is the end-to-end arthrodesis (2). One of the reasons this has become the digital arthrodesis technique of choice is because it is easy to perform. Also, compared to the other digital arthrodesis procedures including the peg-in-hole and the V arthrodesis, the end-to-end procedure produces less digital shortening. One of the disadvantages of the end-to-end arthrodesis procedure however, is that it renders the digit inherently unstable. The success of this procedure then is dependent upon stable fixation in order to achieve osseous union.

Traditionally, the preferred form of fixation of lesser digital arthrodesis was with a Kirschner wire (K-wire) (2-4). In recent years however, increased emphasis has been placed on developing fixation for small bone and joint surgeries, especially in the foot and ankle. Specifically, the number of fixation options for the correction of digital deformities continues to expand, mainly with internal implants. Advocates of these internal fixation devices state that they are more tolerable for the patient and easier to manage postoperatively since there are no exposed wires. These devices have also been touted as resulting in higher success rates and more satisfied patients. (5) Coughlin states that “K-wires do not give long-standing stability to the corrected toe, and often lead to a fibrous union, chronic swelling, and sometimes pain. K-wires are often removed prematurely because of the risk of infection and patients’ dislike of the external fixation.” (5)

We are now left to ask ourselves if our “old” technique with K-wire fixation is inadequate. Did K-wire fixation result in a low fusion rate or a low patient satisfaction rate? Did we have many complications with K-wire fixation? Do these new forms of fixation, internal implants, produce better outcomes and higher success rates compared to K-wire fixation? Do these internal implants have fewer complications and are they cost effective?

Despite the commonality of the end-to-end digital arthrodesis with K-wire fixation for correction of hammertoe deformity, there are few reported success rates. The authors have performed a retrospective analysis to help answer some of our proposed questions. The purpose of this study was to determine the success rate of lesser digital end-to-end arthrodesis utilizing K-wire fixation. The goal was to quantitatively evaluate the procedure through chart review, serial radiographs, and long term follow-up visits. All procedures were performed by one surgeon utilizing the same surgical technique. The only exception was patients presenting to the surgeon initially requiring revisional digital surgery. These patients typically required calcaneal bone graft. The significance of this study was to document the success and or failure rate of this specific procedure and fixation method, document complications, and explore the reason for failure or complication. Ultimately, the surgeons wanted to validate the end-to-end digital arthrodesis with their chosen surgical technique and prove that K-wire fixation is a good, cost-effective choice for this procedure resulting in a high fusion rate with high patient satisfaction.

### METHODS

Patients included in this study were asked to sign a consent form to participate and fill out a patient self-assessment survey (Table 1). They were also asked to come in for a physical examination by the surgeon and a DP radiograph of their foot was taken. The physical examination included documentation regarding motion at the fusion site, pain of the involved digit, any recurrent or new skin lesions, and formation of a mallet toe. A DP radiograph was also

Table 1

### PATIENT SELF-ASSESSMENT SURVEY

1. Please rate the result of the surgery:
  - A. Complete success
  - B. Partial success
  - C. No improvement
  - D. Worse than before surgery
2. Has the toe become contracted again? \_\_\_\_\_
3. If a callus was present before the surgery, has it returned? \_\_\_\_\_
4. Is your toe too stiff? \_\_\_\_\_
5. Does your toe touch the floor when you are standing? \_\_\_\_\_
6. Is your toe too straight? \_\_\_\_\_
7. Have you returned to your regular shoes? \_\_\_\_\_
8. Has your toe become shorter since surgery? \_\_\_\_\_
9. Have you noticed any chronic toe swelling since the surgery? \_\_\_\_\_
10. Has the tip of your toe become contracted? \_\_\_\_\_

obtained to document radiographic osseous union. An extensive chart review on each patient was also performed. During this process any complications were documented. The time of removal of the K-wire was also documented and utilized to determine the time to fusion of the arthrodesis site. The time frame for the patient to return to shoes and any other supplemental procedures performed were also documented. It should be noted that the proximal interphalangeal joint arthrodesis is a common procedure often performed with other procedures in order to gain full correction of the hammertoe deformity. Also, it is not uncommon to have concomitant deformities, such as hallux abducto valgus and pes planus, when hammertoe deformities exist. For this reason, there were many patients in this study that had supplemental procedures performed in addition to the end-to-end digital arthrodesis. The supplemental procedures performed on the patients in this study are listed in Table 2.

### DATA

A total of 69 patients, ranging over a seven-year period, met the criteria to participate in this study. A total of 40 patients are included in the study. Eleven more patients were willing to participate but did not follow through. Six patients

Table 2

### SUPPLEMENTAL PROCEDURES

Metatarsophalangeal joint capsulotomy  
 Neuroma excision  
 Flexor tenotomy  
 Flexor tendon transfer  
 Syndactyly  
 Tendo Achilles lengthening  
 Austin osteotomy  
 Offset V osteotomy  
 Closing base wedge osteotomy  
 First metatarsophalangeal joint arthrodesis  
 First metatarsophalangeal joint implant  
 Hallux interphalangeal joint arthrodesis  
 Sesamoidectomy  
 Pan metatarsal head resection  
 Lesser metatarsal osteotomy  
 Digital arthroplasty  
 Evans calcaneal osteotomy  
 Naviculocuneiform arthrodesis  
 Triple arthrodesis

were lost to follow up. Six patients would not participate. Four patients were unable to participate and two patients were deceased.

A total of 40 patients participated in the study for a total of 43 feet, 26 right and 17 left. This resulted in a total of 86 toes included in the study. Of the 86 toes included, 41 were the second toe, 26 were the third toe, and 19 were the fourth toe. On initial presentation to the surgeon, 20 of the 86 toes were for revisional surgery. The average age of the patient was 60 years old with a range from 31 to 77 years; 36 patients were female and 4 were males. The average follow up was 3.6 years ranging from 2 years to 7.6 years.

### SURGICAL TECHNIQUE

A standard dorsal linear incision was made on the digit. If a skin lesion was present, it was excised in an elliptical fashion. Either a transverse tenotomy or a Z-plasty lengthening was performed on the extensor tendon as warranted. The surgeon then transected the medial and lateral collateral ligaments of the proximal interphalangeal joint. Release of the extensor hood apparatus and capsulotomy of the metatarsophalangeal joint was then performed if deemed necessary to gain adequate correction of the deformity. Next, the cartilage on the head of the proximal phalanx was

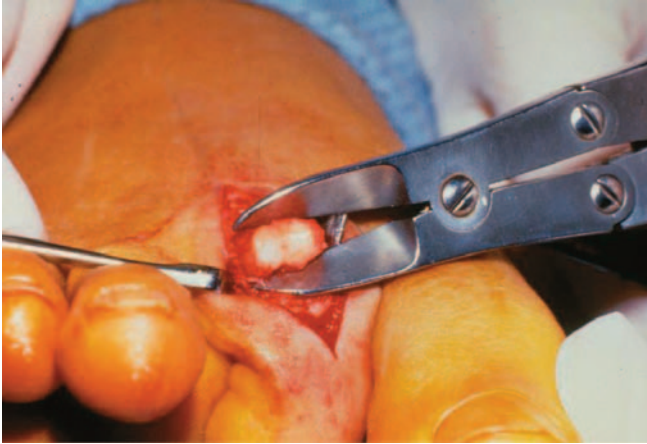


Figure 1. A bone cutting forceps is utilized to remove the cartilage on the head of the proximal phalanx. The surgeon should ensure appropriate alignment of the instrument so a flat even surface is produced for good alignment of the fusion site.



Figure 3. Cartilage removal with minimal osseous resection has been performed on the proximal phalanx producing a good bleeding, flat surface.

resected with a bone cutting forceps. (Figure 1) Removal of the cartilage on the base of the middle phalanx was then performed with a rongeur. (Figure 2) Fixation was obtained with a 0.062" K-wire crossing the metatarsophalangeal joint if necessary. Appropriate tendon repair and wound closure then followed.

Some keys to a successful surgical technique for this procedure include removal of all cartilage with minimal osseous resection of the head of the proximal phalanx and base of the middle phalanx. (Figure 3) The surgeon also has to ensure that the opposing osseous surfaces are flat with good osseous apposition and alignment of the fusion site. To help ease the placement of the K-wire fixation, the surgeon reams the proximal phalanx by hand with a 0.045" K-wire. (Figure 4) This ensures adequate placement and alignment of the 0.062" K-wire utilized for the final

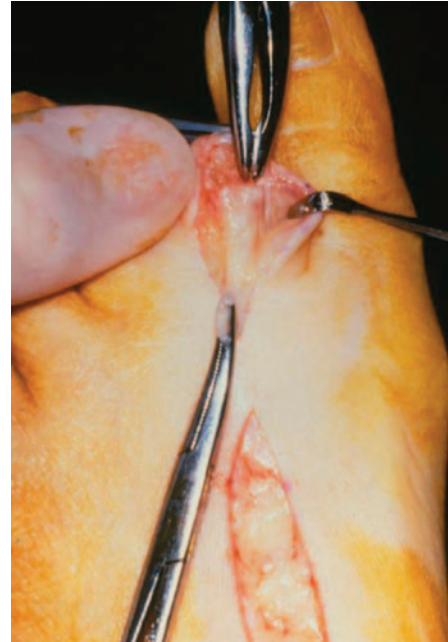


Figure 2. A rongeur can be easily utilized to remove the cartilage on the base of the middle phalanx. One end of the rongeur is placed on one of the four corners of the bone and then the other end is scraped along the content of the bone removing the cartilage. Depending on the size of the toe, this typically takes two to four swipes for complete cartilage resection.



Figure 4. A 0.045" K-wire is utilized to create a pilot hole in the proximal phalanx. This is done by hand, moving it in a conical fashion. This helps to ensure adequate alignment of the 0.062" K-wire utilized for final fixation.

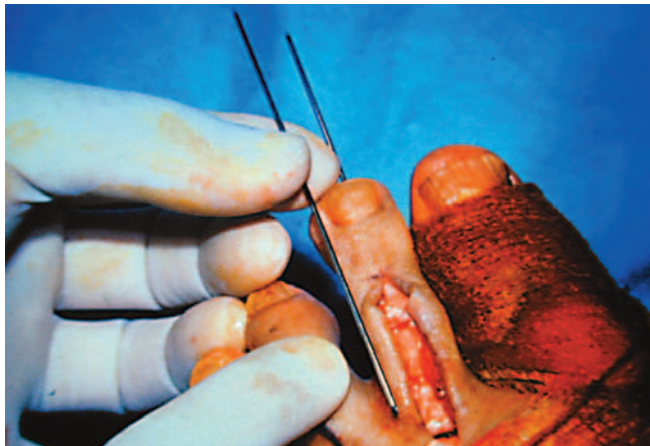


Figure 5. Alignment and length of the K-wire is checked with an unloaded K-wire to ensure adequate placement.

fixation. When the 0.062" K-wire is retrograded back into the proximal phalanx it will follow the path that has already been made by the smaller K-wire. The surgeon can check the length of the implanted K-wire with an unloaded K-wire to ensure that it has not entered the metatarsophalangeal joint if it was not desired. (Figure 5) Finally, the surgeon should check the fusion site intra-operatively at the proximal interphalangeal joint to ensure good alignment and osseous apposition. Gapping at the fusion site could result in non-union or mal-union. It should be noted that all procedures performed on the patients in this study were by the same surgeon so the technique was consistent and should have no effect on the results. Supplemental procedures were performed on many of these patients however, and are listed in Table 2.

## RESULTS

According to the patient satisfaction surveys obtained, 22 patients rated their surgery a complete success and 14 patients rated it a partial success. Of these 14 patients that rated their surgery a partial success, five of them presented initially for revisional surgery. Three of them had supplemental procedures performed with their digital surgery, which was the reason for rating their surgery a partial success. The other reasons for partial success listed by the patients were as follows: calluses, stiff toes, metatarsophalangeal joint deviation, and mallet toe formation. One patient stated that she had no improvement from the surgery because her toe was too straight. This patient also presented initially for revisional surgery. Three patients stated their toe was worse than before the surgery. Of these three patients, one was noncompliant and resulted in a digital fracture. One patient had a recurrent bunion that overlapped the second toe. The

other patient had a hallux varus and stated her toe was too stiff with a new callus formation.

Overall 36 patients were completely or partially satisfied with their surgery resulting in a 90% satisfaction rate. Four patients rated their surgery as no improvement obtained or worse than before surgery resulting in a 10% dissatisfaction rate. If we delete the patients initially presenting for revisional digital surgery or who were dissatisfied with their results from other procedures other than their digital surgery, the patient satisfaction rate is 95%.

The average rate of fusion was 49 days with a range from 37 to 102 days. Successful arthrodesis was determined radiographically and was coincidental with removal of the K-wire. A total of 83 toes resulted in complete arthrodesis. Included in this number is one toe with a delayed union that required additional surgery to achieve a successful fusion. This correlates to a 96.5% successful fusion rate and a 3.5% non-union rate. Three toes resulted in radiographic non-union and they were all revisional surgeries for the surgeon's initial surgery. Interestingly, the toes that resulted in non-union were clinically asymptomatic and rated their surgery as a complete success. If we eliminate patients that initially presented for revisional surgery, the fusion rate is 100%.

The average time it took the patient to return to normal shoe gear was 74 days with a range from 40 to 215 days. This number is a bit skewed mostly because of secondary procedures that were performed in addition to the proximal interphalangeal joint arthrodesis. When we delete the patients initially presenting for revisional digital surgery and those that had supplemental procedures performed requiring a more rigorous postoperative course, the average return to shoe gear in this study was 55 days with a range from 40 to 112 days.

## FINDINGS

In addition to assessing the patient for a successful fusion at the proximal interphalangeal joint, other findings including formation or persistence of skin lesions, mallet toe formation, pain, swelling, and osteoarthritis were assessed and documented. Mallet toe was the most common finding in these patients who underwent a proximal interphalangeal joint arthrodesis. A total of 13 toes in 9 patients (15%) were found to have a mallet toe postoperatively. Corns and calluses were the next common finding resulting in 12 lesions (14%) documented in this study. These lesions were found in various locations including sub-metatarsal 1, 2, and 3 and on toes 2, 3, and 4. Three patients had prolonged edema of the operated toe and two patients had some pain elicited with

palpation of the surgical site. Three patients had motion at the proximal interphalangeal joint however they were clinically asymptomatic and non-painful. Osteoarthritis of the second metatarsophalangeal joint was found on two patients but again they were clinically asymptomatic.

## COMPLICATIONS

This study revealed ten patients with a complication resulting in a complication rate of 10%. Two patients had pin tract infections, three had a wound dehiscence, three had a vascular episode, one had a fracture, and one patient had a delayed union. Fortunately, all of the complications resolved with oral antibiotics and/or local wound care except for one. This patient had a delayed union and required additional surgery for successful osseous union. No complications affected the end result.

## DISCUSSION

Despite the commonality of the end-to-end digital arthrodesis with K-wire fixation for correction of hammer-toe deformity, there are few reported success rates. Coughlin et al conducted a study with 118 toes on 63 patients with an average follow-up of 61 months. The deformity involved the second toe in 35%, the third toe in 21%, the fourth toe in 24% and the fifth toe in 20%. The procedure described however was a resection arthroplasty technique with intramedullary K-wire fixation. They reported a fusion rate of the proximal interphalangeal joint in 81% of toes. A fibrous union resulted in the remaining 19% of cases. Subjective satisfaction was noted by 84% of patients. Minor complications occurred in 5%. Malalignment and numbness were the major factors associated with an unsuccessful result. They conclude that resection arthroplasty of the proximal interphalangeal joint with intramedullary K-wire fixation as a technique for correction of a fixed hammertoe deformity is a reliable technique that consistently gives a high level of satisfactory results. (6)

Baig and Geary reviewed proximal interphalangeal joint arthrodesis with K-wire fixation in 19 patients and 42 toes. They assessed the results at 6 weeks and then again at 6 months and reported a fusion rate of 83% and infection rate of 7%. Postoperative mallet toe formation was a common finding in their study, as well as ours, and this was the biggest reason for patient dissatisfaction. (4)

Recently, increased emphasis has been placed on developing internal fixation devices for the correction of digital deformities. Advocates of these internal implants profess that they are more tolerable for the patient since there are no exposed wires. They also claim to have fewer

complications when utilizing these devices compared with K-wire fixation. The most common complications involving K-wire fixation for digital arthrodesis is pin tract infection and breakage of the K-wire. In our study, only two toes out of 86 resulted in a pin tract infection. Both of these infections resolved uneventfully with oral antibiotics. The authors did not have any episodes of breakage of K-wires in this study. All of the toes were fixated with a 0.062" K-wire. Use of this larger K-wire, instead of the smaller 0.045" K-wire, renders the digit and arthrodesis site inherently stronger and helps avoid breaking and bending of the K-wires.

Ellington et al performed a retrospective review on 38 toes in 27 patients treated with an intramedullary fusion device. The indications for surgery were primary deformity in 12 toes and recurrent deformities in 26 toes. The mean follow-up was 31 months. Union occurred in 23 of 38 toes (60.5%). The union rate was nine of 12 for primary procedures and 14 of 26 toes for revisions. Including non-union, the overall complication rate was 55.3%, 21 of 38 toes. There were 15 non-unions, three hardware failures, one intra-operative fracture, one requiring surgery, and one requiring a larger implant. Even though they report a high non-union and complication rate, they state the intramedullary fusion device was efficacious in maintaining proximal interphalangeal joint alignment in the treatment of lesser toe deformities. (7) When one compares the successful fusion rate and complication rate of this study by Ellington and colleagues with the author's study, K-wire fixation produced a higher fusion rate and fewer complications.

Although the authors feel the goal of this study was achieved, it is not without its shortcomings. It is a retrospective analysis comparing one specific surgical technique. Although the number of toes involved is respectable a larger, multi-center study could produce a higher volume to evaluate. Ultimately, a prospective study comparing fixation techniques would produce the most beneficial results. K-wire fixation compared with internal implants could be studied to see if fusion rate, patient satisfaction rate, and complication rate varied significantly. Even with the shortcomings of this study, the authors have documented the success of the end-to-end digital arthrodesis with K-wire fixation.

## CONCLUSION

Although digital surgery is very common for most foot and ankle surgeons, hammertoe deformities are complex and can be challenging. This study has shown that the end-to-end proximal interphalangeal joint arthrodesis with K-wire fixation affords for good long term correction, high success rates, and happy, satisfied patients. The surgeons have

validated the end-to-end digital arthrodesis, with their chosen surgical technique, and have proven that K-wire fixation is a good, cost-effective choice for this procedure resulting in a high fusion rate with high patient satisfaction and few complications. The surgeon must evaluate all of the components involved with the digital deformity however in order to achieve surgical success. The proximal interphalangeal joint arthrodesis has been proven to produce a stable toe; however, supplemental procedures may be warranted in order to gain full correction of the deformity.

## REFERENCES

1. Good J, Fiala K. Digital surgery: current trends and techniques. *Clin Pod Med Surg* 2010;27:625-8.
2. Hofbauer MH, Shane AM. Lesser digital surgery: Arthroplasty, Arthrodesis, and Flexor Tendon Transfer. In: Chang, TJ, ed. *Master Techniques in Podiatric Surgery: The Foot and Ankle*. Philadelphia, PA: Lippincott Williams and Wilkins; 2005. p. 35-47.
3. Lamm BM, Ribeiro CE et al. Peg-in-hole, end-to-end, and v arthrodesis, a comparison of digital stabilization in fresh cadaveric specimens. *J Am Pod Med* 2001;91:63-7.
4. Baig AU, Geary NP. Fusion rate and patient satisfaction in proximal interphalangeal joint fusion of the minor toes using Kirschner wire fixation. *The Foot* 1996;6:120-1.
5. Angirasa AK, Augoyard M, Coughlin MJ, Fridman R, Ruch J, Weil Jr. L Hammer toe, mallet toe, and claw toe (roundtable discussion). *Foot Ankle Specialist* 2011;4:182-7.
6. Coughlin MJ, Dorris J, Polk E. Operative repair of the fixed hammertoe deformity. *Foot Ankle Int* 2000;21:94-104.
7. Ellington K, Anderson RB, Davis WH, Cohen BE, Jones CP. Radiographic analysis of proximal interphalangeal joint arthrodesis with an intramedullary fusion device for lesser toe deformities. *Foot Ankle Int* 2010;31:372-6.