Title Page:

An Underutilized Technique: Box Joint Arthrodesis of the PIPJ for Correction of Hammertoe Deformity Without Use of K-wires or Commercial Implants

Authors: Kyle Miller, DPM¹, Elliot Olenchek, DPM¹, Gurvikram Boparai, DPM¹, Richard Derner, DPM FACFAS²,³

1. Resident, Inova Fairfax Medical Campus, Foot and Ankle Surgery Residency Program, Falls Church VA
2. Director, Inova Fairfax Medical Campus, Foot and Ankle Surgery Residency Program, Falls Church VA
3. Private Practice, Lake Ridge Foot and Ankle Center, Lake Ridge VA

kylemiller94@gmail.com, 215-353-7571
Elliotolenchek@gmail.com, 989-430-3761
gurvikramboparai@gmail.com, 703-606-1092
richd87@me.com, 703-856-5062

Informed consent was obtained for each patient which includes the possibility of intra-operative photography. No name or any identifying information will be placed on the photographs and/or films released.
Abstract

Two fundamental techniques exist for digital arthrodesis: end-to-end and peg-in-hole. Both methods require either k-wire fixation or commercially available implants which have been found to not be cost effective. For this reason, we will provide a detailed description of the box joint technique for correction of hammertoe deformity utilizing a single 2.0 headless screw with standard AO technique for PIPJ arthrodesis using box joint technique. This procedure was found to be a highly effective and stable technique for PIPJ joint arthrodesis with low rate of symptomatic nonunion (2.3%), hardware removal (2.3%) and revision (4.65%). Overall digital deformity correction continues to be a large part of every foot and ankle surgeon’s practice. There are currently numerous, albeit expensive commercial implants on the market which allow for flexibility in fixation beyond traditional k-wire use. The box joint technique allows for a stable osteotomy with rigid internal fixation. Rates of complication in all hammertoe correction regardless of technique can be high with incidence in the literature of 7-27%. This technique offers an alternative option which respects both standard AO technique and cost with a low incidence of complications.

Level of Clinical Evidence: 4

Key words: Toe surgery, digital deformity, digital arthrodesis, interphalangeal fusion
Introduction

The first documented technique of end-to-end arthrodesis for correction of digital deformity was by Soule in 1910(1). The author opted for a plantar approach with stabilization of the arthrodesis site indirectly with bandaging of the digit in a hyperextended position. This type of fixation persisted until 1940 when Taylor and Sheffield first advocated for Kirschner wire fixation of all three phalanges when performing end-to-end arthrodesis of the proximal interphalangeal joint (PIPJ) (2). In 1941 Selig modified this technique to bend the wire distally and bandage the toe at the level of the metatarsal phalangeal joint (MPJ) in a plantarflexed position(3). Throughout history since these early procedures numerous fixation techniques have been utilized beyond k-wire’s alone, including absorbable pin fixation, 26 gauge monofilament wire, and more recently numerous commercially available intramedullary implants. Various osteotomy types have also been described to increase inherent stability without adjustments in fixation. These include the peg in hole technique initially described by Higgs and modified by Young and subsequently Schlefman (4,5,6). This technique creates a peg with the maintained dorsal cortex of the proximal phalanx head and drilled middle phalanx base and is stabilized with a k-wire. Bernbach and Bernbach described the box joint technique in 1985 which was extrapolated from the tongue and groove method used in cabinet making(7). This technique will be further elaborated on, however it generally relies on the creation of opposing shelves of bone on the proximal phalanx head and middle phalanx base (Fig 1 and 2). In the original article this is then fixated with a 2.2mm x 8mm cancellous screw. This technique is scantily found in the literature with loose descriptions and no further analysis of the technique in terms of
outcomes over the past 35 years since its initial description. The purpose of this paper is to further describe the technique using modern fixation techniques, and retrospectively evaluate the complication and revision rate at our institution.

Material/Methods:

The authors reviewed a total of 85 box joint PIPJ arthrodesis from a total of 50 patients seen at Lake Ridge Foot and Ankle Center from January 2015-January 2020. Assessment parameters were obtained from chart review, post-operative radiographs, and patient demographics. Chart review included age, gender, date of surgery, length of follow up, number of procedures, the surgical digit, ancillary procedures, and surgical complications. Complications were defined as removal of hardware (ROH), non-union, or revision. Radiographic evaluation (anteroposterior, medial oblique, and lateral views) included healing and fixation utilized. The criteria for osseous fusion were based on 1) no gapping at the arthrodesis site, 2) Appropriate alignment of the fused digit, and 3) >50% trabeculations crossing the arthrodesis site. A delayed union was defined as any arthrodesis that did not heal within 3 months postoperatively, and a nonunion was defined as any fusion site that did not heal within 6 months postoperatively. Standard revision procedure for these authors after the index procedure is placement of a long 2.0 headless screw from distal to proximal through all three phalanges.

Surgical Technique:

A linear bi-elliptical incision is made over the dorsum of the digit extending from the proximal aspect over the proximal phalanx to the distal interphalangeal joint. The ellipse of skin is removed and dissection is carried down to the extensor tendon.
Superficial vessels are identified and ligated as needed. The tendon and dorsal capsule is transected at the level of the PIPJ and the tendon ends retracted and dissected free from the base of the middle phalanx and proximal to the metaphysis/diaphysis junction of the proximal phalanx. The collateral ligaments on the medial and lateral sides of the PIPJ are severed to adequately expose the joint. The articular surface of the head of the proximal phalanx is then resected using a sagittal saw (Fig. 3). Attention is then directed to the proximal phalanx where a transverse cut is made in the frontal plane ~5mm proximal to the PIPJ, 50% through from plantar to dorsal, and parallel to weightbearing (Fig. 4). A second cut is then made from inferior to superior in the transverse plane, meeting the first cut and leaving a dorsal cortical shelf intact (Fig. 5). The cartilage is left intact on the base of the middle phalanx to minimize shortening. The first cut is made in the base of the middle phalanx parallel to weightbearing, bisecting the height of the phalanx proceeding into the middle phalanx 3-4 mm (Fig. 6). A second cut is then made dorsal to plantar meeting this first cut, now leaving a plantar cortical shelf in the same fashion. The osseous box joint has now been created and can be trialed for adequate bone apposition.

Temporary fixation is achieved with the use of guidewire from a 2.0 cannulated screw (Fig. 7). This is done in a slightly dorsal proximal to distal plantar fashion in order to prevent fracture of this bone dorsally (Fig. 7). A headless screw is preferred (Fig. 8 and 9).

Results:
The authors selected a total of 50 patients between the ages of 22-80 with an average age of 63 years who had a box joint arthrodesis of the PIPJ. The patient population consisted of 46 (92%) female and 4 (8%) male. A total of 85 digital arthrodesis were reviewed with a minimum of 6 month follow up (Table 1). 53% of the fusions were performed on the 2nd digit, 29% on the 3rd digit, and 18% on the 4th digit. In regards to complications, the following complications were observed: non-union, removal of hardware secondary to pain, revision to a single 2.0 headless screw through all three phalanges. Non-unions of the fusion site were identified in 4/85 digits (4.65%), of which only 2 digits were symptomatic and subsequently managed without further surgery. Removal of hardware (ROH) was required in 2/85 digits (2.3%) due to hardware irritation. 4/85 digits (4.65%) required revisions due to persistent hammering of the digits. Overall total complications involved 5/85 digits for an overall rate of 5.8% (Table 2).

Discussion:

Proper fixation and correction of hammertoes have been an ever-present feature in the world of orthopedic foot surgery. This is partly due to the popularity of the procedure but also the multiple aspects of pathology, anatomy, methods of surgical correction, and complication rate of hammertoes. Most of the literature has focused on the type of fixation in hammertoe arthrodesis, leaving the actual bone-bone interface technique to the wayside. In this study, we used an arthrodesis technique that is rarely discussed in hammertoe surgery. Using a retrospective study at our institution we found
that it has comparable and better clinical outcomes than end-to-end or peg-in-hole arthrodesis techniques.

Bernbach and Bernbach’s original technique article was meant to take a simple idea used in cabinet making and transform it into a correction for a difficult to treat digital pathology. Our results present that the Box Arthrodesis has a low overall complication rate of 5.8%. These results are comparable, and in some cases better, than articles comparing end to end or peg-in-hole. Lamm et al. (8) demonstrated a complication rate up to 27% for end to end arthrodesis and 17% for peg-in-hole. When comparing fusion rates of the 2 more common techniques to the Box Arthrodesis, Lehman et al. in 1995 (9) found a 95% fusion rate in their peg-in-hole study while Coughlin et al. (10) found a fusion rate of 83% with their end-to-end technique. From our study, the Box Arthrodesis displayed a fusion rate of 95.35%. Furthermore, the Box Arthrodesis has an acceptable rate of need for revision at 4.65%.

The disadvantages to this technique include the delicate bone cuts and the cost of using a screw over a K wire. Lundin et al. (11) in their cost-effective analysis study on extra-articular hand fractures comparing ORIF vs. percutaneous K wire found ORIF to be 60.7% more expensive than K wires. Albright et al sought to determine whether commercial implants were cost effective over a patient's lifetime compared to k-wire fixation. The authors found that commercial implants were only minimally more effective than k-wire fixation for PIPJ arthrodesis. As expected these devices do not appear to warrant the exponentially higher upfront cost(12).

There are limitations to our study. Due to the retrospective design we had a non homogeneous series due to a wide range of adjunct procedures, ranging from lesser
metatarsal osteotomies to bunionectomies and flatfoot reconstructions. No hammertoe correction was performed in isolation within this case series. This may have affected the recurrence rate and thus the revision rate of the procedures. Also, all procedures were performed by one surgeon and from one practice with significant experience with this technique. Our study also did not use any radiographic parameters for recurrence, nor have any outcome measures for clinical success.

More research is needed in order to understand whether utilizing concomitant procedures on the same digit with this type of arthrodesis increases success of clinical outcomes. A large amount of our findings radiographically demonstrated a metatarsal shortening osteotomy, middle phalanx arthroplasty or 1st ray arthrodesis/osteotomy were done in conjunction. In conclusion, our retrospective study of the Box Joint Arthrodesis for correction of hammertoe deformities shows it is a viable, mechanically strong technique with a low complication rate.

Acknowledgements:

Dr. Marc Bernbach for his permission to re-publish he and his father’s early description and illustration of this technique
References:

11. Lundin M, Woo E, Hardaway J, et al. The cost of quality: Open reduction and internal fixation techniques versus percutaneous Kwire fixation in the


Tables:

Table 1: Patient Demographics

<table>
<thead>
<tr>
<th>Number of Patients</th>
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<tbody>
<tr>
<td>Male</td>
<td>50</td>
<td>4 (8%)</td>
<td>46 (92%)</td>
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<tr>
<td>Female</td>
<td></td>
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| Number of Digits Fused | 85          |          |          |
| 2nd Digit             | 45 (53%)    |          |          |
| 3rd Digit             | 25 (29%)    |          |          |
| 4th Digit             | 15 (18%)    |          |          |
| Average Age           | 63         |          |          |

Table 2: Total Complications

| Non-union            | 4 (4.65%)   |
| Symptomatic non-union| 2 (2.3%)    |
| Revision             | 4 (4.65%)   |
| ROH                  | 2 (2.3%)    |
| Total digits involved| 5 (5.8%)    |
Figures:

Figure 1: Lateral illustration of claw toe deformity with extensor tendon release and creation of box joint with screw fixation

Figure 2: Dorsal illustration of the lesser digits with superimposed creation of box joint with screw fixation
Figure 3: With proper exposure of the proximal phalanx head, Sagittal saw is then used in the coronal plane for the first cut.

Figure 4: Resection of the dorsal aspect of the head of the proximal phalanx is finished transversely.
Figure 5: Once cut is complete, the fragment is removed to display proper bony contouring for acceptance of the middle phalangeal portion.

Figure 6: Resection of the plantar base of the middle phalanx.
Guidewire is then placed for temporary fixation.

2.0mm headless cannulated screw is then inserted. Note: Pictured is previous technique of using a standard AO cortical fully threaded screw for fixation.
Figure 9: Immediate postoperative AP and lateral view radiograph of the final correction of 2nd and 3rd digits with associated weil osteotomies to metatarsal 2 and 3.

Audio or Video Add-on/s:

None