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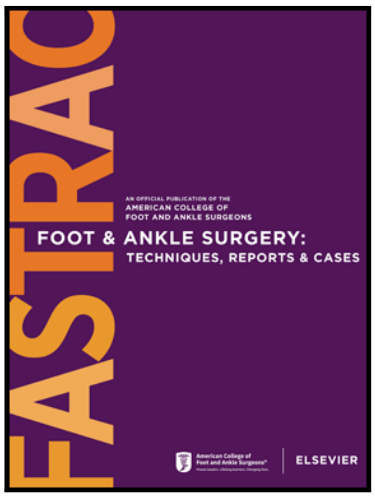

The Digital Mini External Fixator: A Novel and Inexpensive Technique for Forefoot Pathology

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ABSTRACT:

External fixation is widely accepted as a potential fixation technique in the treatment of various foot and ankle pathologies. These constructs may be especially useful in acute trauma stabilization and deformity correction, and can be used to temporarily stabilize an area after excision of infected bone. Unfortunately, these constructs can be complex or expensive. They may not be readily available in the operating theater during emergency cases or if their use was not planned in advance. Additionally, most of the commercial external fixators are too large for small anatomic locations such as the digits in the feet. Therefore, our group has utilized an external fixation technique that is simple, inexpensive, and amenable to small anatomic locations. In this paper, we describe an innovative Digital Mini External Fixator technique that can be applied easily and rapidly to the forefoot in multiple settings, including trauma and limb salvage, with little pre-planning required.

LEVEL OF EVIDENCE: V

KEY WORDS:

Digital trauma, forefoot fracture, diabetic limb salvage, external fixation, Digital Mini External Fixator

INTRODUCTION:

Digital trauma and forefoot osteomyelitis can be difficult to treat. The use of external fixators provides a good option in treating these conditions. However, current commercial constructs can be complicated, expensive, and too bulky for small anatomic structures such as the forefoot. Surprisingly, there is very limited work describing the use of digital external fixators in the foot. To this end, our group has been using a Digital Mini External Fixator technique that is simple, inexpensive, and amenable to small anatomic locations, and its component parts are readily available in most operating theaters without pre-planned ordering or coordination.

Although there is limited work describing digital mini external fixators in the foot, there have been reports of finger external fixator constructs in the hand literature. In 1999, McCulley and Hasting described an external fixation technique using plastic sheathers of IV cannulas and Kirschner wires (K-wires) [1]. Monreal described a similar finger external fixator construct device using a syringe and K-wires [2]. In 2011, another group analyzed the crude costs of their finger external fixator devices which included K-wires and a cement gun tube and compared it to commercial external fixators and found that their finger external fixator construct cost 80% less than the commercial external fixators [3].

Our group has been utilizing a simple construct adapted to the foot since the 1990s. We have utilized the procedure for temporary stability in open fractures with and without

significant soft tissue loss including gunshot wounds, degloving injuries, stability after resection of osteomyelitic bone and arthrodiastasis procedures with and without cartilage replacement in the metatarsophalangeal joints [4] (Figure 1). In a previous study, our group described the application of a full-thickness skin graft that was harvested from the hallux and applied to a complicated open digital fracture wound, which was stabilized with our Digital Mini External Fixator technique [5]. This technique successfully limited micromotion and promoted appropriate healing over the graft recipient site.

In this current paper, we describe a step-by-step approach to the application of our Digital Mini External Fixator technique using only a needle cap or syringe and Kirschner wires (K-wires) that can be applied to the forefoot in multiple settings, including trauma and limb salvage.

SURGICAL TECHNIQUE:

One plastic needle cap, or one plastic syringe with the plunger removed can be utilized as the “stabilizing bar” in the external fixation device. We utilize needle caps more frequently, generally using the syringes when additional length is needed. The needle cap or syringe stabilizing bar is then held to the foot with multiple K-wires. We generally use 0.045 inch K-wires for lesser phalanges and 0.062 inch K-wires for metatarsals and hallux phalanges. The minimum materials required are two double ended wires, as each wire can be cut in half and used for two different spots in the stabilizing bar. The only

other requirements are a wire driver, a surgical marker and protective caps for the K-wires (Figure 2).

After appropriate surgical treatment to the site of interest, the stabilizing bar is placed over the area of interest to establish the appropriate length and wire placement. Medial and lateral positioning of the stabilizing bar and K-wires can be used on the 1st and 5th rays respectively, whiles K-wires should be placed at the dorsomedial or dorsolateral aspects of the middle three digits with care to avoid the long extensor tendon and nail plate. Once appropriate placement is determined, the stabilizing bar is marked with a surgical marker to designate planned wire placement for four holes. Generally, four wires, two proximal and two distal to the site of interest, are required for adequate stabilization. Intraoperative fluoroscopy can also be used to aid appropriate placement of the wires. The location of planned wire positions in the stabilizing bar are marked. On the side table or Mayo stand, the stabilizing bar is pre-drilled through and through with the appropriate sized K-wire at the markings (Figure 3). It is important to perform this step at a side table to prevent contamination of the surgical site with plastic particles. Additionally, the drill holes should be made without significant wobble of the wires, or the drill hole will be enlarged to a diameter larger than the wire and the wire will be loose in the final construct. Occasionally, we pre-drill with a smaller diameter wire (ie. pre-drill with a 0.045 wire and then use a 0.062 wire through that hole into the foot), or place wires slightly non-parallel to each other, to further enhance the final stability of the construct. The stabilizing bar is then lavaged with normal saline, and positioned adjacent to the foot again.

Similar to the application of standard commercially available external fixation devices, the order of wire placement is the surgeon's preference. Depending on the procedure, we usually start with the most proximal or the most distal K-wire, and ensure the stabilizing bar is longitudinally adjacent to the entire segment to be spanned. The 2nd wire is usually placed farthest from the 1st wire placed. For stable areas, such as when performing an arthrodiastasis, we start with the proximal two wires, and then distract the toe according to our preference prior to applying the distal two wires. We place both proximal wires in this situation to provide more stability for the distraction. For unstable areas, such as when spanning large bone voids, from trauma or infection,especially in which the toe may be “floppy”, we can start with the distal two wires to ensure we have good purchase of bone and can then manually hold the toe in our desired position prior to placing the proximal two wires. Regardless of the surgical procedure for which this digital mini external fixator is utilized, this frame is static and the desired amount of distraction or compression must be achieved manually prior to placing the 1st wire on the far side of the area to be spanned, as distraction or compression cannot be adjusted later without removing and replacing wires into bone.

In the sawbones demonstration, we start with the most distal wire. The K-wire is manually advanced through the most distal pre-drilled hole in the stabilizing bar . With the tip exposed, the K-wire is advanced under power through skin into the distal bony segment with bicortical purchase. The K-wire is then cut with approximately 3-4 cm protruding outside the skin. The removed portion of the K-wire can be recycled for the

next pre-drilled hole. The stabilizing bar is then held in the desired position along the foot segment being spanned, and appropriate sized K-wires are subsequently placed through the stabilizing bar and into their corresponding bony segments, all with bicortical purchase (Figure 4). The stabilizing bar is adjusted away from the skin, over the four wires, to rest approximately 2 cm off the skin. The four wires are then all bent and capped outside the stabilizing bar (Figure 5). Intraoperative fluoroscopy can be used to confirm placement, but is often not necessary. The Digital Mini External Fixator is left in place for the desired length of time, as any commercially available external fixation device would be, and it can easily be removed in the office setting generally without the need for local anesthesia.

DISCUSSION:

External fixation is a widely researched and accepted treatment modality. Unfortunately, commercially available fixation devices can be expensive, complicated, and unaccommodating to small anatomic regions such as toes and distal metatarsals. Furthermore, they often need to be requested days prior to a case to ensure availability, which is not possible when treating acute trauma. This current paper describes an innovative Digital Mini External Fixator technique that is inexpensive, simple, and accommodating to small anatomic regions. Moreover, this technique includes readily accessible materials such as K-wires and the plastic cap from a needle, a plastic syringe with the plunger removed or even a plastic suction catheter, without pre-planning to have commercial external fixation devices available in the operating theater.

In our previously published case study, we demonstrated this Digital Mini External Fixator technique's utility in the setting of complex digital trauma [5]. We use this technique often in the treatment of open forefoot fractures with unstable bones or bone voids. We have also used this technique for spanning bone voids after removal of infected bone (Figure 6) and for arthrodiastasis procedures (Figure 1).

Surprisingly, little has been published on toe salvage with external fixation. One study reported successful results of an observational case series of 4 patients that underwent osseous resection of osteomyelitis with polymethylmethacrylate antibiotic-loaded bone cement spacer and toe stabilization with a modular, tube-bar mini external fixator with subsequent autogenous bone graft [6]. Another group reported the successful application of a commercial mini external fixator to treat an open, comminuted 1st metatarsal fracture in a case study [7]. Another paper described the use of a dynamic external fixator for gradual soft tissue expansion and subsequent desyndactylization for the treatment of toe syndactyly [8]. Although these techniques can be useful in different settings, they all use commercial external fixators. Our Digital Mini External Fixator technique is more similar to other "homemade" digital external fixators in the hand literature [9–13]. Although our technique has not incorporated the capacity for dynamization, there are successful reports within the hand literature [14–18]. Moreover, there are no biomechanical studies of this construct in foot models. This provides multiple avenues for further investigation.

Some considerations should be taken when deciding when to apply this technique.

This is a concept utilized by our team for over 25 years, that we believe can be easily replicated, but has had little published about it. Although we have given podium presentations on this topic and previously published a case report in which this technique was used, the technique was not the primary focus of that report, nor have we conducted case controlled research comparing it to commercially available external fixation devices. Future research could help establish long term outcomes and comparative results vs commercially available external fixation devices.

This innovative Digital Mini External Fixator technique we present can be used for the treatment of a variety of complex forefoot pathologies. The materials required for the application of the Digital Mini External Fixator technique are ubiquitous in operating theaters. This construct is relatively low cost compared to commercially available systems. This technique also has a low profile and it allows for multiple Digital Mini External Fixator constructs to be applied to the same foot. The technical simplicity and relatively low cost provides the surgeon another useful tool when dealing with complex foot or digital pathology.

FIGURE LEGEND:

FIGURE 1: Use of Our Innovative Digital Mini External Fixator device for an Unplanned Arthrodiastasis of the First Metatarsophalangeal Joint after a Decompression Osteotomy was Performed.

FIGURE 2: Materials Required for the Digital Mini External Fixator. The only materials required in the digital mini external fixation technique are a surgical marker, a plastic 18 gauge needle cap (or syringe), a K-wire driver, two or three double-sided 0.045 K-wires for digits and 0.062 K-wires for metatarsals, and their corresponding caps.

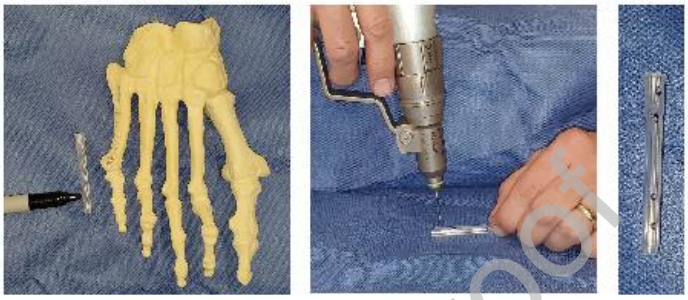

FIGURE 3: Preparation of the Digital Mini External Fixator. (Left) The syringe needle cap is placed over the area of interest and marked for K-wire placement. (Middle and Right) The syringe needle cap (or syringe) is pre-drilled at each marking.

FIGURE 4: Application of the Digital Mini External Fixator. (Left) The K-wire is applied at the distal segment. (Middle) Subsequent K-wire insertion to the proximal aspect. (Right) Sequential K-wire insertion.

FIGURE 5: Final Product of the Digital Mini External Fixator. The Digital Mini External Fixator is completed with bent wires and wire caps.

FIGURE 6: The Digital Mini External Fixator in the Treatment of Diabetic Foot Osteomyelitis of the Second Proximal Phalanx Base and Second Metatarsal Head.

(A) The plantar wound probes directly to the second metatarsal head and tracks to the second proximal phalanx base. (B) Immediate postoperative radiographs following a second metatarsophalangeal joint resection and application of the Digital Mini External Fixator with 0.045 K-wires at the phalanges and 0.062 K-wires at the metatarsal. (C and D) Clinical photos of the plantar and dorsal foot at postoperative day one following application of the Digital Mini External Fixator. (E and F) Clinical photos of the plantar and dorsal foot at two months postoperatively revealing complete wound closure. Notably, the patient had hardware removal in the clinic at 1 month postoperatively.

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