Strategies and Application of Ankle-Spanning Multiplanar External Fixators

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Introduction

Complex, high energy, open, periarticular fractures are seen regularly in most Level I and II trauma centers. Practicing orthopaedic surgeons in the trauma call pool should be capable of applying a lower extremity, joint-spanning external fixator for temporary fracture stabilization. There are several advantages to temporary joint-spanning external fixation over acute internal fixation including less vascular compromise to already traumatized bone, minimizing further soft tissue damage, rapid application in emergency situations, and stabilization of open and contaminated fractures until definitive fixation can take place.[1] Applying an external fixator also allows the traumatized soft tissue envelope to improve prior to definitive fixation, resulting in a staged management of the injury.[2]

Techniques regarding the application of joint-spanning external fixators are grounded in biomechanical principles that significantly affect the stability of the construct. The three variables under surgeon control that directly affect construct stability are the bone-pin interface, the components of the fixator, and the fixator configuration.[3] To increase stiffness in the overall construct, one can decrease the distance between the Schanz pins and the fracture, increase the diameter of the Schanz pins, increase the distance between consecutive Schanz pins in the same fracture fragment, decrease the distance from bar to bone, add additional bars, increase the bar diameter, use a triangular or multiplanar frame, align the pins with the major bending axis of the bone, combine limited internal fixation with external fixation, and achieve bone-to-bone reduction.[1,3,4]

There are several principles that orthopaedic traumatologists agree on regarding lower extremity external fixation. One concept involves the need for CT scans in preoperative planning for definitive fixation. However, the utility of a CT scan prior to application of an external fixator is limited. By placing a patient with a periarticular fracture into an external fixator, ligamentotaxis can be utilized to achieve better alignment of the fracture providing for greater information to the operative surgeon. To obtain the greatest improvement in bony and soft tissue alignment, it is important to obtain length, alignment, and rotation. The external fixator will also protect the soft tissue allowing the envelope to heal. Pins should not be placed in the zone of injury or future surgical incisions are hypothesized to lead to increased infection.[5] Issues that are less agreed upon are the use of power in pin insertion, the bar/pin/clamp construct, the brand of fixator used, and overall frame configuration.[5] Here we will discuss the thought process and preferred method for application of an ankle-spanning multiplanar (delta-configuration) external fixator, as would be applied for a tibial plafond fracture or high-energy ankle fracture-dislocation.

Case

VK is a 65 year old female who sustained a left trimalleolar fracture dislocation of the ankle after falling while walking down steps (Figure 1). She was initially evaluated in the emergency department, where the remainder of her trauma workup was negative. Given the instability of the fracture and the large concomitant soft tissue injury, the decision was made to go to the operating room for application of an ankle-spanning external fixator.

Preoperative Considerations

Imaging

Adequate AP, lateral, and mortise views of the ankle and AP and lateral of the ipsilateral knee are imperative before proceeding to the operating room. This helps to both better characterize the injury as well as rule out any concomitant injury at adjacent joints. Should the radiographs reveal a dislocated or subluxated tibiotalar or subtalar joint, reduction should not be delayed until the time of operative intervention. Instead, expeditious reduction should take place. Advanced imaging, such as a CT scan, does not necessarily need to be performed prior to application of an external fixator unless it will directly affect the initial surgery. Some advocate early CT to guide limited articular reduction and fixation through open wounds; however this is not universally agreed upon. By applying an external fixator and restoring appropriate length, the fracture fragments are disimpacted, and overall fracture pattern and location can be better evaluated on a subsequent CT. In addition, ligamentotaxis can help reduce some

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Figure 1. AP and lateral radiographs of a trimalleolar ankle fracture dislocation.

fragments to aid in planning for ultimate anatomic reduction and fixation.

Positioning/Equipment/Fluoroscopy

The patient should be positioned supine on a regular OR bed with a distal table extension to facilitate intra-operative fluoroscopy. Though a flat top radiolucent bed (Jackson table) may facilitate more proximal imaging, getting adequate images of the foot and ankle may be difficult due to the attachments at the foot of the bed. A regular bed with extension also facilitates physical access of the foot from the end of the bed. We prefer using a bump under the operative hip to position the patella pointing directly at the ceiling and an elevated ramp under the operative lower extremity to bring the leg away from the table and facilitate lateral imaging. Fluoroscopy should be brought in from the contralateral side of the table, and all necessary views should be obtained prior to prepping and draping the extremity. By bumping the hip and positioning the patella straight up and down, the AP and lateral shots of the knee and ankle are simplified with the machine able to alternate between positions parallel and perpendicular to the floor.

Implant Selection

The techniques used to apply an external fixator are significantly more important than the manufacturer of the implant. No specialized implants are necessary, and the pins, bars, and clamps used do not affect the stability of the construct as long as they are biomechanically sound and follow principles of fixation.

Prior to beginning the procedure, make certain that there are an adequate number of pins, bars, and clamps. There should be both 5mm Schanz pins for the tibia and a 5mm or 6mm centrally threaded pin for the calcaneus. In our preferred construct, five pin-bar clamps are necessary. Also ensure that there are bars of adequate length to span from the calcaneal pin to the tibial pins. The clamps need not be polyaxial. Though multi-axial clamps facilitate ease of use, they are not necessary for application of an ankle-spanning, multiplanar frame. Other implants to have available include any plating system that might be used for early fixation of the fibula in a pilon fracture. However, the indications and techniques regarding that are beyond the scope of this review. Current recommendations are such that acute fixation of the fibula during external fixation is not routinely performed.

Intraoperative Considerations

Tibial Pin Placement

Placement of Schanz pins should be well thought out before entering the operating room. When planning pin placement, one must consider the definitive surgical procedure. The pins should be well away from the fracture site for several reasons. First, during definitive fixation, the external fixator can be left on and utilized as a reduction tool, and having the construct away from the area of work can facilitate a window in which to work. Second, placement of pins within the zone of final fixation that overlap with permanent implants could lead to increased risk of bacterial inoculation and ultimately osteomyelitis, a devastating complication. Third, incisions for pin placement should be well away from the area of the incisions being used for definitive fixation. Small skin bridges and increased trauma to an already compromised soft tissue envelope could lead to wound breakdown ultimately necessitating soft tissue coverage. This also ensures that the surgical trauma avoids the zone of injury. Application of an external fixator should be designed to help avoid compromise from any secondary procedure.[1]

There are multiple options for Schanz pin tip design including standard, self-tapping, and self-drilling/self-tapping. We prefer the self-tapping screws that do not self-drill. Self-drilling pins could theoretically lead to decreased pin stability due to the nature of their insertion. Also, the pins should be less than one third the total bone diameter. When the drilling tip engages the far cortex, the threads of the near cortex are stripped, therefore lessening their interference with the near cortex and leaving the pin engaged in only one cortex. In addition, a self-drilling pin will be more prominent through the far cortex with the same thread purchase. We prefer 5mm, self-tapping, non-coated Schanz pins inserted by hand. The surgeon should also know if the pin has a tapered design which can increase pin-bone interface as it moves forward but will be compromised if it is reversed.

The first tibial pin is placed as proximal as three finger breadths distal to the tibial tuberosity (for pilon fractures) or as proximal as the middle third or the shaft (ankle fracture-dislocation) on the medial border of the tibia just off of the apex of the crest. Once the appropriate position has been determined, a 1 cm incision is made, and blunt dissection is carried to the level of the periosteum. A small periosteal elevator can then be used to clear off any remaining soft tissue. The soft tissue protection sleeve (comprised of an outer sleeve, drill sleeve, and trocar) can then be positioned against the cortex of the tibia, making sure that all soft tissue is protected. Initially the sleeve should be at 90° to the medial border of the tibia, but once the drill engages, the trajectory should be shifted to perpendicular to the table, therefore making it straight along the AP plane and perpendicular to the mechanical axis of the tibia (on a lateral view). If the trajectory is not changed, the risk of a "burner" or all cortical pin is high. This is suboptimal, and if the drill is advanced too far past the cortex, the peroneal nerve could be at risk. Once two cortices are drilled, the inner drill sleeve can be removed, and the Schanz pin, loaded on a T-handled chuck, can be advanced. It is of the utmost importance that the trajectory of the outer sleeve does not change as you insert the pin to avoid losing the trajectory that was drilled. The pin will give some resistance as it goes through the first cortex, then continue to advance until the resistance of the second cortex. After several more turns, a lateral fluoroscopic image should be checked to gauge the depth of the pin (Figure 2). The entire tip should have passed through the second cortex with at least one thread engaged and through the far cortex.

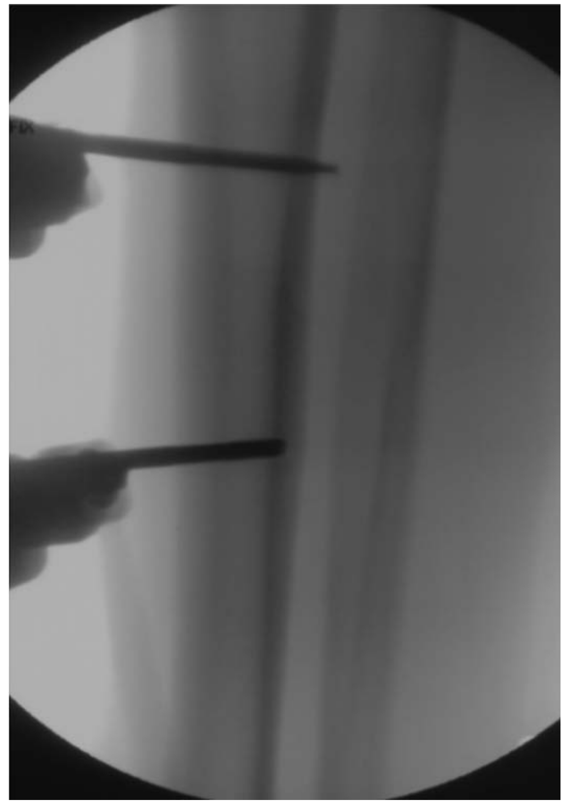

Figure 2. Fluoroscopic view of the tibia after final pin insertion.

Calcaneal Pin Placement

Placement of the calcaneal pin is slightly more difficult given the neurovascular structures in close proximity to the ideal window. The medial calcaneal nerve, the posterior branch of the lateral plantar nerve, and the lateral plantar nerves are at all risk.[6] The pin should be inserted from medial to lateral to avoid injury to the posterior tibial artery, the tibial nerve, and adjacent tendons. The posterior tibial artery should be clearly identified and can even be palpated during insertion to avoid injury. Many textbooks describe the location for the insertion of the trans-calcaneal pin as a point 2 cm posterior to the posterior border of the medial malleolus and 2 cm distal to the distal tip of the medial malleolus. We prefer to place our pins slightly more distal and posterior. This allows the calcaneal pin to abut the physeal scar, which contains the hardest bone in the calcaneus. This also serves to keep the pin further away from at risk neurovascular structures. The pin should be placed orthogonal to the tibial pin and to facilitate positioning of the calcaneus and, if possible, the foot should be supinated and the ankle dorsiflexed to lock the subtalar joint and keep the ankle in neutral.

When inserting the pin, first make a small skin incision and bluntly dissect down to the level of the medial calcaneal wall. Then, position the tip of the pin at the desired starting point and check your position in two planes. Drill only the medial cortex of the calcaneus. After correct positioning is confirmed, insert the centrally threaded pin directly across the calcaneus. We prefer a centrally threaded calcaneal pin that allows bars to be placed both medially and laterally on the same pin. The threads should be inserted slowly so as to not strip them in the soft cancellous bone of the calcaneus. After the pin is inserted, check a perfect lateral of the pin to ensure that it is completely within bone (Figure 3). By pre-drilling

Figure 3. Lateral fluoroscopic view after calcaneal pin insertion.

the calcaneus pin you can ensure a correct trajectory, as well as make real time corrections without leaving a large defect in the cancellous bone, as you would with a misplaced threaded calcaneal pin.

Construct

After confirming the position of both tibial pin and the trans-calcaneal pin, the overall construct can be assembled. Two pin-bar clamps should be placed on the tibial pin and one each side of the calcaneal pin. Our preferred construct is a bar from the tibial pin to the lateral aspect of the calcaneal pin, a bar from the tibial pin to the medial aspect of the calcaneal pin, and an out-of-plane tibial pin connected to the medial bar, added after the reduction has been performed and the rest of the clamps tightened.

The directionality of the clamps is also important. The pin side of the pin-bar clamps should open away from the fracture so that the distraction force is "pushed" through the imbedded pins rather than "pulled." Also, the bar side of the tibial clamps should be positioned with the open side facing posteriorly and the bar side of the calcaneal clamps, with the open side facing anteriorly. This is to decrease the posterior vector force, thereby preventing subluxation. All pin-bar clamps should be left loose on the bar side so that the bars slide through the clamp as the reduction maneuver is performed. Often times, a posteriorly directed force on the distal tibia and an anteriorly directed force through the calcaneal pin will help reduce the subtalar or tibiotalar joint. The ankle should also be dorsiflexed to help reestablish the ankle as the center of rotation.

After the reduction is performed and the ankle is positioned appropriately, the clamps can then be finger tightened and ultimately fully tightened once an acceptable reduction has occurred. The bars should be about two to four finger breadths away from the skin of the calcaneus and should accommodate additional swelling so that there is no risk of contact between the bars and the skin either at the tibia or the calcaneus.

Reduction

Once the pins, clamps, and bars are in place, the reduction can take place. Restoring length, alignment, rotation, and maintaining a reduced ankle are key considerations during this step. Fluoroscopy should be brought into the field and multiple images should be acquired as you perform your reduction. The initial maneuvers should be performed while

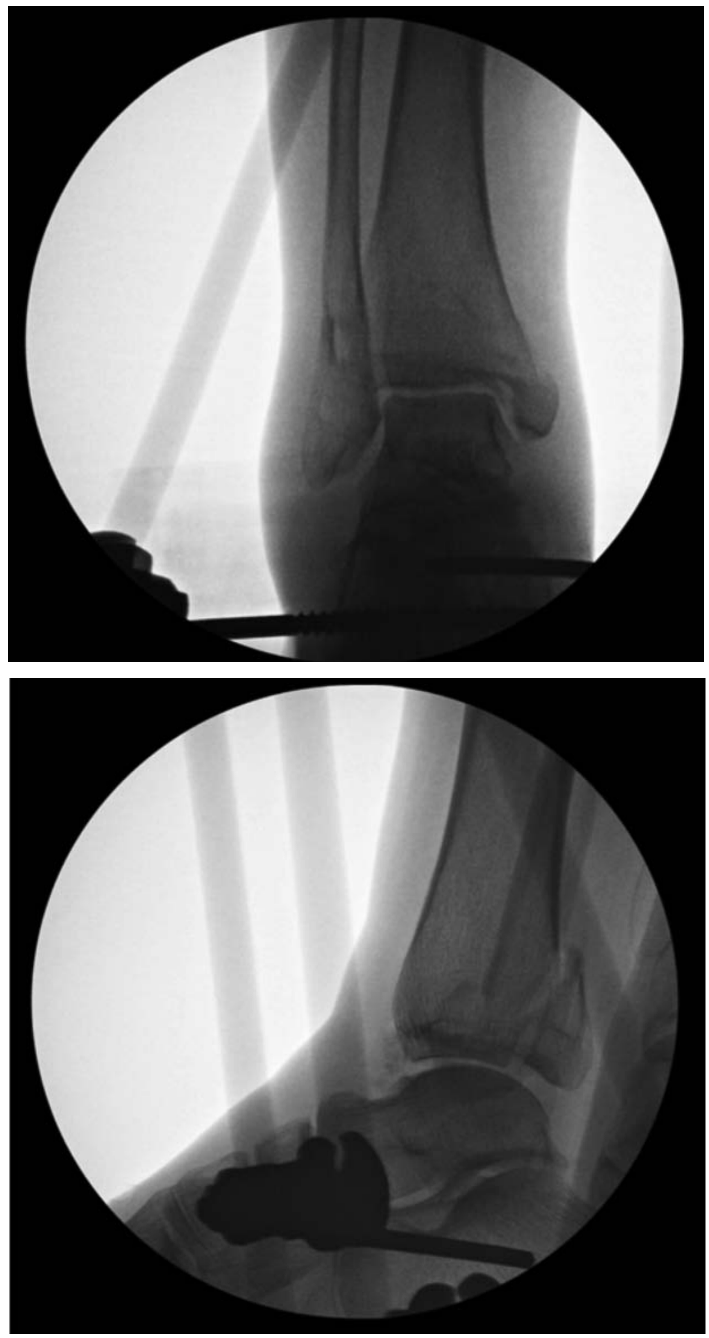

Figure 4. Mortise and lateral fluoroscopic images of the ankle after reduction maneuver.

taking lateral fluoroscopic images to confirm that the talus is reduced under the tibia. Usually axial traction, with slight anterior or posterior translation, and minimal internal or external rotation should achieve an adequate reduction. Once a satisfactory reduction has occurred, tighten the bar side of the pin-bar clamp to hold the reduction and release traction. Take AP, lateral, and mortise views of the ankle to confirm restoration of length, alignment, rotation, and a reduced joint (Figure 4). If the reduction appears satisfactory, tighten all the clamps fully. Never tighten dual-nut clamps with a single wrench, as this may cause the pins to strip out of the bone. Instead, take a second wrench and place counter traction on the opposite side of the clamp to resist increased torque through the pins. Lastly, after the reduction has been performed and all the pins have been fully tightened, use a drill guide that can be mounted on the medial tibial to calcaneal bar, and place a second tibial pin out of plane to the first pin, to give increased stability. After the pin has been inserted but prior to removing the T-handle chuck, the pin can be used to help modify the reduction but only slightly. At this point only small changes in the overall reduction can be implemented given that the rest of the construct is locked. After the reduction is satisfactory, tighten the clamps and recheck fluoroscopy shots. Make sure that all clamps have been fully tightened in order to avoid losing your reduction.

Conclusion

The application of an ankle-spanning multiplanar (delta-configuration) external fixator is a tool that all orthopaedic surgeons should have in their armamentarium. By understanding the biomechanics of building a stable construct, performing adequate preoperative planning, and adhering to strict principles of fracture stabilization and soft tissue management, the application of a joint-spanning external fixator can be used successfully as temporary stabilization of a high energy, comminuted, or open fracture that needs to be managed in a staged fashion.

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