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Forefoot applications of external fixation

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The use of external fixation in foot and ankle surgery has steadily increased with the advent of devices geared toward the foot and ankle that have evolved over the past decade, as well as a greater understanding of the indications and advantages of external fixation. The application of external fixators in the forefoot may at first glance seem both limited and possibly overkill, but once the basics of external fixation and the types of devices available are understood, the options for use become numerous. External fixation is essentially divided into one of two categories: unilateral and circular fixators. The use of circular external fixators in the forefoot has been described in the literature, but its use is limited [1,2]. Unilateral frames are more commonly used in forefoot surgery, particularly mini-external fixation devices. The two primary types of unilateral mini-external fixation devices available are the Orthofix system (Orthofix, Richardson, TX) and the Dynafix system (EBI Medical Systems, Parsippany, NJ). Both of these systems allow for distraction and compression. Other small or minisystems, such as the Synthes mini-external fixation device, act as primarily a stabilizer instead of allowing for true distraction or compression (Fig. 1).

The Orthofix mini-external fixators consist of two types: the minirail system and the Pennig minifixator. The minirail system consists of minirail lengtheners (long, 135.5 mm; standard, 57.5 mm; and short, 32.5 mm) and articulated minirail lengtheners (horizontal and vertical axis) (Fig. 2). The minirail is secured by the use of four threaded pins designed specifically for the Orthofix system (2 mm or 1.6 mm) inserted through one of three possible slots in each of the two clamps normally used. Compression and distraction are obtained through the use of an Allen wrench to adjust the compression-distraction nut in the minirail.

The Pennig minifixator's main component consists of a central element with a double ball joint and a single-screw locking mechanism within a 15-mm modular square 3(Fig. 3) [3]. This unique component (known as the PMF body) connects threaded bars of various lengths, which can move independently to allow for multidirectional external fixation. Two types of universal clamps are available to attach to the threaded bars: the standard clamp and the L-clamp. The clamps

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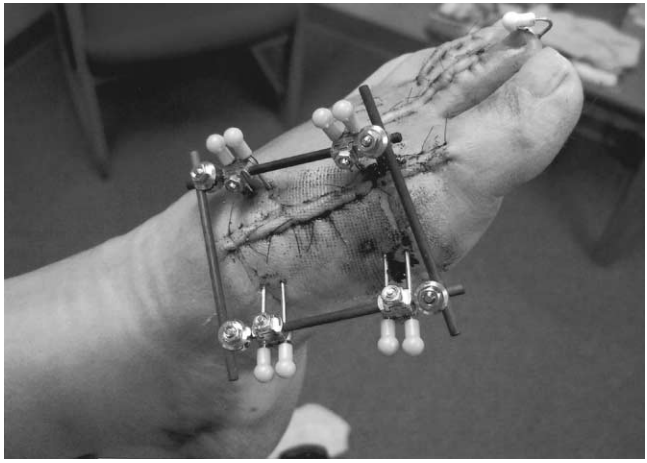

Fig. 1. Synthes mini-external fixator in a delta frame configuration for stabilization of a fractured "Z" osteotomy.

allow for insertion of up to four threaded pins, but most commonly only two are used (identical to those used by the minirail system). Compression and distraction are made possible by a supplementary nut attached to the threaded bar, which lies adjacent to each clamp. Compression is achieved by placing the nuts outside of each clamp, which allows the clamps to be brought closer together. Distraction is realized by placing the nuts on the inside of each clamp, resulting in the clamps being moved further apart.

The DynaFix system by EBI is similar to the Orthofix system in that it has two systems in its mini-external fixator set. The small rail system is used for

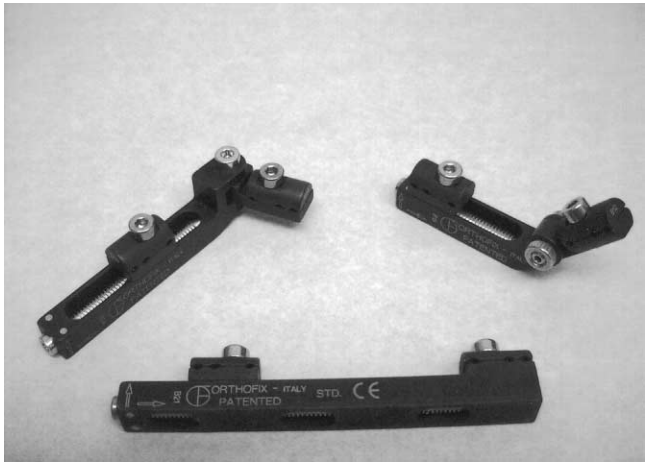

Fig. 2. Orthofix minirail systems. Transverse plane minirail (top left); sagital plane minirail (top right); straight mini rail (bottom).

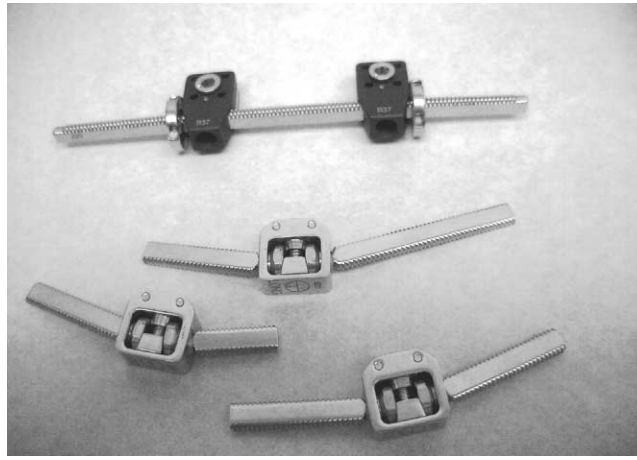

Fig. 3. Orthofix Pennig devices with various bars (bottom three); long lengthening bar with clamps and distraction/compression nuts (top).

lengthening and consists of a rail (100 mm, 150 mm, 200 mm, and 250 mm), clamps, and compression/distraction nuts. The clamps are attached to bone by pins of various lengths and diameters. The EBI MiniFixator is similar to the Pennig device in that it has an adjustable component with a ball-and-socket configuration that provides versatility in fixator placement and range of motion (Fig. 4). Compression and distraction is accomplished with the use of a nut placed either between the clamps or on the outside of the clamps. One difference between the EBI system and the Orthofix system is that the EBI system requires

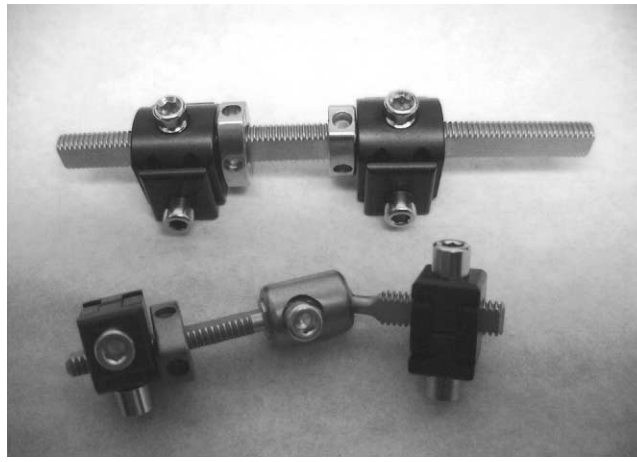

Fig. 4. EBI DynaFix system. Small rail with clamps and compression/distraction nuts (top); Minifixator with clamps and compression/distraction nuts (bottom).

the clamp-locking nut to be loosened for the compression/distraction nut to move the clamps along the rail.

As with any type of fixation, there are advantages and disadvantages to external fixation. When considering the use of external fixation in forefoot surgery each case should be analyzed by taking into account the particular procedure to be performed. The most obvious advantage to external fixation is adjustability postoperatively, which allows for immediate or gradual deformity correction or bone lengthening [4]. Another well-known advantage is the possibility of early weightbearing allowed by the superior stability of external fixation. An often-overlooked benefit is the potential for a minimally invasive surgery [5]. Their modular designs offer mini-external fixators a great deal of flexibility allowing for multiplanar and multifunctional correction [4].

The disadvantages of external fixators too often prevent their use when it may be the most suitable type of fixation. There are disadvantages to external fixation, but most are remedied by surgeon education and experience, and preoperative patient education. External fixators can be difficult to assemble and handle intra-operatively (although the mini-external fixators are much less so than circular frames). External fixators also require more monitoring postoperatively by both patient and surgeon, have a higher potential for neurovascular damage due to pin placement, increase the risk for pin tract infections, and have a higher level of postoperative discomfort and patient dislike [5].

Generalized indications for mini-external fixators fall into one of two categories, compression and distraction, with each having several subcategories.

Compression

First metatarsal phalangeal joint arthrodesis

Although there are several methods of fixation, external fixation probably provides the most stable fixation for first metatarsal phalangeal joint (MPJ) arthrodesis and allows for added compression during the postoperative period [6]. External fixation can be used as the sole type of fixation or in combination with internal or other types of external fixation. The approach to the first MPJ is a standard dorsomedial incision, unless a previous surgical procedure has been performed, in which case the prior incision should be used when possible. Anatomic dissection should be employed to the level of the capsular and periosteal structures. The capsular and periosteal dissection is the surgeon's choice but typically follows the incision. Several types of joint resection have been described in the literature, but the two types most commonly used by the author are abrasion arthroplasty and curettage with subchondral bone drilling. If shortening is required to maintain the proper metatarsal parabola, such as with a rheumatoid pan metatarsal resection, reamers or joint resection with a power bone saw may be used.

Like with any arthrodesis procedure, position is of utmost concern. Many variations of the ideal position for fusion have been described, but the author's

preferred first MPJ position is fused in about 5 to 10 degrees of dorsiflexion and parallel to the lesser digits. Intraoperatively, temporary fixation is achieved by a single 0.062'' k-wire inserted from distal to proximal through the hallux and across the first MPJ into the first metatarsal shaft. Position is then checked with a flat surface, like a lid from an instrument set, while loading the foot. Ideally, the hallux should be just off the weightbearing surface, and while squeezing the pulp of the toe, the plantar surface of the hallux will touch the flat surface. With the foot loaded, the transverse plane position should also be checked because it may differ from the non-weightbearing position. The hallux should not be in varus or impeding upon the second toe in excessive valgus. If the second digit is not in a rectus position, it should be manually or surgically reduced while checking the transverse position. Once position has been verified, fixation is then implemented. If an external fixator is going to be used with the 0.062'' k-wire, then the external fixator is applied directly. If, however, internal fixation is going to be used with the external fixator, then it is inserted before application of external fixation. The author's preferred method is a 3.0-mm cannulated screw from distal medial to proximal lateral in conjunction with an external fixator (Fig. 5). The guide pin is inserted at the flare of the base of the proximal phalanx medially and directed to the first metatarsal neck laterally with the cortex being penetrated. Position and length of the guide pin is checked with a C-arm and adjusted intraoperatively. The temporary 0.062'' k-wire is removed and the 3.0-mm cannulated screw is inserted via the usual technique. Bicortical purchase of the screw should be achieved. The external fixator is applied either medially or dorsally; it has been the author's experience that application medially can lead to a varus position during the postoperative tightening of the external fixation

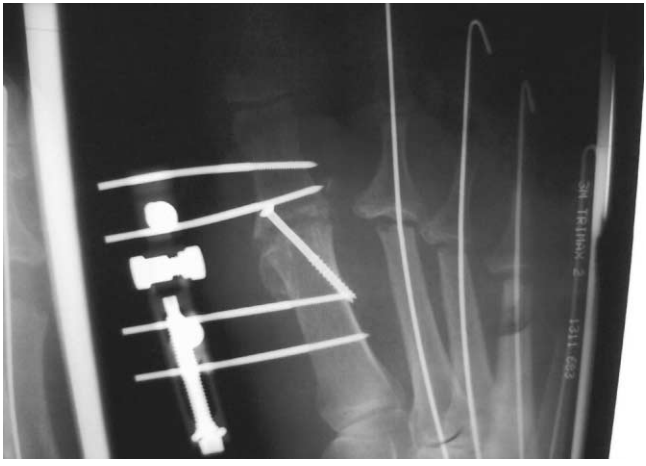

Fig. 5. First MPJ arthrodesis with Orthofix Sagittal plane mini-external fixator and 3.0-mm Synthes cannulated screw, pan-metatarsal head resection, and digital arthrodesis with 0.045'' k-wire fixation.

(Fig. 6). Therefore, dorsal placement with a sagittal plane-hinged device is recommended. The sagittal plane hinge accommodates for the dorsiflexion of the MPJ and will help maintain the position while the surgical site is compressed postoperatively. Typically, 1.6-mm pins are used in the hallux, and 2.0-mm pins are used in the first metatarsal. The pins may be inserted through the incision or just lateral to it, whichever allows for easiest closure. The frame itself should be used as template for pin insertion.

After the frame is connected to the pins and secured, compression is then achieved by tightening the compression nut. The internal, if used, should be tightened as needed at this time. The frame must be sufficiently off the skin to allow for postoperative edema. The pins are then cut just above the frame with a pin cutter. Closure is then by surgeon preference, but is typically 2-0 absorbable for capsule, 4-0 absorbable for subcutaneous tissue, and 5-0 non-absorbable for skin. Alternatively, closure may be done as described above with the pins in place and the frame then applied after closure. This method may make closure easier, but the internal fixation cannot be tightened after the frame is applied and compressed.

During the postoperative period the external fixator may be adjusted for added compression by tightening the compression nut to an end point of firm resistance on a weekly basis. The frame is left on for approximately 8 weeks or until radiographic consolidation is noted. The frame can be removed in the office, usually without anesthesia; Orthofix supplies an adjustable pin extractor for this. Weightbearing is typically allowed during the entire postoperative period with a cast brace, unless otherwise contraindicated. It can be difficult for a patient to wear a cast boot even with something as small as a mini-external fixator; therefore often a slightly modified surgical shoe is used.

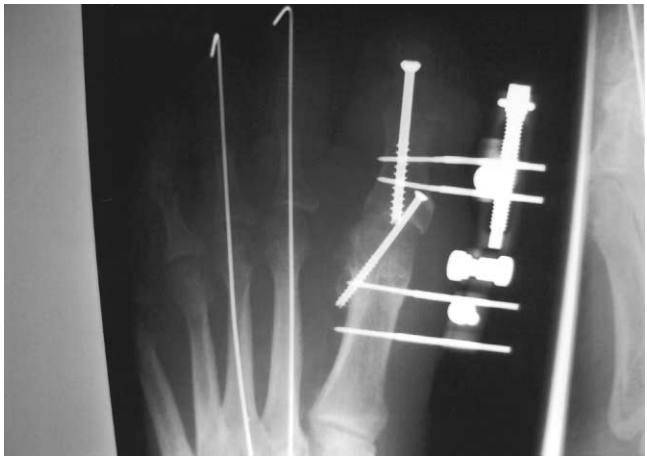

Fig. 6. Varus position after adjustment of a medially placed Orthofix Sagittal plane mini-external fixator for a first MPJ arthrodesis; additional fixation of MPJ with 3.0-mm Synthes cannulated screw.

First metatarsal cuneiform joint arthrodesis

Similar to first MPJ arthrodesis, first metatarsal cuneiform joint (MCJ) arthrodesis can be fixated with several types of fixation [7]. It has been the author's experience that when trying to correct for either sagittal or transverse plane deformity, the use of a bone graft is essential to deformity correction and arthrodesis position. Care must be taken to avoid damaging the graft with multiple types of fixation. The author recommends that only one type of fixation perforate the graft, using a second point of fixation on either side of the graft. With this goal in mind, the use of a single cannulated screw from distal-dorsal to plantar-proximal and an external fixator is an excellent choice of fixation (Fig. 7). The approach consists of a dorsal medial incision centered over the first MCJ just medial to the Extensor Hallucis Longus (EHL) tendon. Anatomic dissection is used to reach the periosteal and capsular structures, which are then linearly incised and reflected medially and laterally to expose the first MCJ. It is important to fully mobilize the joint by releasing all the ligaments around the first MCJ. Once mobilized, the articular surfaces may be resected via curettage and subchondral drilling, or with the use of a power bone saw to remove the articular surfaces just behind the subchondral bone plate, removing as little bone as possible. When using a bone graft, the latter is often the best choice for joint resection. If not using a bone graft, the transverse plane deformity is corrected by manually closing down the intermetatarsal angle and using a feathering technique to obtain position with either type of joint resection. Dorsal wedging or plantar dislocation of the first metatarsal accomplishes sagittal plane correction when a graft is not used. With graft use, the placement of the graft base is used to obtain correction by placing the base dorsally for sagittal plane correction or medially for transverse plane correction (Figs. 8, 9).Studies have shown that autografts are

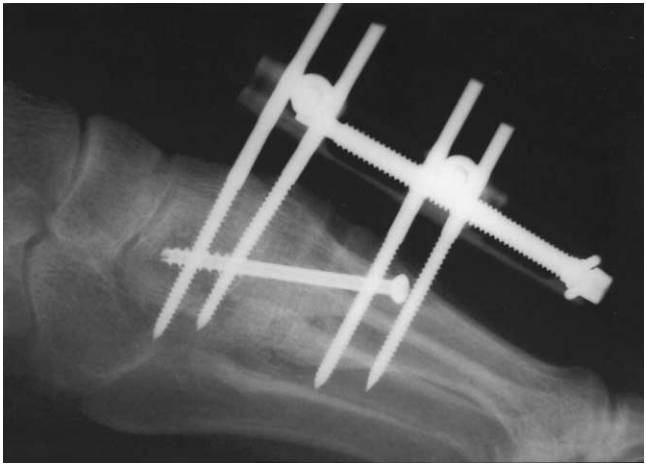

Fig. 7. Lapidus arthrodesis with dorsally wedged calcaneal bone graft fixated by a 4.0-mm Synthes cannulated screw and an Orthofix straight rail mini-external fixator.

superior to allografts for foot surgery [8]. The lateral aspect of the calcaneus provides bone graft for the size of graft used with this procedure.

Once position and graft placement are deemed acceptable, a 4.0-mm cannulated guide pin is placed from dorsal-distal to plantar-proximal across the arthrodesis site. It is important to place the guide pin at about the midshaft level and as flat as possible so that the pin is as close to 90 degrees to the arthrodesis site as possible. The pin length and placement should be verified with a C-arm intraoperatively. The 4.0-mm cannulated screw is then inserted via the usual technique, with care to adequately countersink the first metatarsal, allowing the screw head to pass. The external fixator is placed dorsally and, most frequently, laterally to the incision, which allows for easier wound closure. For this type of procedure, a nonhinged minirail is used most often with 2.0-mm pins for fixation—two pins each in the first metatarsal and the first cuneiform. After compression is achieved, the internal fixation should be checked and tightened as needed, as with any procedure where internal fixation and an external fixator are used. Pins should then be cut to appropriate length making sure the frame is adequately off the skin to allow for postoperative edema. The wound is then flushed and closed with 2-0 absorbable suture for periosteum and capsule, deep structures are closed with 3-0 absorbable suture, and skin is closed with 4-0 or 5-0 nonabsorbable suture. The pins may also be placed in the incision and closure completed before frame application.

Although the patient could be allowed theoretically to weightbear, the author prefers to use a postoperative course of nonweightbearing for 4 weeks, partial weightbearing for 4 weeks, and assisted weightbearing for 4 weeks. This is primarily due to the use of a bone graft but also to protect the graft harvest site.

Fig. 8. First MPJ arthrodesis with medially based wedge for correction of metatarsus adductus associated with a Cavus deformity fixated with a 4.0-mm Synthes cannulated screw and an Orthofix straight rail mini- external fixator. Note cuboid osteotomy for additional correction of metatarsus adductus and bone graft harvest site.

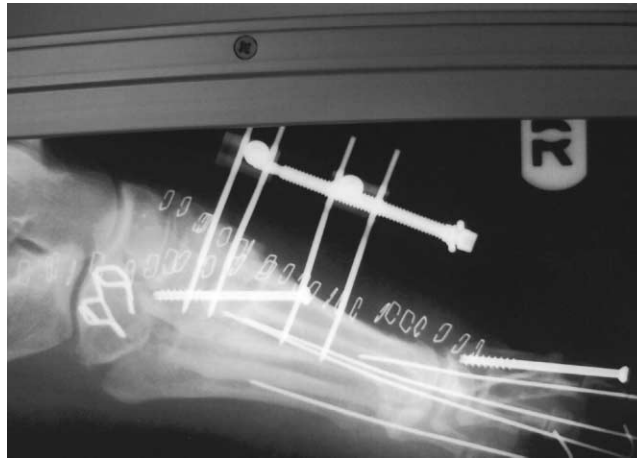

Fig. 9. Same patient as Fig. 8, lateral view.

Similar to the first MPJ arthrodesis, a modified surgical shoe is used during the postoperative period. The frame is tightened weekly to firm resistance and left on for approximately 8 weeks or until radiographic union is seen. The frame can usually be removed in the office without anesthesia.

Fracture management

Both intra-articular and shaft fractures can be fixated with mini-external fixators [3,9]. Fractures to the fifth metatarsal are the most commonly treated metatarsal fractures with external fixation [3]. Pins are placed in a horizontal direction medially for the first metatarsal and laterally for the fifth metatarsal [3]. Care must be taken to avoid the sole of the foot with the external fixator. Pin position for the second through fourth metatarsals is approximately 30 to 45 degrees dorsal to the horizontal plane either from the medial or lateral side [3]. Lesser metatarsals and phalanges require 1.6-mm pins, whereas 2.0-mm pins may be used on the first metatarsal. A straight minirail device without a hinge is most often used on metatarsal fractures. Intra-articular fractures of the MPJ are usually treated with a sagittal plane hinged device to allow for early range of motion while maintaining fracture fixation. The primary benefit of forefoot fracture fixation with mini-external fixators is a minimally invasive procedure with outstanding stability and compression. Postoperative care and weightbearing are individualized for each case, but in most instances at least partial weightbearing may be allowed once edema has resolved.

Osteotomy fixation

Osteotomy fixation with external fixation has been described in the literature, particularly in cases of hallux abducto valgus or an Akin osteotomy [10,11]. For

hallux abducto valgus, either a cresentic base osteotomy or a MCJ arthrotomy has been described in association with external fixation [10]. In both cases, the external fixator is used to maintain correction obtained by the surgical correction, as opposed to postoperative adjustment to allow for further deformity correction. The Akin osteotomy requires the proximal pins to be placed vertically and the distal pins to be placed horizontally. For the hallux, 1.6-mm pins are typically used, whereas the metatarsal may be fixated with either 2.0- or 1.6-mm pins, depending on the size of the patient.

Bone graft fixation

When using a bone graft for an osseous defect such as with avascular necrosis or osteomyelitis debridement of a metatarsal, external fixation can provide stability and compression [11]. The external fixator is often technically less difficult with graft insertion compared with internal fixation. For most osteotomies and graft fixation, a straight minirail system is used.

Distraction

Brachymetatarsal correction

The use of callus distraction for the treatment of congenitally short metatarsals has been well documented in the literature as a primary indication for callotasis in foot surgery with excellent results [2,12–18]. In fact, the use of callus distraction for the surgical treatment of brachymetatarsia was the original description of the use of callotasis in foot surgery [19]. The surgical approach consists of a dorsal linear incision placed over the metatarsal base and corresponding cuneiform or cuboid. Anatomic dissection is used to reach the level of the deep fascia, and the extensor tendons are retracted medially or laterally. With congenital brachymetatarsia, the extensor tendons do not require lengthening at the time of surgery, as they will be lengthened with the metatarsal postoperatively. If the osteotomy is going to be placed in the metaphysis, it is advantageous to perform the osteotomy directly through the periosteum instead of trying to reflect the periosteum and causing increased soft tissue damage due to the periosteum's firm attachment to the metaphyseal bone. Though the metaphyseal osteotomy is usually the location of choice because of its increased vascularity, osteogenic potential, increased surface area for distraction, and added stability, it is not without technical difficulties. These technical difficulties may indeed make a proximal diaphyseal osteotomy more practical [20]. The diaphysis is easier to access because the periosteum is not as firmly attached and may therefore be reflected medially and laterally without significant soft tissue disruption. The diaphyseal osteotomy also allows for technically easier pin placement than that of a metaphyseal osteotomy. Pin placement should be initiated before performing the osteotomy, which if done first makes the respective fragments unstable and pin insertion very difficult. The

pins should be placed perpendicular to the metatarsal shaft without any angulation to ensure the frame is held parallel to the metatarsal [15]. Once a pin has been engaged, the frame can be applied and used as a template for the three remaining pins (two pins located distal to the osteotomy, one proximal to it with the final pin placed in either the respective cuneiform or cuboid). It may make pin placement easier if the cuneiform/cuboid pin is placed first and the other pins placed in relation to it, making sure the osteotomy site lies between the two middle pins. Pins may be inserted percutaneously with C-arm guidance and do not need extensive dissection, especially periosteal dissection that may inhibit callotasis. If a pin guide is available, it may be used instead of the frame for subsequent pin placement. Once all four pins are adequately inserted, the osteotomy/corticotomy may then be performed. Much has been written on the debate of osteotomy/corticotomy selection in callus distraction, and it is quite clear that a corticotomy is the method of choice. However, in small bones like metatarsals a true corticotomy may not be feasible. An osteotomy with a number 38 blade is typically performed with a maximum of two to three passes through the osteotomy site perpendicular to the weightbearing surface. Thermal necrosis must also be minimized with the use of cold saline dripped on the osteotomy site while the metatarsal is being cut. The other option would be to use a drill and k-wire to circumferentially drill around the metatarsal and then use an osteotome to break through the cortical bone, minimizing the endosteal disruption resulting in more of a corticotomy. Maintaining the endosteum via corticotomy, however, it has been shown to be of minimal importance to clinical healing [21]. Once the osteotomy/corticotomy is completed, the surgical site should be flushed and closed anatomically (especially the periosteal structures). This typically involves 3-0 absorbable for periosteum, 4-0 absorbable for deep structures, and 5-0 nonabsorbable for skin. Application of the mini-external fixator after closure is much easier than trying to close the wound with the frame in place. With major lengthening or in cases where there is already digital deformity present, it advised to pin the toe in a plantarflexed position leaving the k-wire long to accommodate for the lengthening process [16]. The frame can then be applied and tightened for the initial phase of compression. Care must be taken to leave enough space between the frame and skin to allow for soft tissue swelling postoperatively. Non-weightbearing has been recommend from 3 to 4 weeks up to the point of desired length and radiographic healing, which is noted at approximately 12 weeks [12,14,16,17,20]. On the other hand, some authors have advocated partial weightbearing immediately after surgery [2,15,18]. A latency period of 7 to 10 days is required before distraction, with a general distraction rate thereafter of approximately 1/2 to 3/4 mm per day. Mini fixators usually allow for 1 mm of lengthening with each full turn of the compression/distraction nut. To reach the desired amount of daily lengthening it is most practical for a patient to do a 1/4 turn two to three times a day. Radiographic callus formation may not be noticed for up to 2 to 3 weeks after distraction has been initiated. Although this lack of bone callus can cause the surgeon a great deal of concern about healing, lengthening should continue until the desired length is reached. Once the appropriate length

has been reached and radiographic callus is noted throughout the lengthened aspect of the metatarsal, weightbearing is initiated with the frame kept in place to protect the new bone and allow for dynamization for 2 to 4 weeks. During this time period of dynamization the frame may be removed and the pins left in place to further promote the healing process. The pins may then be removed in the office setting without anesthesia.

The time from surgery to removal of frame varies significantly in the literature from Fox's article that had an average of 55.67 days to Kawashima et al.'s 112.5 days. Callus distraction can lengthen a metatarsal between 25% and 50%, but callotasis has been reported up to 83% of the original metatarsal length [14–16]. Magnan et al. noted that as long as the lengthening was less than 50%, they experienced no significant complications in their study with completely satisfactory clinical outcomes. Both Magnan and Kawashima noted MPJ subluxation in patients that had greater than 50% lengthenings and directly correlated these two findings. The most commonly reported complication in the literature with callotasis is pin tract infection, which usually responds to local or oral antibiotics [2,14,16,17]. Another complication described by Magnan was premature closure of the osteotomy in an 8-year-old patient, though the remaining patients in their study were all older than 13 years of age and had no such complication. Fracture through the lengthening site has also been reported in the literature, which provides strong support for the dynamization process [15]. Although delayed or nonunions would be an expected complication, malunions have described more frequently in the literature [2,14,17]. One overlooked potential complication that has been described is hypertrophic scarring caused by movement of the pins through the skin during the lengthening process [14]. One interesting note in reviewing the literature was the metatarsal reshortening noted by Kawashima et al. after frame removal of an average of 4.7 mm (20.5% of the distracted length). More than 90% of the shortening was noted to occur within the first month after frame removal. Callotasis of brachymetatarsia utilizing the above technique closely follows the seven principles described originally by Ilizarov for the formation of new bone within the area of distraction: (1) maximum preservation of endosteal and periosteal blood supply; (2) stable external skeletal fixation; (3) a latency period before distraction; (4) distraction rate of 1 mm/day; (5) distraction in small frequent steps; (6) a period of neutral distraction; and (7) normal physiological use of the elongated limb [22–24].

Shortened first metatarsal

A congenital or iatrogenic shortened first metatarsal can have a significant negative impact on the biomechanics of the foot, and, similar to brachymetatarsia, is readily treatable by callotasis with a mini-external fixator [25–27] (Fig. 10). A short first metatarsal, also known as a Morton's foot, results in increased lateral loading of the lesser metatarsals, destabilization of the medial arch, and increased pronation [28–30] (Fig. 11). The basic technique for first metatarsal callotasis is the same as for a lesser metatarsal, but one very important aspect that must be

Fig. 10. Iatrogenic brachymetatarsal with DJD of the 1st MPJ.

taken into account, first MPJ range-of-motion. It is well documented that a long first metatarsal is a common cause of hallux limitus, and a similar occurrence can be seen with lengthening of the first metatarsal. In Takakura et al.'s study, which considered severe shortening of the first metatarsal to be less than 75% of the second metatarsal, their results showed the average shortening in affected feet to be 65.8% of the second metatarsal compared with 86% in normal feet. They also showed that once callotasis reestablished appropriate length of the first metatarsal, an average decrease in first MPJ dorsiflexion of 33% and plantarflexion of 46%. In their study they lengthened the first metatarsal until it was the same

Fig. 11. Same patient as figure 10 post-op callus distraction of the 1st metatarsal base and MPJ fusion.

length as the second metatarsal, or there was severe limitation of motion of the first MPJ. They recommend not lengthening the first metatarsal more than 40% of its original length and starting active and passive dorsiflexion of the first MPJ soon after the procedure.

Another possibility is the use of simultaneous distraction of the first MPJ while lengthening the metatarsal proximally, followed by range-of-motion exercises once the external fixator is removed. The Orthofix Pennig device with a lengthening bar, two standard clamps proximally at the osteotomy/corticotomy site, two standard clamps on either side of the MPJ, and distraction/compression nuts between each set of clamps will allow for both callotasis and joint distraction. Postoperative care is similar to that of brachymetatarsia.

Hallux limitus/rigidus

Magnan et al. described the use of joint distraction of the first MPJ for hallux rigidus in conjunction with a modified stone procedure (Fig. 12). They used a sagittal plane hinged Orthofix device to allow for passive and active mobilization with subsequent weightbearing and ambulation. Magnan et al. recommended leaving the external fixator on at least 60 days. Although the exact mode of arthrodiatasis has not been described in the literature, the consensus seems to be initial distraction one of two ways with active range-of-motion exercises. An initial distraction of twice the original joint space or 1.0 to 1.5 cm is generally recommended (Figs. 13, 14). Once the early postoperative pain and swelling start to decrease, anywhere from 3 days to 1 week postoperatively, range-of-motion exercises are started. A second in office distraction is then performed at anywhere from 2 to 3 weeks postopertively, which consists of either one half of the original joint space distance or 0.5 cm. One important factor in determining the amount of

Fig. 12. Patient with hallux limitus with mild degenerative joint disease.

Fig. 13. Same patient as figure 12 post arthrodiastasis of the 1st MPJ.

this second distraction is patient tolerance. Again, a period of 3 days to 1 week after this second distraction should elapse before initiation of range-of-motion exercises. The frame is generally left on for about 6 weeks.

Freiberg's disease

Osteochondrosis of the lesser metatarsal heads can be treated similar to hallux limitus/rigidus by joint distraction with the use of external fixation. Initially, all the periarticular spurring surrounding the MPJ must be removed, and the external fixator is applied to the dorsal lateral aspect of the MPJ [10]. Subchondral

Fig. 14. Same patient as figure 12 post-op lateral view.

drilling of the metatarsal head may also be helpful. Like with any other arthrodiastasis, early range-of-motion exercises are of paramount importance for a successful outcome.

Maintaining length and prevention of soft tissue contraction

The use of mini-external fixators for preservation of length after debridement of osteomyelitis has been described in the literature with excellent results [31]. Other examples of this application would be either burn or iatrogenic/traumatic scar tissue contracture at the MPJ level, which could be treated with soft tissue lengthening utilizing an external fixator.

Complications

Both specific and general complications of external fixation used for compression or distraction have been discussed with the individual procedures mentioned earlier. Generally, complications are classified as minor or major. Minor complications include pin tract irritation and infection, pin fracture, and increased pain [1,32]. Major complications are nonunion or malunion, osteomyelitis, neurovascular injury, joint subluxation, and bone fracture [1,32]. What may come as a surprise when first managing external fixators postoperatively is the amount of edema caused by lack of compression at the surgical site. Bandaging around a mini-external fixator can be difficult, and applying compression is difficult if not impossible. This lack of compression also may lead to hematoma formation, which adds to the importance of intraoperative hemostasis.

External fixator management

After suture removal, typically between 10 to 14 days, the patient may get their foot wet with a quick shower but is instructed on no soaking of the surgical site. Pin care includes daily cleaning of the pin sites by the patient with peroxide or a sterilizing solution and application of an antibiotic ointment around the pin-skin junction. Betadine solution and scrub should be avoided because of their corrosive properties. The author typically does not have the patient apply any type of gauze around the pins of a mini-external fixator.

Conclusion

External fixation in forefoot surgery can provide the foot surgeon with an additional tool for treating a number of commonly encountered pathologies. However, before using an external fixator the surgeon should have a basic understanding of the types external fixation available for the forefoot, the technical concerns with each type of mini-external fixator, the indications and

contraindications for external fixators, the possible complications of their use, and fixator management postoperatively. The use of a mini-external fixator in forefoot surgery can provide for compression or distraction while offering stability and postoperative adjustability for deformity correction, bone lengthening, or compression.

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