CHAPTER **13**

MULTIPLE METATARSAL LENGTHENING

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INTRODUCTION

Brachymetatarsia is a condition in which one or more of the metatarsals is abnormally short, resulting in a shortened toe. The condition usually is bilateral, symmetric, and most often affects the fourth toe. When it involves more than one toe, the condition is called brachymetopody. The considered pathogenesis is premature closure of the epiphyseal plate of the metatarsal without a specific cause (Figure 1).

Brachymetapody has been linked to several disease processes, including Down syndrome, Apert's syndrome, Albright hereditary osteodystrophy, myositis ossificans, Turner's syndrome, pseudohypoparathyroidism, sickle cell anemia, and dystrophic dwarfism. Brachymetatarsia and brachymetapody may be acquired postsurgery or secondary to trauma or Freiberg's disease. The incidence of brachymetapody and brachymetatarsia is reported to be between 0.022% (1 in 4,586) and 0.05% (1 in 1,820). The ratio of male to female patients is approximately 1:20 (1).

Figure 1. Brachymetatarsia classically affects the fourth toe in females. Generally patients present as an adolescent with a shortened or elevated toe.

Diagnosis is made radiographically when the involved metatarsal is 5 mm or more proximal to the parabolic arc of the metatarsal heads (Figure 2).

Patients may remain asymptomatic, or metatarsalgia may develop due to the transfer of weight to adjacent metatarsals. The proximal phalanx of the shortened metatarsal may deviate to lie between the metatarsal heads, with subluxation or dislocation of the metatarsophalangeal joint. The resultant retrograde buckling deformity sometimes also causes painful callus formation, and adjacent metatarsals may have increased plantar hyperkeratosis as a result of the increased load. Adjacent digital deformities may also result due to the loss of the transverse stabilizing effect of the shortened digit.

Treatment options for brachymetapody and brachymetatarsia include both operative and nonoperative methods. Most patients do not require treatment, though pain, adjacent deformity, and cosmesis are appropriate indications for surgery. Nonoperative techniques include metatarsal pads and orthoses. Operative techniques include one-stage lengthening procedures for cases in which less than approximately 10 mm of lengthening is needed. These procedures include inlay grafting or slide lengthening, such as with a Z-type osteotomy. If more than 10 mm is needed, gradual metatarsal lengthening reduces the risk of neurovascular compromise in the affected digit (Figures 3 and 4).

Figure 2. Less frequently seen is multiple brachymetatarsals, a condition called brachymetapody.

Figure 3. Radiographs demonstrate a shortened fourth metatarsal, however the measured length required for radiographic and clinical correction fell below the threshold for gradual correction.

Figure 4. A Z-lengthening was carried out for acute correction, which is safely performed when the required length needed is less than 10 mm.

DOUBLE METATARSAL LENGTHENING: SURGICAL TECHNIQUE

The patient is placed supine on the operating table with the foot positioned so that the neutral frontal plane position can be appreciated. As with any lengthening procedure, the direction of distraction is critical to ensure that the final distracted position of the bone lies in the desired plane. In this case the adjacent metatarsal position must be appreciated so that the lengthened metatarsal head does not create excessive plantar pressures in its final position, while sufficiently relieving pressure from the adjacent metatarsals. Often this is difficult to accurately assess, especially in cases of adjacent metatarsal or digital deformity. These deformities should be corrected prior to distraction osteogenesis procedures (Figures 5 and 6).

General anesthesia is preferred, which provides patient comfort and relaxation of the musculotendinous units, which is critical when initially testing distraction on the operating table. Local anesthetics are only used after completion of the procedures. It is essential to be able to palpate the local subcutaneous anatomy without the added fluid distortion.

Fluoroscopic imaging is essential for identifying underlying abnormal anatomy and the lengthening axis in the sagittal and transverse planes. Orthogonal planes should

Figure 5. Bilateral brachymetapody with the third and fourth toes involved. Concomitant deformity exists in the medial column as well, with severe hallux abductovalgus and metatarsus primus varus, elongated second metatarsal and lateral second metatarsophalangeal joint deviation, as well as collapsing pes valgus deformity.

Figure 6. Lateral view of bilateral brachymetapody.

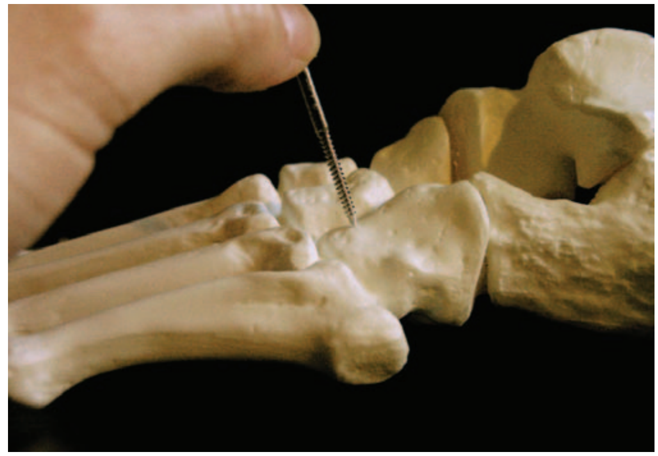

Figure 7. The first pin and all subsequent pins should be perpendicular to the underlying bone. This helps to firmly anchor the half-pins, avoid inadvertent joint violation, and mimic the usually inherent normal metatarsal declination angle. It is critical to take time and have patience with placement of the first half-pin; all of the others will be straightforward if this first pin is placed correctly.

Figure 8. When the first pin is placed perpendicular to the underlying bone and consequently at the correct declination angle, the fixator is then attached so that the correct transverse position of the second pin can be established.

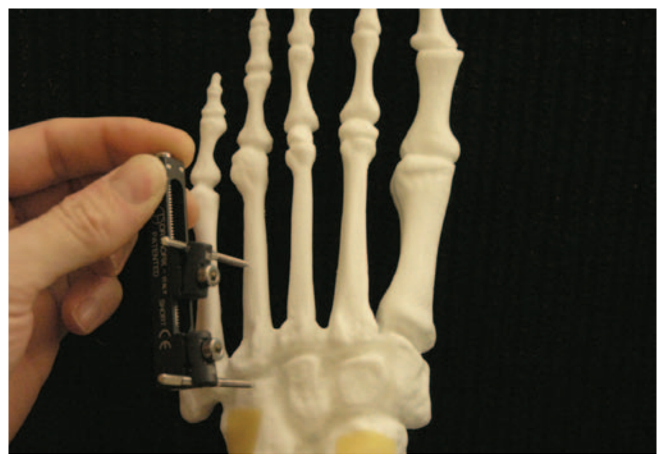

Figure 9. The lengthening axis should correspond to the adjacent metatarsal axes. Once fluoroscopic confirmation is obtained, the remaining pins can be placed.

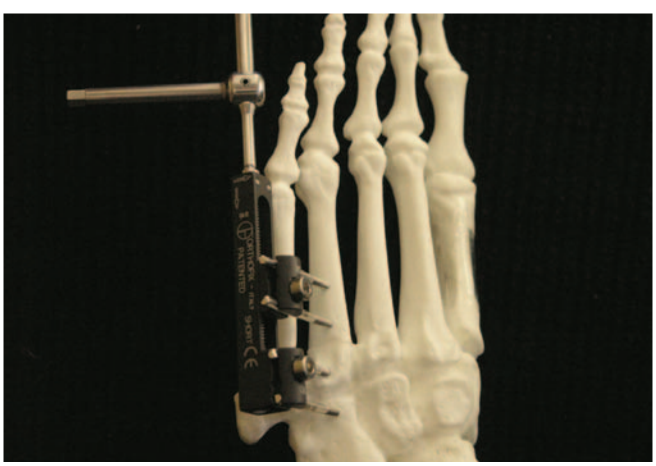

Figure 10. The final construct before lengthening.

Figure 11. The lengthening axis can now be appreciated. This is the basic premise to all metatarsal lengthenings.

be understood very well, as even small angular errors during placement of the lengtheners can result in major angular deviations upon completion of distraction. Pin placement is always perpendicular to the bone, unless sagittal plane correction is desired. Generally, we find that distracting along the normal anatomic plane of the shortened metatarsal results in the correct weightbearing parabola (Figures 7-11).

One of the authors (RBW) recommends capturing the cuneiform bones in the construct, however this is not an absolute requirement. The geometry of the fixator must be taken into account, in light of the shortened metatarsal, where at least two pins must fixate the bone proximal and two distal to the osteotomy. Placement of one of the pins in the cuneiform allows the most flexibility in placement of the osteotomy, especially in cases of very short metatarsals. Success in anatomic location and position of the first pin is critical to the procedure outcome. All other pins will be placed based on this first pin, so it cannot be overemphasized how much time and deliberation should be given to the acceptability of the placement of this pin.

We start with 0.062-inch Kirschner wires, as they are easily repositioned if unacceptably placed after viewing on an image intensifier. Pin placement is percutaneous. We place all pins and assess both visually and under fluoroscopy for sagittal and transverse plane alignment. Proximal pins are placed first, then the fixators are used to "template" placement of the distal pins. If the first pin is placed correctly, the angle of declination of the fixator will correspond to the natural angle of the metatarsal. Then it is only a matter of maintaining alignment on the transverse plane (Figure 12A). When all of the wires are successfully placed, they are sequentially replaced with half pins. Proximally larger half pins can be used, whereas distally smaller pins are used in the more fragile cortex of the metatarsal shaft and the phalanx of the toe, if that is being captured (Figure 12B).

A small linear incision is made adjacent to the second

Figure 12A. Kirschner wires are a useful way of starting a pilot hole for the larger half-pins without commitment to pin placement. This allows visual and fluoroscopic confirmation of anatomic and geometric arrangement for correct lengthening.

Figure 12B. Each Kirschner wire is replaced by a half-pin of appropriate size. Often larger pins are used in the proximal segment that offer increased stability over the smaller diameter pins. Distally, bone mass is often limited and smaller diameter pins are used to secure this segment.

Figure 13. A longitudinal incision is made adjacent to the metatarsal, outside of the boundary of skin tension that will be created during the lengthening. This will be easier to sew together after the osteotomy and reduce the likelihood of wound complication.

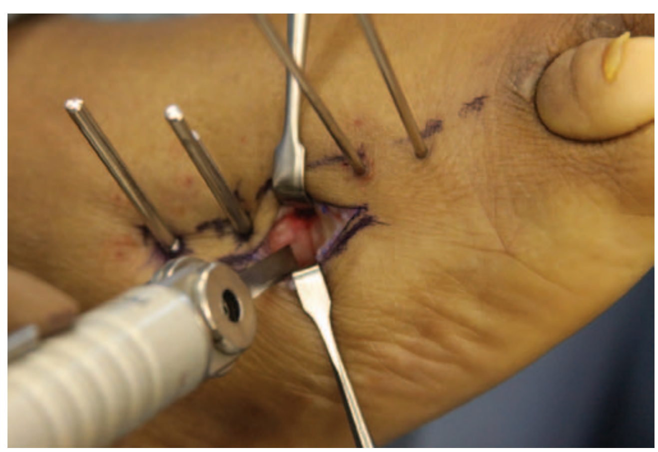

Figure 14. A sagittal saw fitted with the skinny oscillating saw blade is also an alternative to placement of these osteotomies. Note the skin incision adjacent to, but not between, the half pins.

and third pins. Keeping this incision away from the pins protects against incision strain and the typical drag that often keeps the incision open throughout the lengthening. A microsaw is used to make a transverse osteotomy. This is usually performed at the proximal metaphyseal-diaphyseal junction. Oscillating saws are often used because the saw blade size is appropriate, and since the long axis of the saw can mimic the long axis of the bone, then a perfectly transverse cut can be created. However, placing a small narrow blade on the sagittal saw is an acceptable alternative. The osteotomy is made without the fixator attached as the soft tissue attachments will not permit much movement of the fragments from each other. The wounds are closed with 4-0 absorbable suture to close the periosteal incision, then 4-0 nylon simple interrupted sutures in the skin (Figures 13 and 14).

The fixator clamps are connected to the half pins. In one of the cases presented the two fixators were connected by a third fixator. This device ensures symmetric distraction, which is made difficult by the lack of absolute measures for precise distraction on the small fixators. When one device is advancing more than another, the bridge frame is stressed creating internal tension. This is detected by the patient as pain on turning the lengthening nut. The tension is easily remedies by adding on a fifth turn to the 'slow' fixator daily until the pain resolves (Figures 15-17).

Lengthening is carried out at 1 mm per day, beginning on the 6th or 7th postoperative day, in four increments per day. Catch-up turns for slow or off-schedule lengtheners is corrected using 5 turns of the lengthening nut daily, approximately one turn every 5 hours instead of every 6 hours (Figures 18 and 19).

POSTOPERATIVE MANAGEMENT

Much of the surgical procedure is carried out outside of the operating room. The surgeon must monitor the distraction process, from the rate of distraction, appropriate pin site maintenance, and quality of bone regenerate forming. The timing of removal of the devices is also important, since the quality of the regenerate can only advance as it detects less stability from the rigid fixator (Figures 20 and 21).

Pin site care through the lengthening process is very basic for these fixators. Application of povidone-iodine tinged 2x2 sponges with slots for the pins are placed at the skin interface, and replaced only once weekly in the clinic. Compressive dressings are used, although no dressing is placed to constrain the distal pin-clamp construct. As previously described, lengthening begins at postoperative day 6 or 7. Serial radiographs are then taken weekly until the appropriate length is achieved. A simple math calculation will

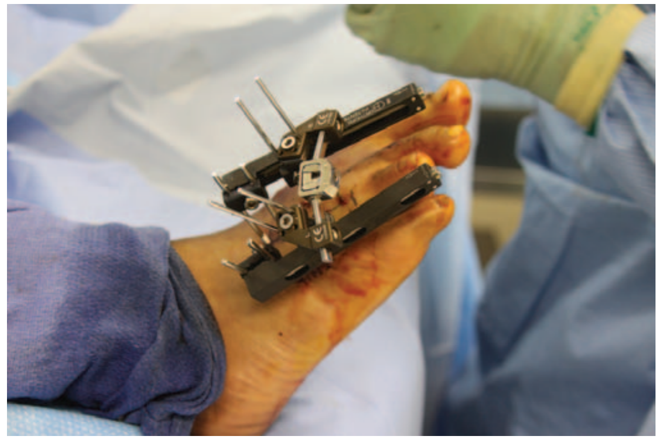

Figure 15. Intra-operative device assembly for symmetric distraction. The bridge member secures to the half pins above the lengthening members, ensuring symmetry in distraction.

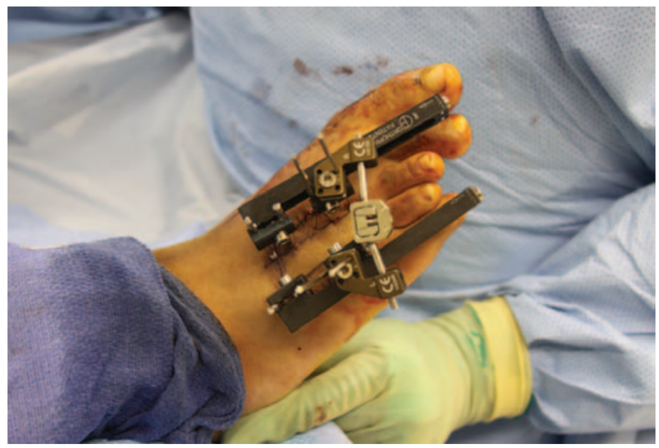

Figure 16. Intra-operative device assembly for symmetric distraction. Note that lengthening is designed to occur along normal anatomic planes so that the final position of the toes is within a normal parabolic shape for the forefoot.

Figure 17. Intra-operative device assembly for symmetric distraction. Declination angle of the fixators can be appreciated, so that the final lengthened metatarsals occupy the correct space between the adjacent bones.

Figure 18. A base wedge osteotomy and Weil-type osteotomy was performed, and the resultant forefoot parabola was slightly changed from preoperative examination. This was accounted for in placement of the lengtheners, which are seen here along the adjacent transverse metatarsal axis.

Figure 19. Because the typical metatarsal parabola is not completely flat, declination angle to some degree requires careful planning and analysis. Here it is obvious the two fixators will lengthen together in the same place. The transverse proximal osteotomy can easily be seen in both metatarsals.

Figure 20. The wisps of bone regenerate are clearly visible at this stage. Note how the appearance is fairly homogenous, and occupies only the endosteal region. At this stage there is no evidence of periosteal callous. This is why the traditional radiographic appearance of a cortical bridge used in the assessment of fracture healing cannot be utilized as a healing benchmark. The bone at this stage is too immature for fixator removal.

Figure 21. When the regenerate is approximately 60-70% of the density of the adjacent bone, the fixators can be removed. After this point the fixators may begin to stress-shield the regenerate bone, slowing down mineralization and strengthening.

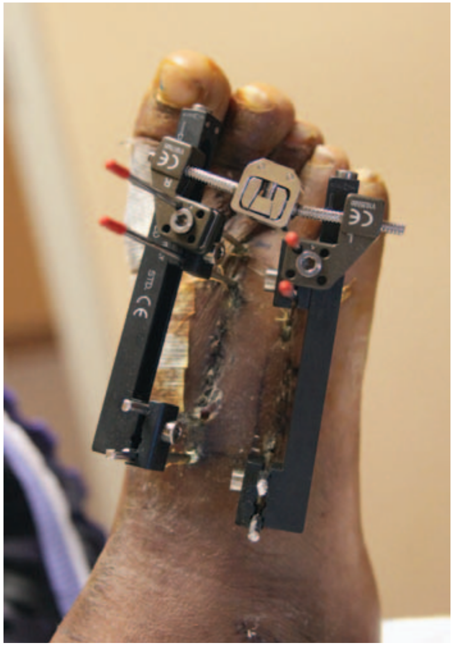

Figure 22. Clinical appearance of the completed lengthening.

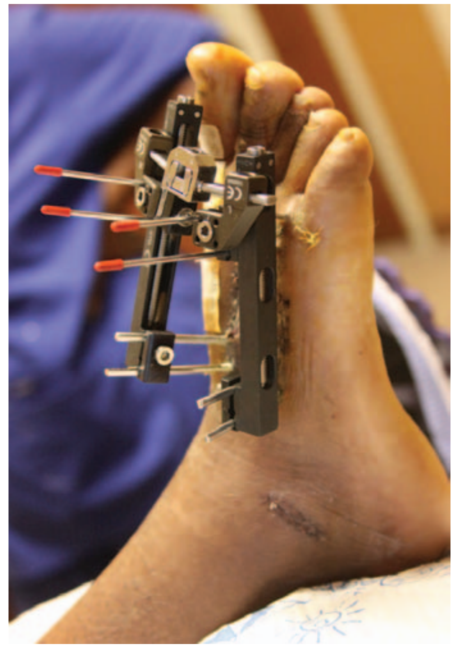

Figure 23. Clinical appearance of the completed lengthening. Over correction of declination is often a goal as the plasticity of bone will result in slight elevation of the final metatarsal position upon weight bearing.

reveal how much time it will take to reach length (desired length - starting length + 7 = number of days to correction). A clinic appointment should be made for this date, to assess the parabola and determine if lengthening should be stopped. Coaching the patient should include the "catch-up turn" method if they should experience pain with distraction and radiographs reveal one fixator advancing faster than the other. Once lengthening is stopped, all clamps are re-tightened while regenerate is monitored radiographically. Unlike fracture situations where cortical bridging is used to assess osseous stability and healing progress, regenerate is a uniform material that most often is endosteal whisps rather than dense cortex. A basic rule is that the fixators can be removed when the regenerate is 60-70% of the radiodensity of the adjacent metatarsal bone. Patients should be non-weightbearing on the operative limb until removal of the fixators. Sutures are removed when the wounds are healed, but never before lengthening is stopped (Figures 22-24).

Once the fixators are removed, protected weightbearing is started in a pneumatic walking boot. The mechanical stress of weightbearing pressure along with removal of the external support will lead to rapid strengthening of the regenerate. The risk of regenerate fracture is low as long as this protected weightbearing is initiated at the appropriate time. Up to a month in the protective boot is a good general estimate for adequate protection (Figures 25-36).

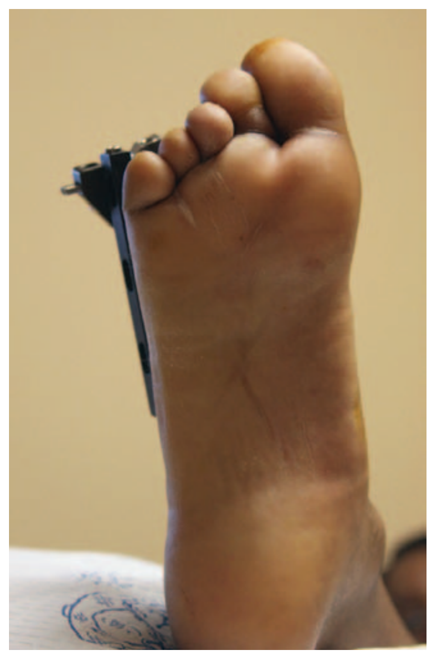

Figure 24. Clinical appearance of the completed lengthening.

Figure 25. Final appearance of the foot post correction. A normal digital parabola is the cosmetic goal of the operation.

Figure 26. Final appearance of the foot post correction. Weightbearing of the affected toes is the functional goal of the operation.

Figure 27. Right foot of an adolescent female with third and fourth toe brachymetapody. Concomitant first ray deformity exists in this case as well.

Figure 28. Symmetric deformity of the third and fourth metatarsals.

Figure 29. External fixator application to the third and fourth metatarsals with inclusion of the digits on each corresponding fixation. This will aid in prevention of joint subluxation and stabilize the construct further.

Figure 30. The declination angle of the fixators matches the corresponding normal anatomic declination. The fixators are at identical angles and completely overlap on the lateral projection, confirming symmetry in lengthening axis.

Figure 31. Symmetric distraction of metatarsals, midway through correction.

Figure 32. Dense regenerate just prior to lengthener removal.

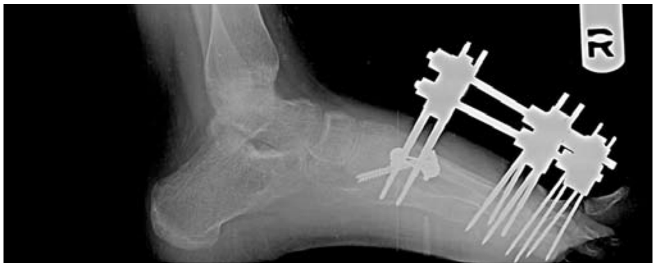

Figure 33. Dense regenerate just prior to lengthener removal.

Figure 34. Restoration of the normal metatarsal parabola.

Figure 35. Restoration of the normal metatarsal parabola.

Figure 36. Final appearance of the foot with normal digital parabola.

CONCLUSION

Brachymetatarsia surgery is complicated enough when a single metatarsal is involved. Presented are two cases of double adjacent metatarsal lengthenings that demonstrate when specific principles of lengthening are followed, the outcome is as predictable as when single lengthenings are performed. In these cases caution is taken to align frame components with attention to the anatomic requirements, but also with respect to each other to ensure symmetry in the final lengthened position. Minimal tissue disruption is also stressed and when possible the entire operation should be performed percutaneously. Incisions for the osteotomies should be made some distance away from the pins and as far from each other as possible to maximize the size of the intervening skin island. Finally, stability of the constructs are paramount, and this can be enhanced with more half pins, larger half pins, or locking the frame assemblies together.

REFERENCE

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