CHAPTER **26**

BRACHYMETATARSIA: Current Concepts of Surgical Repair and Review of Morbidities

A. Louis Jimenez, DPM
Margo A. Jimenez, DPM

Brachymetatarsia is a condition that is frequently seen in the podiatric physician's office. Prior to 1958, most of the therapies rendered for this condition were prophylactic in nature. Advances in osseous surgery, internal/external fixation techniques, and perioperative care have improved so that this condition can be treated more aggressively. Patients with short metatarsals need not continue exhibiting emotional, psychological, and physiological consequences of this condition. We can now attain cosmetically acceptable and functional results.

OCCURRENCE

Brachymetatarsia most commonly affects the fourth metatarsal.[1-3] The condition can be unilateral or bilateral.[3,4] Urano et al noted bilateral shortening in 72% of patients.[4] The etiology may be congenital, which is most common, post-traumatic, post-surgical, or secondary to a specific disease state.[2,3,7] It affects females more frequently than males at a 25:1 ratio becoming more evident from ages 4-15 years old.[2,3,7] Mah et al in 1983 reported the incident of brachymetatarsia in the US to be 1 in 1,820.[7,8] This condition can affect the patient both psychologically and physiologically.

Causes of brachymetatarsia include humeral, traumatic, epiphyseal arrest and iatrogenic deformities. The clinical presentation is usually one of a short digit with metatarsophalangeal joint extension and usually adjacent submetatarsal hyperkeratoses (Figure 1). The toe may appear to be telescoped upon itself and may cause shoe wearing problems. This becomes more prevalent in adolescent patients as they become more active and wear more stylish shoes.

Pathomechanically, in conjunction with a short toe, the long extensor and flexor tendons, and pericapsular structures are contracted. The toe lateral to the involved digit will usually be in varus and the medial digit will be in valgus, each trying to fill in the space vacated by the shortened toe. Due to the unequal length of the metatarsal parabola and uneven weight distribution, adjacent submetatarsal hyperkeratoses are often evident.

In cases where the first metatarsal is short, the hallux adducts and extends and the second digit will adduct in an effort to try to fill in the space of the hallux. It is not unusual for these patients to lack medial column stability therefore creating more stress on the lesser metatarsals. As the patient tries to supinate for the deformity, lateral weightbearing stresses are increased creating pain along the lateral column.

Roentgenographically the short affected bone generally is more radiolucent than the adjacent metatarsals as a result of non-weightbearing stresses placed on that segment.

Takakura et al found that in "normal subjects" the length of the first metatarsal is 86% of the second metatarsal.[9] They found that when the first metatarsal was 75% shorter than the second metatarsal, that subsecond metatarsal head lesions developed.

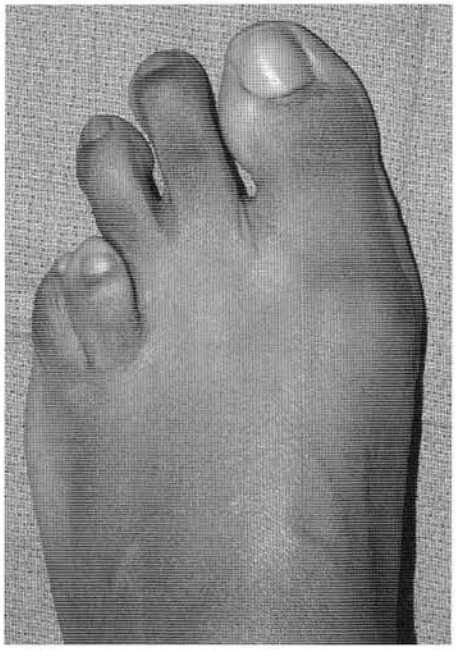

Figure 1. Weightbearing dorsoplantar clinical demonstrating the typical presentation of brachymetatarsia of the fourth metatarsal.

Figure 2A Preoperative x-ray demonstrates short 4th metatarsal by 20 mm.

Figure 2C. The calcaneal graft incorporating within the 4th MT and improved parabola.

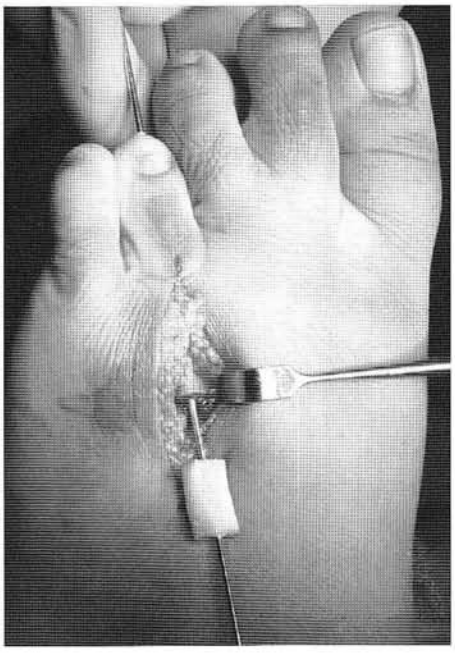

Figure 2B. Autogenous graft from calcaneus stabilized with K-wire readied for interposition at 4th MT osteotomy site.

SURGICAL TREATMENT

Surgical treatment for brachymetatarsia is of two types: osteotomy with bone grafting or osteotomy with callus distraction. These procedures should be carried out when the patient has reached skeletal maturity.

Prior to the late 1980s the standard of care for the treatment of brachymetatarsia was to use cortical cancellous autogenous or allogeneic bone grafts. Of course it is always safer and more appropriate to use the patient's own bone (Figure 2). The downfall of this procedure is that it often requires an additional surgical site intervention, which increases donor site morbidity. Use of autogenous graft may also increase the surgical time and lengthen the duration of convalescence.[4] In addition, neurovascular embarrassment caused by rapid stretching and small length gain due to high tension exerted to surrounding soft tissues may occur. Allogeneic bone grafting is better indicated for adolescent patients that have very strong osteogenic capacities and more apt to replace transplanted bone. Callus distraction became more common in the 1980s and early 1990s as greater knowledge was gained in the histology and physiology of bone healing under tension and external fixation methods used to assist in the stabilization and transport of osseous segments.

Authors such as Codivilla, Ilizarov, DeBastiani, D. Paley, and G. Vito, have been key in helping to develop and understand the physiology of bone healing, bone grafting and methods of internal and external fixation apparatus that help the surgeon in performing more successful bone lengthening procedures.

PRINCIPLES OF CALLUS DISTRACTION

1. Corticotomy/osteotomy.
2. Minimal soft tissue and periosteal destruction.
3. Performed at sites of greatest vascularity, typically metaphyseal bone.

Figure 3A. Radiograph demonstrating over lengthening of 4th metatarsal and jamming with partial dorsomedial dislocation of 4th MTPJ.

4. Latency period of 4-14 days to allow for the initial inflammatory response to diminish at the surgical site.
5. Distraction of 0.5-1mm/day, which will allow for muscle, periosteum, nerve and tendonous structures to elongate as the regenerate bone fills the osteotomy gap.
6. Ossification/neutralization: when all osseous and soft tissue structures mature to the desired length.
7. Dynamization that allows calcification and maturation of the regenerate bone as part of the external fixation pins are removed. The patient's dependence on exogenous support diminishes as osseous maturation through Wolfe's Law ensues.
8. Fixation removal when regenerate bone has matured to the point where it can accept the weightbearing stresses placed through it. This period is considered to be two times that of the lengthening/distraction period and ends when there is radiographic appearance of bone consolidation.

Choi et al performed a comparison study of one stage bicortical iliac bone grafting, (10 patients/15 bones, age 12.3 years, mean followup 3 years) versus callus distraction (5 patients/9 bones, age 12.4 years, mean followup 4.6 years).[10] Statistical analysis revealed that there were few differences in the outcomes between the 2 groups in terms of length gain, percentage increase, and complications. However, the time to consolidation was longer in the callus distraction group than the one-stage lengthening group. When multiple and longer lengthenings are required, lengthening by callostasis was more effective and safe. They found that with one stage lengthening, the afflicted metatarsal could be lengthened 21 mm without Z-plasty of the extensor tendons or V-Y plasty of the skin. The main advantage of gradual lengthening includes no need for bone grafting, easier tendon stretching, lesser neurovascular complications, and the capability of early weightbearing. Patients could bear full weight as soon as surgical pain subsided and daily activities were not limited. When the regenerate was radiographically visible, patients could walk without ambulatory aids.

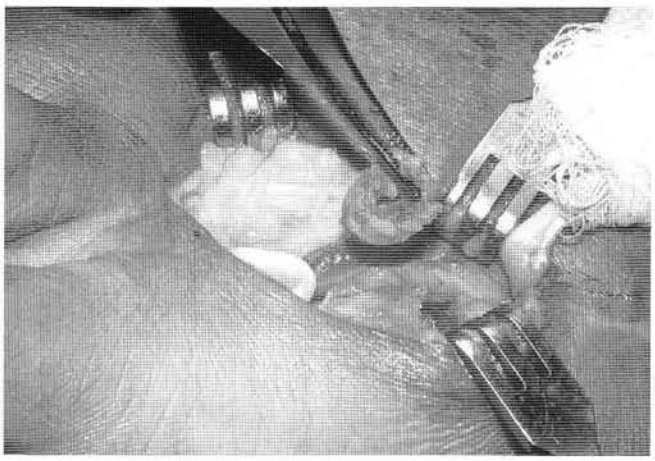

Figure 3B. Intraoperative section of regenerate removed to shorten the 4th metatarsal.

Figure 3C. 2 month postoperative radiograph after the second, reconstructive procedure demonstrating the regenerate consolidating and metatarsal parabola reestablished. Note the 4th MTPJ squaring and early DJD.

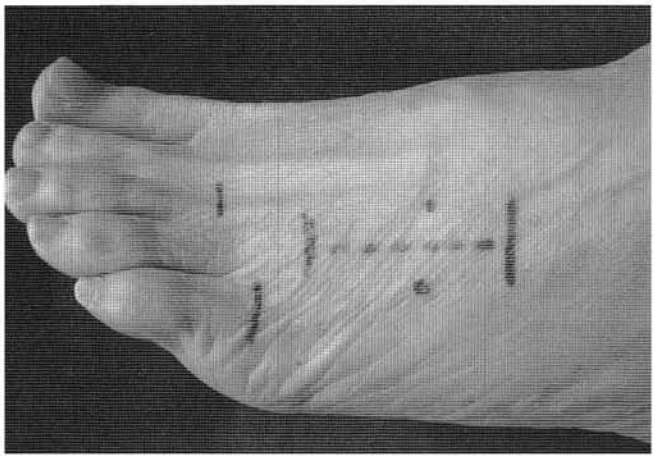

Figure 4A. Intraoperative marking of the proposed incision under fluoroscopy to inhibit wrong site surgery.

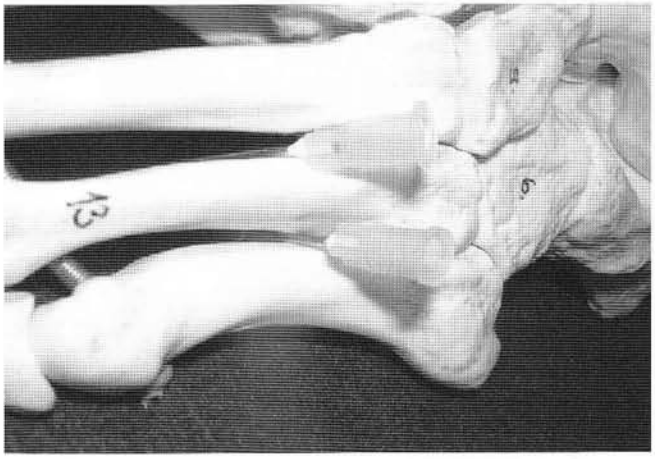

Figure 4B. Using 18 gauge needles allows easier identification of metatarsal margins.

COMPLICATIONS

The most common complications following callus distraction include: metatarsophalangeal joint subluxation with partial or total joint stiffness, transverse and sagittal plane deformities, pin tract infections, fracture, premature closure, wrong site surgery, external fixator that is too short or small, and reverse turning of fixator resulting in compressing the osteotomy site versus lengthening.

Song et al in a study of 16 patients with 4th metatarsal brachymetatarsia, 22 metatarsals, mean followup of 30 months, found that the most common complication was metatarsophalangeal joint subluxation, (5 patients) attributable to over lengthening of greater than 40% of the original length of the metatarsal.[11] We stabilize the involved digit and metatarsophalangeal joint any time we perform metatarsal lengthening. This has also been reported by Magnan et al.[12] In addition to brachymetatarsia, the patient may also have a hypoplastic proximal phalanx. In an effort to make the involved toe look more normal clinically, the metatarsal may be lengthened greater than 40% which can contribute to MTPJ subluxation and stiffness. This may require surgical intervention to reestablish an acceptable metatarsal parabola (Figure 3). Patients that have a hypoplastic proximal phalanx and the calculated amount of lengthening required is greater than 40%, should be instructed that the final outcome may not be what he/she expects. Angular deformities greater than 5 degrees were found in 3 patients, and pin tract infections in 2 patients (9%). Pin tract infections are usually found 10% of the time and usually respond to oral antibiotics.

Premature closure is a function of ceasing the lengthening process too early or lengthening too slowly. Adolescents have a very active osteoblastic system and are more apt to cause premature closure if not lengthened in a constant manner. If the surgeon is not happy with the amount of lengthening needed, then reosteotomizing the prematurely healed bone and restarting the lengthening process is recommended.

Figure 5. Plantar hyperkeratoses subMT 2-4 as a result of short first ray.

The metatarsal bases flare laterally and wrong site surgery can be a problem. It is important to remember that as the metatarsal bases flare laterally and they also drop more inferior. Wrong site surgery can be avoided by intraoperatively identifying the site under fluoroscopic control and outlining the proposed line of incision by using a marking pen (Figure 4).

The metatarsal in question for lengthening in most patients can easily be lengthened with most standard small external fixators. It is imperative that the amount of length for surgical correction be predetermined and the appropriate sized external fixator applied to allow for the lengthening. In addition, when greater than 40% lengthening is required, soft tissue tension may resist the ability of a weak frame to overcome muscle and soft

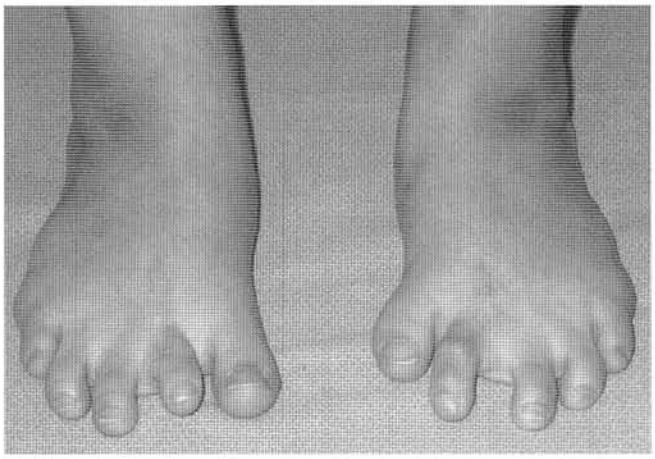

Figure 6A. Preoperative clinicals demonstrate short first ray with adduction of digits 1-2 bilateral.

Figure 6B. Weightbearing dorsoplantar foot x-rays reveal the left first metatarsal is 23 mm shorter and the right first metatarsal is 15 mm shorter than the third metatarsals to which they are compared (did not compare to 2nd due to decreased length of 2nd metatarsals).

tissue tension. Therefore, the frame may need to be changed or replaced with a stronger one.

KEYS TO SUCCESS

We have found that the best results with metatarsal lengthening revolve around seven key principals.

1. Lengthening requirement not to exceed 40% of the original length of the metatarsal.
2. Patient selection when skeletal maturity has occurred and the patient is understanding of the perioperative requirements and able to participate in the perioperative course.
3. Minimal soft tissue and osseous trauma.
4. Excellent rigid internal and/or external fixation.
5. K-wire fixation of the metatarsophalangeal joint to avoid dislocation of the metatarsal.
6. Distraction of 1 mm per day in divided periods ranging from BID-QID.
7. Controlled weightbearing.

CASE PRESENTATION

The patient, an 18-year-old female presented to the office with the chief complaint of "my feet hurt half an hour after walking and standing" and of having "a short big toe of both feet, with the left foot being more painful than my right." History revealed that the condition has progressively gotten worse with time and the patient is now more symptomatic complaining of pain along the lateral aspect of the foot, which has worsened as she attempts to get more active. In addition she has developed calluses on the ball of the 2nd, 3rd and 4th MTPJs (Figure 5). Cosmetically, the patient is very concerned about this condition and hesitates to remove her shoes in front of other people and avoids social contact. The patient has one sibling, a younger sister, who does not have similar concerns. Review of family history reveals no brachymetatarsia of any other family members. The patient had previous podiatric surgical intervention consisting of shortening second metatarsal osteotomy bilaterally staged one year apart, and second digit arthroplasty right foot with excellent healing.

Clinical evaluation reveals a very short hallux bilaterally with the left greater than the right. There is substantial hyperkeratotic formation underneath the 2nd, 3rd, and 4th metatarsals with pain over the lateral column left foot. The hallux was adducted as well as the 2nd digit. A good range of motion is present in the first metatarsophalangeal joint.

Roentgenographically the left first metatarsal is 23 mm (59%) shorter than the third metatarsal to which it is compared. On the right foot, the first metatarsal is 15 mm (35%) shorter than the third metatarsal (Figure 6).

On 7/31/05, the patient was taken to the operating room where under fluoroscopy a short Orthofix linear mini-rail M100 external fixator was applied. An EBI mini-external fixator was piggybacked to the Orthofix external fixator so that as the patient continued with the healing process, active range of motion could ensue. The EBI system has a universal joint, which would allow for triplane motion. In addition, it will hold the toe in a rectus attitude at the metatarsophalangeal joint avoiding the need for a Kirshner wire (Figure 7). A small linear incision was placed at the base of the first metatarsal, the osteotomy was performed, and distracted intraoperatively to ascertain that the metatarsal would

lengthen (Figure 8). This was confirmed fluoroscopically and the osteotomy was closed and allowed to remain quiescent for 7 days. The medial capsule of the second metatarsophalangeal joint was released to diminish the adduction deformity and K-wired in a rectus alignment (Figure 9). This position allowed the hallux not to impinge on the second toe.

The patient was sent home and followed by the referring physician. She had been instructed to distract the osteotomy 1 mm daily using two half-turns of the Orthofix external fixator. The patient was seen in our office one month postoperatively and although the arms of the external fixator were spreading, roentgenographically there was minimal lengthening of the osteotomy site. The external fixator was removed in the office, checked to see that it would lengthen and, in fact, it was functional. The fixator was reapplied on the patient. Upon reapplication, attempted distraction was once again not possible. At this point a diagnosis of premature closure of the osteotomy was made. It was evident on x-ray that the bone appeared to be consolidating at the osteotomy site.

The patient returned to surgery where the surgical site was explored and, indeed, the inferior 1/3 of the osteotomy had synostosed. A power saw and osteotomy were used to recreate the osteotomy. Intra-operatively 3 mm of length was maintained (Figure 10). The patient was then asked to increase distraction to 1.5 mm per day for 7 days. The patient was followed in the office and it was noted that distraction was occurring appropriately. However 2 months postoperatively the patient could no longer distract the surgical site. Examination revealed the apparatus had "run out" so that no further lengthening was possible and therefore, the short Orthofix external fixator was replaced with a standard Orthofix fixator (Figure 11).

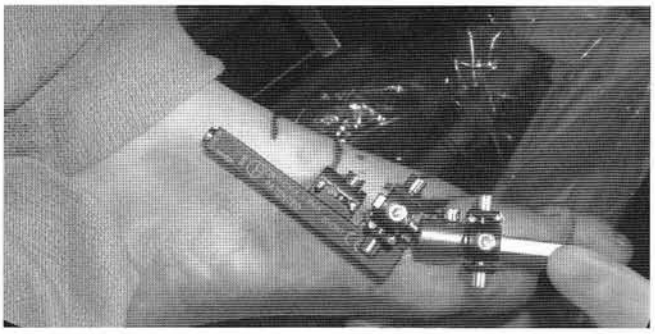

Figure 7A. The EBI mini-external fixator has a universal ball joint which allows for triplane motion. Clinical view reveals the hallux in dorsiflexion and

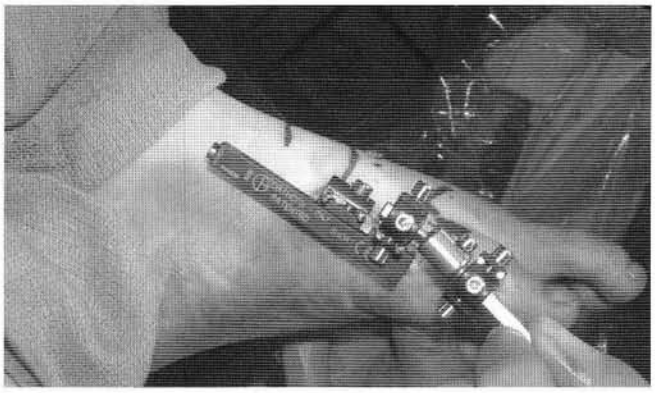

Figure 7B. The hallux in plantarflexed position

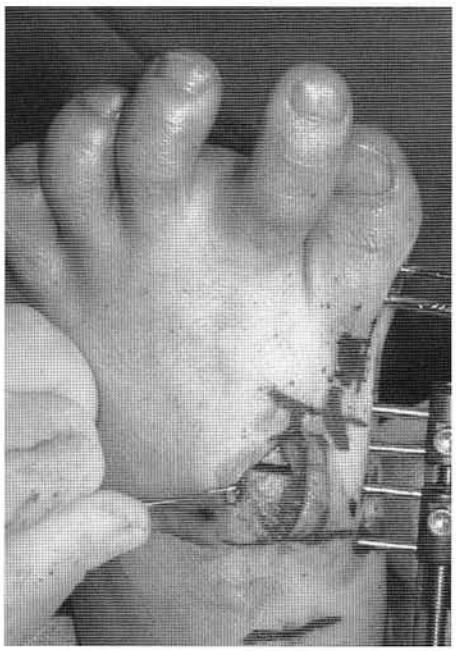

Figure 8. Intraoperative distraction of the osteotomy to determine its ability to lengthen.

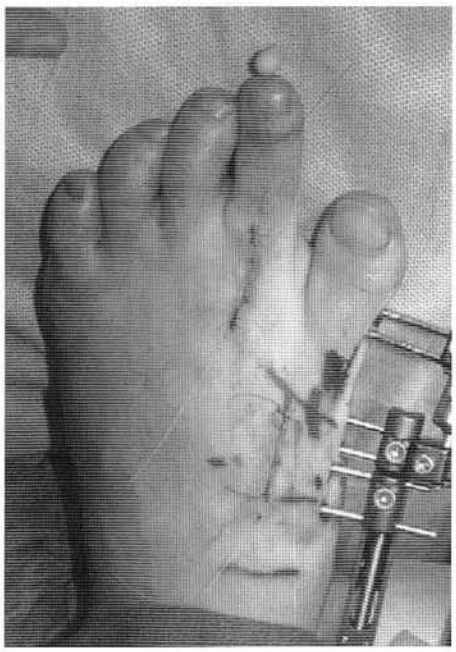

Figure 9. Final intraoperative clinical demonstrating external fixators in place and pinning of the second MTPJ and digit.

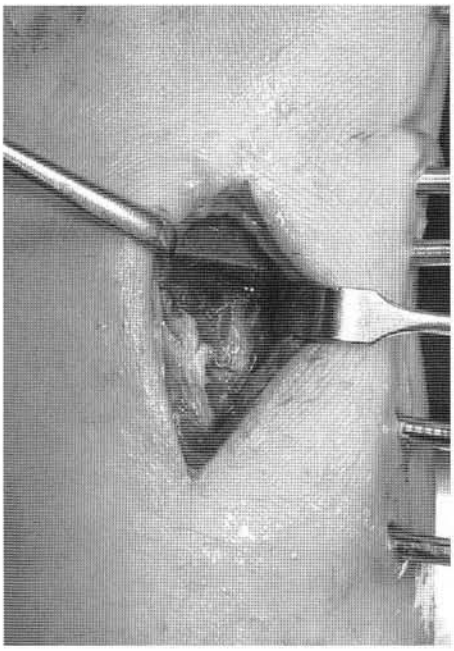

Figure 10A. Intraoperative view.

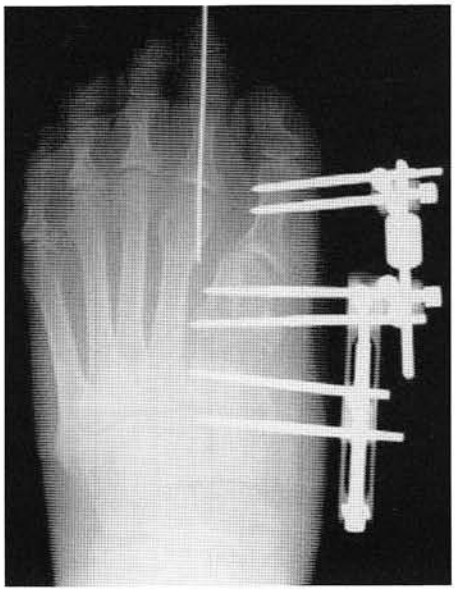

Figure 10B. Radiographic demonstration of the re-osteotomy of the first metatarsal following premature closure of the initial osteotomy.

Figure 11A. After 21 days of distraction, the shortened mini-fixator had "run out".

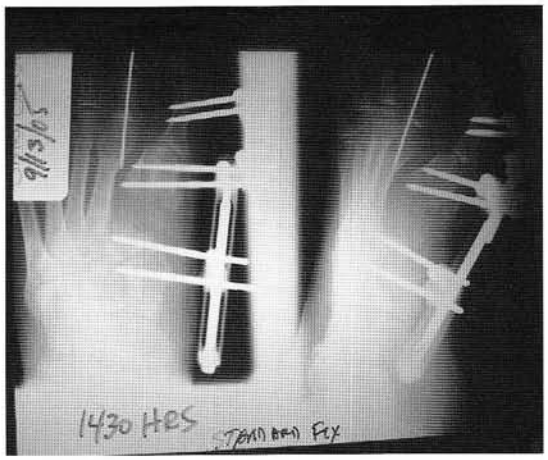

Figure 11B. Short fixator is replaced with a standard fixator.

Two months after surgery the patient had acquired a length that was 6mm shorter than the third metatarsal and could no longer distract as there was significant soft tissue resistance (Figure 12). At this point we decided to wait and the patient was seen back one month later. The patient wished to try to increase lengthening again to the appropriate length of 6 mm more. Therefore lengthening was restarted at 0.5 mm per day in an effort to acquire a necessary first metatarsal length. Roentgenographically osseous consolidation was occurring of the regenerate and the authors expect to remove the ex-fix in 2 months (Figure 13).

SUMMARY

Patients who present with brachymetatarsia need not suffer the psychological and physiological consequences of this condition. Advanced diagnostic and surgical modalities to include rigid internal and/or external fixation have been a boon to the successful treatment of congenital and iatrogenic brachymetatarsia.

It is important to remember the keys to success, which include:

1. Lengthening requirement not to exceed 40% of the original length of the metatarsal.
2. Patient selection usually when skeletal maturity of bone growth has occurred and the patient is understanding of the perioperative requirements and able to participate in the perioperative course.
3. Minimal soft tissue and osseous trauma.
4. Excellent rigid internal and/or external fixation.
5. K-wire fixation of the metatarsophalangeal joint to avoid dislocation as the metatarsal is lengthened.
6. Distraction of 1 mm per day in divided periods ranging from 2-4 settings.
7. Controlled weightbearing.

Figure 12. Two month postoperative x-ray. The first metatarsal has lengthened to a position approximately 6 mm shorter than the third metatarsal.

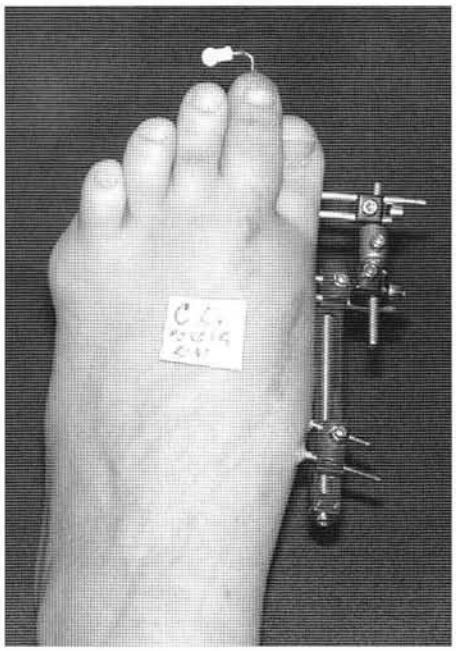

Figure 13A. AP view.

REFERENCES

1. Anderson M, Green WT, Messner MB. Growth and prediction of growth in the lower extremities. *J Bone Joint Surg Am* 1963;45:1-14.
2. Banks AS. Callus distraction techniques for brachymetatarsia. Podiatry Institute Update, 2002. Tucker (GA) Podiatry Institute Publishing,; 2002. p. 29-31.
3. Fox IM. Treatment of brachymetatarsia by callus distraction. *J Foot Ankle Surg* 1998;37:391-5.
4. Bartolomei FJ. Surgical correction of brachymetatarsia. *J Am Podiatric Med Assoc* 1990;80:76-82.
5. Martin DE, Kalish S. Brachymetatarsia: recent advances in surgical technique. Podiatry Institute Update 1990. Tucker (GA): Podiatry Institute Publishing; 1990. p. 193-8.
6. Martin D. Callus distraction in brachymetatarsia: a clinical update and pearls in operative technique. Podiatry Institute Update 1994. Tucker (GA): Podiatry Institute Publishing; 1990. p. 251-6.
7. McGlamry ED, Fenton CF. Brachymetatarsia: a case report. *J Amer Podiaty Assoc* 1983;73):75-8.
8. Hendelman RB, Perlman, MD, Coleman WB. Brachymetatarsia: a review of the literature and a case report. *J Am Podiatric Med Assoc* 1986;76:413-6.
9. Urano Y, Kobayashi A. Bone lengthening for shortness of the fourth toe. *J Bone Joint Surg Am* 1978;60:91.
10. Goforth WP, Overbeek TD. Brachymetatarsai of the third and fourth metatarsals. *J Am Podiatic Med Assoc* 2001;91:373-8.
11. Mah KK, Beegle TR, Falknor BW. A correction for short forth metatarsal. *J Am Podiatry Assoc* 1983;73:196.
12. Takakura Y, Tanaka Y, Fujii T, Tamai S. Lengthening of short great toes by callus distraction. *J Bone Joint Surg Br* 1997;79:955-8.
13. Choi HI, Chung MS, Baek GH, Cho TJ, Chung CY. Metatarsal lengthening in congenital brachymetatarsia: one-stage lengthening versus lengthening by callostasis. *J Ped Ortho* 1999;19:660.
14. Song HR, OJ CW, Kyung HS, Kim SJ, Guille JT, Lee SM, et al. Fourth brachymetatarsia treated with distraction osteogenesis. *FAI* 2003;24:706-11.
15. Magnan B, Bragantini A, Regis D, Bartolozzi P. Metatarsal lengthening by callostasis during growth phase. *J Bone Joint Surg Br* 1995;77:602-7.

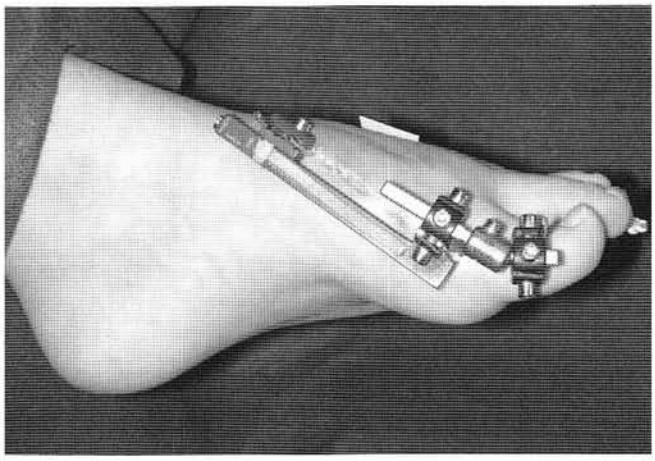

Figure 13B. Lateral clinical view. The first metatarsal clinically appears to be plantarflexed in relation to the lesser metatarsals.