

Elongation of the Proximal Phalanx with External Fixation After Correction of Bilateral Fourth Brachymetatarsia

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INTRODUCTION

Brachymetatarsia is a disorder in which there is early closure of one or more of the metatarsal growth plates secondary to acquired or congenital conditions. Acquired etiologies include idiopathic, trauma involving metatarsal physeal fractures, iatrogenic, infection, inflammation secondary to juvenile rheumatoid arthritis, or polio (1). More commonly, brachymetatarsia is caused by congenital deformities such as family history, brachydactyly, Down's Syndrome, and pseudohypoparathyroidism (2). These congenital deformities tend to present with bilateral shortening. On an anteroposterior (AP) radiographic view, this condition can be diagnosed when one metatarsal ends 5 mm or more proximal to the parabolic arc (2). Females have a higher prevalence of brachymetatarsia than males 10-25:1.

Patients often present reporting the affected foot is cosmetically displeasing, metatarsalgia pain, an overlapping cock-up toe, or plantar callosities. However, patients most commonly present with skin irritation and pain with shoe wear (1,3). Often these patients are interested in surgical correction. The goal of brachymetatarsia surgery is to restore normal weight-bearing alignment and a functional metatarsal parabola. The toe length of these patients must be taken into consideration as well (4).

Many techniques for surgical correction have been reported in the literature, which include slide osteotomy, transpositional osteotomy, scarf osteotomy, and syndactylization (5). Recently the 2 most utilized techniques include elongation of the metatarsal utilizing bone graft in a single-stage technique, or distraction osteogenesis with use of external fixators. Benefits to single-stage lengthening procedures include shorter time to bony union and better patient compliance. Disadvantages include the inability to perform if length needed is greater than 10 mm, donor site morbidity, and neurovascular impairment due to tension on soft tissues (2,3,5-11).

Callus distraction utilizing external fixation is performed by placing a fixator on half-pins that are on either side of the proximal metaphysis diaphysis osteotomy and then distracting the bone to promote growth. This technique does not require bone grafting, early weightbearing can be performed, and gradual lengthening can achieve greater

length gain while allowing the soft tissues to adapt (10). Postoperative AOFAS scores reported in studies by Kim et al, Oh et al, and Lee et al were 80%, 89%, and 95% good or excellent results, respectively, for fourth brachymetatarsia utilizing distraction osteogenesis (4,9,11). The disadvantages to this technique include metatarsophalangeal joint (MPJ) stiffness, a short proximal phalanx affecting the overall toe length, and greater time to bony union (3,4,11).

Lamm (7) published a case where percutaneous external fixation technique for distraction osteogenesis was utilized to limit devascularization and preserve periosteum. He tried to prevent the most common complication of MPJ stiffness by placing an additional half-pin with clamp in the proximal phalanx to distract the MPJ at the same time as the metatarsal (7).

Many surgical techniques have been described to treat brachymetatarsia, however, there are few recommendations in treatment of the shortened phalanx, which can affect the toe-tip parabola. We present a case where lengthening of a shortened proximal phalanx via external fixation was performed after correction of bilateral fourth brachymetatarsia.

CASE REPORT

A 32-year-old woman presented with bilateral foot pain secondary to bilateral fourth metatarsal brachymetatarsia diagnosed by radiographic imaging and clinical examination. Despite modifications in shoe gear, she continued to have pain with ambulation. The patient refused to wear sandals as this was a cosmetic "psychological" deformity. The patient was interested in surgery.

Physical examination revealed bilateral shortened and elevated fourth toes (Figure 1) with painful range of motion (ROM) of the fourth MPJ. There was no tenderness to palpation of the fourth metatarsal head bilaterally, however, the patient did have generalized metatarsalgia to the forefoot. In addition, the forefoot was everted relative to the rearfoot in neutral calcaneal stance position, bilaterally. There was no ankle joint ROM limitation with the knee extended, bilaterally. There was adequate pain-free ROM of the ankle, subtalar, midtarsal joint, bilaterally. In gait, the patient pronated throughout without resupination.



Figure 1. Clinical examination of bilateral brachymetatarsia.



Figure 2. External fixator application with osteotomy in proximal metaphysis diaphysis of fourth metatarsal, bilateral.

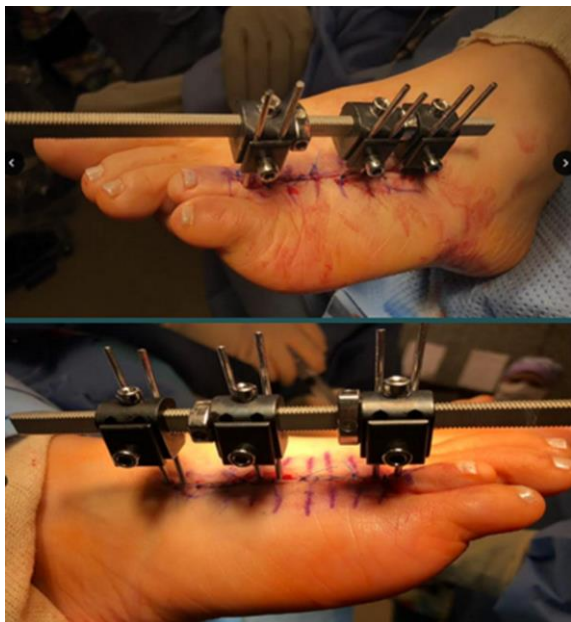


Figure 3. Half pins placed in the proximal phalanx to distract the joint at the same time of the osteotomy.



Figure 4. Offloading fourth metatarsal utilizing cork in a postoperative shoe.

The patient underwent bilateral open external fixation callus distraction technique utilizing half-pin and clamp in the proximal phalanx as described by Lamm (7) (Figure 2 and Figure 3). Postoperatively, there was a latent period of approximately 7 days with 1 mm lengthening by 0.25 mm turns 4 times per day. On the left side, the patient distracted the metatarsal and joint for 8 weeks and the external fixator remained on the foot for an additional 13 weeks. The patient was allowed to be immediate weightbearing in a postoperative shoe where the fourth metatarsal was offloaded utilizing cork, bilaterally (Figure 4).

At 3.5 weeks postoperatively, the patient presented to the clinic where postoperative radiographs were taken.

The left foot images revealed adequate spacing between the distal portion of the fourth metatarsal and the proximal portion, as well as between the proximal phalanx and the metatarsal head. On the right foot, there was distraction significant at the MPJ, however, the metatarsal osteotomy had consolidated prematurely. This required an additional osteotomy to allow for distraction. The patient distracted the external fixator on the left foot for approximately 5.5 weeks and it remained on the extremity for 11.5 weeks. The osteotomies and lengthening of bilateral fourth metatarsal went on to heal successfully.

At 11 months postoperatively, physical examination revealed residual fourth toe



Figure 5. Adducted and dorsiflexed left fifth toe. Toe length appropriate.



Figure 6. Left fourth proximal phalanx shorter than adjacent. Notice the overlengthened fourth metatarsal violating the parabola.



Figure 7. Right fourth toe shortened and cosmetically displeasing.



Figure 8. Right fourth proximal phalanx shorter than adjacent fourth metatarsal of appropriate length.

stiffness, bilaterally. The toes did not purchase the ground. The left fourth toe was slightly dorsiflexed and adducted. There was pain when the toe was placed in an abducted and plantarflexed position on the MPJ. In addition, there was tenderness to palpation sub fourth metatarsal head, distal fourth toe, and fourth distal interphalangeal joint (DIPJ). Radiographs showed a long fourth metatarsal, which violated the metatarsal parabola with a fourth proximal phalanx that was short. The fourth toe proximal phalanx measured approximately 15.43 mm, whereas the fifth toe proximal phalanx measured 19.54 mm and the third measured 21.36 mm (Figure 5 and 6). However, due to the overlengthening of the metatarsal length, the fourth toe was clinically of appropriate length.

The right fourth toe was slightly dorsiflexed and semi-reducible (Figure 7). There was tenderness with palpation to the plantar aspect of the fourth metatarsal head. On the right foot, the AP radiograph showed a newly elongated fourth metatarsal, which was slightly shorter than the third metatarsal. The metatarsal was in the appropriate position within the metatarsal parabola. The fourth proximal phalanx was significantly short. It measured 15.67 mm compared to the third proximal phalanx at 20.69 mm and the fifth proximal phalanx 22.27 mm (Figure 8). This toe was clinically much shorter than the third toe, and slightly longer than the fifth toe. The metatarsal head was painful, and the toe continued to be cosmetically displeasing to the patient.

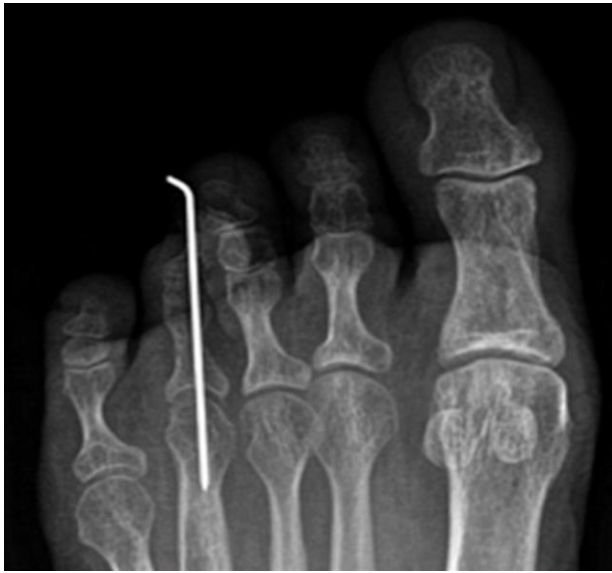


Figure 9. Left fourth toe Kirschner-wire fixation after soft tissue work.



Figure 10. Osteotomy within the right fourth proximal phalanx.



Figure 11. Three half pins in proximal phalanx. Two half pins in right fourth metatarsal head



Figure 12. External fixator removal from right foot with osseous length gained to fourth proximal phalanx.

The left fourth toe was dorsally deviated on an over-lengthened metatarsal. The right fourth toe had similar length to the right fifth digit, and the fourth metatarsal length was appropriate. In addition, retrograde buckling of the dorsal deviated digits caused fourth metatarsal head pain, bilaterally. Further surgical intervention was warranted. The patient underwent left-sided extensor digitorum longus (EDL) lengthening of the fourth toe, and release of the medial interossei with MPJ capsulotomy (Figure 9). On the right side, EDL lengthening and release of the fourth MPJ

along with osteotomy of the fourth proximal phalanx with application of an external fixator was performed.

A mini-rail was applied to the right fourth toe proximal phalanx by placing three half pins in the proximal phalanx and two pins in the metatarsal head. The osteotomy was created in the proximal phalanx and the external fixator was applied. There was a latency period of 5 days. The patient performed 0.25 mm turns 4 times per day for a total of 6 weeks (Figure 10, Figure 11, and Figure 12).



Figure 13. Final length of right fourth metatarsal.



Figure 14. Final length of left fourth metatarsal.

LITERATURE REVIEW

Brachymetatarsia correction has been discussed extensively in the literature and we were able to correct the metatarsals utilizing external fixation for callus distraction. On the other hand, we realized that the proximal phalanges of the fourth digits were shortened. The right foot fourth toe needed to be corrected as there was continued pain and the toe was still clinically displeasing. However, few articles suggest treatment for a short proximal phalanx.

Kim et al (4) reminded us that the correction of the metatarsal parabola is important for weight-bearing function, however, they state that the toe-tip parabola is important for the cosmetic component. They recognized that a short proximal phalanx can create an inadequate toe parabola. Therefore, Kim et al corrected brachymetatarsia and/or shortened proximal phalanges by lengthening or shortening adjacent metatarsals or phalanges with single stage lengthening or external fixation application (4). This technique, in our opinion increases the risk of morbidity and complication.

Song et al state that MPJ stiffness is the most common complication when metatarsal length gained is $> 40\%$ (3). Masada et al states that with $>40\%$ length gain there is a large decrease in ROM (12). Song believes that excessive lengthening of the metatarsal is performed as compensation of a short proximal phalanx. When extrapolating data, 59% of feet with brachymetatarsia had a short proximal phalanx in their report and 11/13 of patients (85%) with a short proximal phalanx had an over-lengthened metatarsal. A total of 7/11 (64%) of these patients with an over-lengthened metatarsal had a complication: 5 with subluxation (total or partial stiff

joint), 1 with pin tract infection, and 1 with angulation.

Song et al would obtain preoperative AP radiographs to measure the metatarsal and proximal phalanx length. If the assumed length to gain was greater than 40%, they would simply inform the patient that the outcome of the final result may not be as expected (3). Meaning the metatarsal may be out to the appropriate length, but the toe clinically will not be at its correct position in the toe parabola.

Oh and Sharma (11) classified two groups: short metatarsals with or those without an associated short proximal phalanx. They found that the lengthening percentage was larger (39.6%) and mean AOFAS score was lower (81.7) in the short proximal phalanx group compared to the normal proximal phalanx group (28.7%, AOFAS 88.9). However, no procedure was performed to address the short proximal phalanx (11).

RESULTS

At final follow-up examination, the patient had no residual pain and was happy with the results. On musculoskeletal physical examination, the left fourth toe was rectus with the fourth metatarsal. However, there was minimal dorsiflexion on the MPJ, but the toe length was appropriate. No tenderness was apparent with palpation of the sub fourth metatarsal head, distal fourth toe, and fourth DIPJ. AP radiographs again showed an over-lengthened metatarsal disrupting the metatarsal parabola along with a short proximal phalanx (Figure 13).

The right fourth toe was rectus on the MPJ with ability to dorsiflex the right fourth toe. The toe length was

Table 1. The preoperative, postoperative, and final (%) length gained of each bone.

	Preoperative Length	Postoperative Length	gained
R Proximal Phalanx	15.67 mm	18.60 mm	18.7%
R 4th metatarsal	47.07 mm	72.84 mm	54.7%
L 4th metatarsal	50.30 mm	74.55 mm	48.2%

appropriate with no tenderness on palpation to the plantar aspect of fourth metatarsal head. AP radiographs showed a metatarsal lengthened to its appropriate position in the parabolic arch. In addition, the proximal phalanx was successfully lengthened as well (Figure 14).

Overall, we were able to successfully lengthen the metatarsals and the right fourth proximal phalanx. Table 1 lists the lengths preoperatively, postoperatively, and final percentage length gained of each bone.<<Table 1>>

DISCUSSION

Several complications arose during the treatment of this patient. Three and a half weeks after the initial surgery, the osteotomy of the right fourth metatarsal had consolidated. This required an additional osteotomy. At the 11th month follow-up, it appeared that the metatarsals were out to length. However, the left fourth metatarsal appeared to disrupt the metatarsal parabola, the left fourth proximal phalanx was short, and the fourth toe was dorsally deviated on the metatarsal head (Figure 15). Clinically, the fourth toe was within the appropriate toe parabola position as the over lengthened metatarsal compensated for the short proximal phalanx. Soft tissue surgery was able to successfully bring the toe down. On final examination, there was minimal dorsiflexion at the left fourth MPJ as a result of over-lengthening the metatarsal, but there was no residual pain to the left foot.

At the 11th month follow-up, the right fourth metatarsal was positioned appropriately within the parabolic arc. The fourth proximal phalanx was short and because this metatarsal was not over lengthened the fourth toe clinically appeared short of the toe parabola. In addition, the fourth toe remained dorsiflexed and there was pain at the fourth metatarsal head at this time.

It has been documented in the literature that a short proximal phalanx plays a role in brachymetatarsia correction. According to Song et al (3), 59% of patients with brachymetatarsia also had an associated short proximal phalanx. Oh et al (11) recognized this phenomena as well,



Figure 15. Right fourth metatarsal violates metatarsal parabola.



Figure 16. Right fourth metatarsal length appropriate. Lengthen fourth proximal phalanx.

however, other than soft tissue correction neither groups performed osseous correction directly to the proximal phalanx. Kim et al (4) mentioned that the metatarsal and toe parabola are very important for successful surgery. To achieve their goal, extensive surgery was performed on the forefoot, but we believe this increases the risk for complications.

Our patient continued to have right forefoot pain and the toe was cosmetically unsatisfactory. Therefore, further surgery was warranted. We were able to successfully utilize a mini-rail external fixator on the right fourth toe proximal phalanx to perform callus distraction and lengthen the toe to its appropriate toe parabola position (Figure 16).



Figure 17. Final clinical follow-up of bilateral feet.

We were able to lengthen the fourth metatarsals and the right fourth toe proximal phalanx to relieve the forefoot pain, as well as satisfy the patient's cosmetic psychological deformity. The bilateral brachymetatarsia correction was achieved with slightly different results and because of this we now have a better understanding of the appropriate surgical technique.

Song et al state that MPJ stiffness is the most common complication when metatarsal length gained is $>40\%$. On the right side, we had an overall length gain of 54.7% and on the left side, 48.2%. On the left side, residual stiffness at the MPJ did occur and we did violate the metatarsal parabola while lengthening. On the other hand, the right fourth metatarsal was at the appropriate metatarsal parabola position on final radiographs and MPJ stiffness was not present with ROM. Therefore, we believe that it is imperative to closely follow a patient's progress of lengthening with serial radiographs to ensure the metatarsal does not violate the metatarsal parabola.

In conclusion, we were able to successfully lengthen the proximal phalanx of the right fourth toe by utilizing external fixation and callus distraction after correction of bilateral brachymetatarsia. With this case report, we are able to suggest a technique to perform lengthening of the proximal phalanx and make certain a toe is in its appropriate position in the toe parabola without having to disrupt the metatarsal parabola by overcompensation (Figure 17).

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