Case Report

AMERICAN ORTHOPAEDIC FOOT & ANKLE SOCIETY

Foot & Ankle International®
2018, Vol. 39(2) 242–249

DOI: 10.1177/1071100717737481
journals.sagepub.com/home/fai

Distraction Osteogenesis and Fusion for Failed First Metatarsophalangeal Joint Replacement: Case Series

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Level of Evidence: Level V, expert opinion

Keywords: failed MTP joint arthroplasty, distraction osteogenesis, first MT joint fusion

Introduction

Hallux rigidus is a progressive osteoarthritic condition, and operative intervention is often required.[6] It can affect gait, lead to a decreased range of motion, particularly dorsiflexion, and can cause stiffness and pain.[5,6] First metatarsophalangeal (MTP) arthrodesis is the traditional standard treatment for end-stage hallux rigidus[1] and has been repeatedly shown to be the most consistent and successful operative technique.[10] In 1952, first MTP arthroplasty emerged as a new treatment option for end-stage hallux rigidus.[3,6]

First MTP arthroplasty involves prosthetic replacement of the first MTP joint with either a unipolar or bipolar implant and has the potential to improve joint motion and reduce pain.[3] However, arthroplasty involves additional risks, including malposition, implant fracture, stress fracture, arthrofibrosis, and synovitis, all of which can lead to failure.[3] Additionally, failed arthroplasty often leads to a significant amount of first ray shortening, which can make revision surgery a challenge.[1] There is little literature following the long-term results of hemiarthroplasty[6] and total joint arthroplasty, and even less exists describing outcomes of salvage arthrodesis in cases where arthroplasty fails.[5] Brage and Ball reported that many of the hemiarthroplasty implants would fail.[2] Delman et al also reported that arthroplasty procedures to treat hallux rigidus would fail, opining that the compressive and shear stresses placed on the implant surfaces put them at high risk of loosening.[3] Furthermore, unlike the knee and hip, there is little surface area available to establish a strong bone-implant interface. This, combined with higher stresses, particularly during walking and stair-climbing, leads to higher failure rates. In a study comparing arthroplasty and arthrodesis over a 6-year period, 24% of the arthroplasties failed, with 4 converted to an arthrodesis to alleviate pain.[8] Failed implants, once removed, create significant bone loss, which can make the reconstruction operation difficult.[1] Because of the bone loss, the revision arthrodesis usually necessitates bone grafting in order to restore first ray length.[2] Depending on the amount of bone loss, local autologous bone graft may be an option, but in cases with significant loss, grafts from other areas might be necessary as well, increasing the potential rate of failure of the operation.[5] Commonly, surgeons use tricortical iliac crest autograft wedges to manage defects. However, this can have associated morbidity in terms of pain and even fracture.[12]

These salvage arthrodesis procedures often have a long time to union and increased rates of nonunion and malunion compared to primary first MTP arthrodesis procedures.[2] To avoid the complications associated with iliac crest bone graft harvest, tricortical allograft wedges have also been used. However, the nonunion rate associated with allograft in foot arthrodesis cases has been reported to range from 9% to 23% and is thus a less favorable option.[7,8] To improve the chance of healing, many surgeons elect to acutely shorten the first

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Table 1. Patient Data.

	Patient 1	Patient 2	Patient 3
Age	55	67	48
Gender	Female	Female	Male
Type of implant	Unipolar	Unipolar	Bipolar
Defect size, mm	10	24	24
Infection	None	None	None
Implant loose	Yes	No	Yes
Bacteria isolated	None	None	None

metatarsal defect to achieve fusion without addressing the loss of length of the ray. We present a series of failed first MTP arthroplasties requiring revision-reconstruction operations using a novel application of the Ilizarov technique, in which distraction osteogenesis was used in combination with primary arthrodesis to restore stability and length to the first ray. In our experience, this technique leads to good results and minimized morbidity to the iliac crest.

Methods

A retrospective chart review was conducted from a prospectively collected registry to identify fusion after joint arthroplasty surgery. We identified all cases of a failed first MTP joint arthroplasty that were revised to a first MTP joint arthrodesis with first metatarsal lengthening between 2011 and 2014. We excluded patients with concomitant foot pathology including nonunion. Four patients met the inclusion criteria. One patient was excluded because of preoperative complex regional pain syndrome (CRPS). Thus, 3 patients were included in this case series. Baseline patient demographics and intraoperative findings are summarized (Table 1).

Operative Technique

The anesthetic protocol was similar for all patients, consisting of a peripheral popliteal nerve block under ultrasound guidance and spinal anesthesia. Antibiotics were held until tissue samples were obtained for culture. A dorsal incision was made, centered over the first MTP joint. In 2 of the 3 cases, the implants were loose. When the implant was removed, all devitalized or necrotic tissue was removed, including bone. Bone defects measured, on average, 19 mm (range 10-24 mm). The Wright Medical (Memphis, TN) conical and cup reamer set was used to contour the joint surfaces for arthrodesis. A 3.5-mm Kirschner wire (K-wire) was used to penetrate each joint surface several times to improve bony integration at the fusion interface. Cancellous bone autograft was harvested from the calcaneus. Between 3 and 7 cc of bone graft was harvested. The autograft was used to fill any defects in the metatarsal head as well as packed into and around the fusion site. Satisfactory alignment was obtained and the joint was pinned in position with 1 to 2 K-wires.

The first ray was confirmed to be short by 10 to 25 mm and indicated for lengthening. The Biomet mini rail external fixation system (Warsaw, IN) was utilized to construct a dorsally mounted compression-distraction frame. Three-millimeter self-drilling, self-tapping half pins were placed percutaneously with fluoroscopic assistance. The most proximal pin in the proximal first metatarsal was placed first, followed by the most distal pin in the proximal phalanx establishing the axis of compression and distraction. The remaining 4 half-pins were placed using the frame as a targeting device. All pins were placed bicortically. Overall, there were 2 pins in the proximal phalanx, 2 pins in the distal first metatarsal, and 2 pins in the proximal first metatarsal. The pins were oriented to allow compression across the first MPT joint and distraction through the proximal metatarsal. Once satisfactory position of all pins was confirmed, the frame was removed, and the mid-diaphysis of the first metatarsal was exposed through a small dorsomedial incision. Multiple drill holes were made at the desired osteotomy site in the middle of the first metatarsal, and the osteotomy was completed using an osteotome. The external fixator was reattached, and compression was applied across the first MTP joint fusion site. The K-wire was kept in some cases across the joint to aid in maintaining the joint reduction and preventing apex plantar deformity during compression.

Postoperative Protocol

The patient was initially instructed to remain nonweightbearing with the operative foot in a postoperative splint. Empiric oral antibiotics were prescribed for infection prevention prophylaxis, a practice we no longer advocate.[4] Chemical deep vein thrombosis prophylaxis was also prescribed in each case. On postoperative day 5, distraction of the osteotomy was initiated at a rate of 0.5 mm per day, split into two 0.25-mm turns. The technical challenge was to lengthen the metatarsal while keeping the Meary angle constant with appropriate dorsiflexion of the first MTP arthrodesis. The frame was parallel to the first metatarsal on both the AP and lateral view in order to maintain the position of first MTP fusion (Figure 1B and C). The patient was assessed at 2-week intervals postoperatively to evaluate progress of the distraction regenerate bone. Additional compression (1-mm) was applied with the external fixator across the fusion site at these visits. Distraction was continued at this rate until the metatarsal length was restored to within 1 mm of the contralateral side. Adequate distraction and restoration of metatarsal length was typically achieved at 4 to 6 weeks postoperation. The patient was then permitted partial heel weightbearing only in a postoperative rigid

Table 2. Results.

Patient	Age	Time to Union, mo	Reoperation	Complications	Time NWB to Partial Heel Weightbearing, wk	Time to Full Weightbearing, mo	Final Follow-up, mo	Pain at Final Follow-up	Final Function
1	55	5	No	None	3	5	6	No	Return to all activities
2	67	4.5	No	Superficial pin site infection	2	4.5	9	No	Return to all activities, including jogging
3	48	3.5	Yes	Premature consolidation requiring revision osteotomy	3	3.5	8	Mild	Returned to work as a laborer with rocker bottom shoe

Abbreviation: NWB, nonweightbearing.

Table 3. Lengthening Data.

Patient	Bone Defect, mm	Lengthening, mm	LD, mm	Time in Frame (TIF), d	Ex Fix Index (TIF/length), d/cm
1	10	10	0.7	96	96
2	24	24	1.1	97	40.4
3	24	24	0.8	146	60.8

Abbreviation: LD, length discrepancy between operative and contralateral first metatarsal.

shoe with an ambulatory assistive device. The K-wire that was initially placed across the first MTP joint was removed in the office at 6 to 8 weeks when the fusion site was felt to be partially united. The external fixator was maintained for an additional 2 months from the time of final distraction and then removed in the office. This was generally performed at 12 to 14 weeks postoperation. Radiographs were assessed and 4 cortices of healing at the lengthening site were required prior to frame removal. Partial weightbearing at 50% body weight in a postoperative rigid shoe was initiated once the external fixator was removed and progressed to full weightbearing as tolerated over a 4- to 6-week period based on radiographic union. The patient was transitioned back into regular shoes at 4 to 6 months postoperatively and generally permitted to return to all activities as tolerated at 6 to 9 months postoperatively.

Results

The results of the 3 cases are summarized in Table 2 and specific lengthening data for each case detailed in Table 3. Cases 1 and 2 had similar clinical courses and therefore only case 2 is described in detail with corresponding images. Case 3 required reoperation and revision and is therefore also described in detail with corresponding images.

Case 2 Summary

This patient was a 67-year-old woman who previously underwent a right first MTP hemiarthroplasty 4 years prior at an outside institution (Figure 2). The patient continued to have limited range of motion with dorsiflexion limited to 10 degrees and persistent, daily pain. The patient underwent implant removal, first MTP arthrodesis, first metatarsal osteotomy, and external fixation application. A K-wire transfixing the arthrodesis site was maintained in situ to prevent deformity during lengthening and removed at 8 weeks postoperation. Distraction was initiated at postoperative day 5 at a rate of 0.5 mm/d and continued for 48 days, yielding a final lengthening of 24 mm. The first metatarsal length was restored to within 1 mm of the contralateral side (Figure 1). The patient was maintained at partial heel weightbearing in a rigid postoperative shoe for 3 months. The external fixator frame was removed at 3 months postoperation and the patient was progressed to partial foot flat weightbearing at 50% body weight. Radiographic union of both the arthrodesis site and lengthening site were achieved by 4 months postoperation (Figure 3). At 4 months postoperation, the patient was progressed to full weightbearing as tolerated. The patient achieved full weightbearing without an assistive device in regular shoe wear by 6 months

Figure 1. Case 2. (A) Oblique and (B) lateral radiographs 5 weeks postoperation demonstrating excellent bone contact at the fusion site and early regenerate bone formation at the lengthening site. The frame must be parallel to the first metatarsal on both the AP and lateral view in order to maintain the position of first metatarsophalangeal fusion. Panel C demonstrates that the frame and the metatarsal are parallel, ensuring lengthening along the anatomic axis. (C) Bilateral comparison AP radiographs show that metatarsal length as measured from the base of the first metatarsal to the interphalangeal joint has been restored to within 1 mm of the contralateral side. AP, anteroposterior.

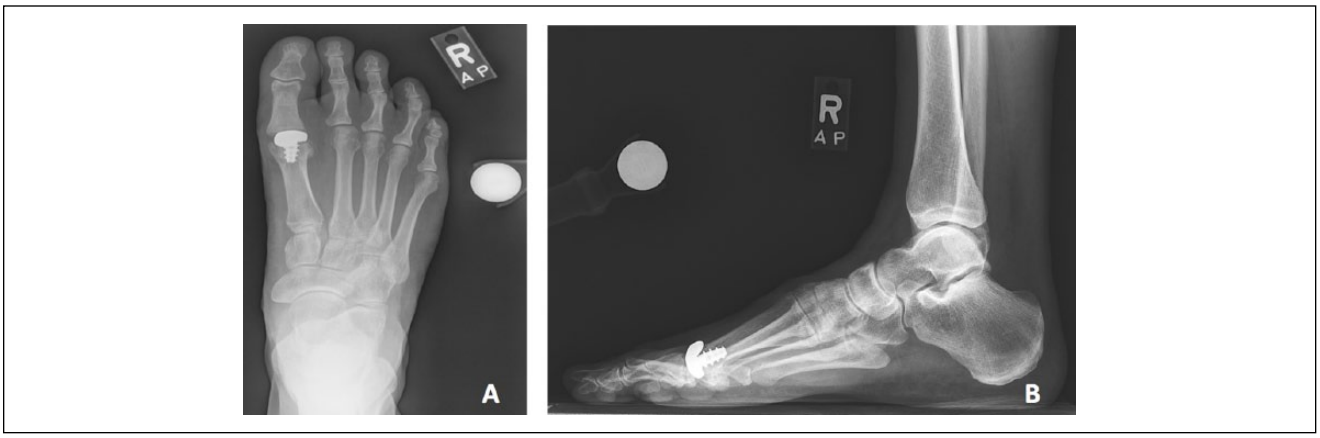

Figure 2. Case 2. (A) Preoperative anteroposterior and (B) lateral radiographs with a first metatarsophalangeal hemiarthroplasty implant in situ. There is radiographic evidence suggestive of implant loosening. There are familiar signs of phalangeal cartilage loss.

postoperation. The patient returned to full activities without restrictions, including jogging and hiking, by 9 months postoperation. The patient had complete resolution of pain. This patient experienced a superficial pin site infection that resolved completely with a 10-day course of oral antibiotics. The patient experienced no other complication. There were no issues with first toe interphalangeal joint stiffness noted postoperatively.

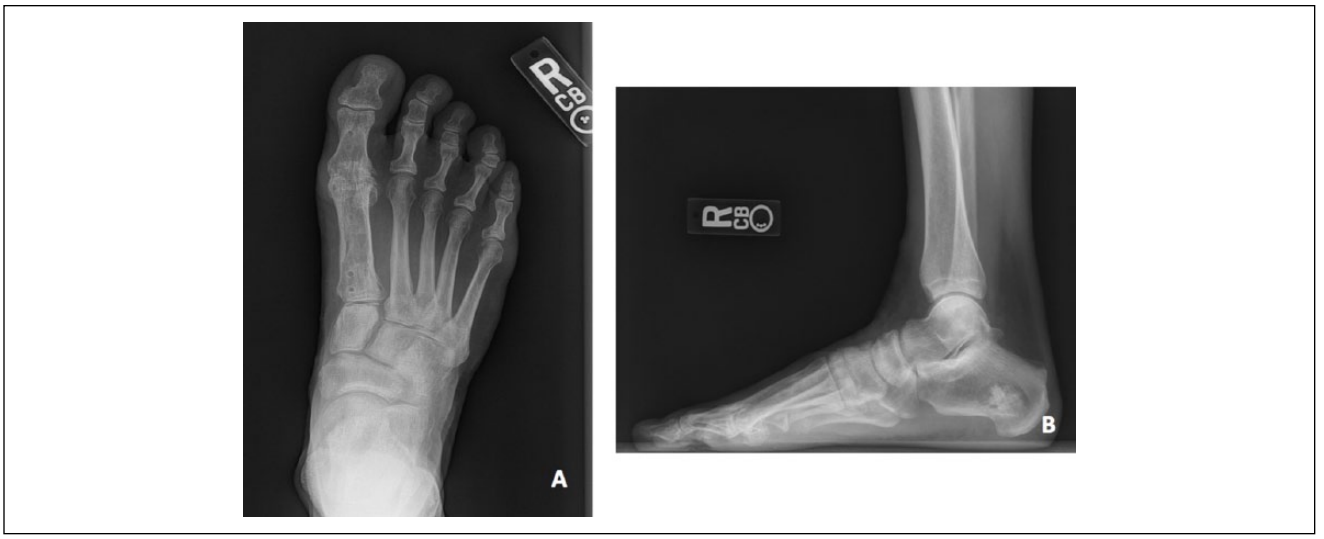

Figure 3. Case 2. (A) Anteroposterior and (B) lateral radiographs at 6 months postoperation demonstrating complete healing at both the distraction site and arthrodesis site with restoration of metatarsal length. Note on the lateral image that the first metatarsophalangeal fusion mass contacts the floor anatomically as a result of lengthening along the anatomic axis of the metatarsal.

Figure 4. Case 3. (A) Preoperative anteroposterior and (B) lateral radiographs with a first metatarsophalangeal total arthroplasty implant in situ. Radiographically, there was evidence of implant loosening.

Case 3 Summary

This patient was a 48-year-old man that previously underwent a right first MTP arthroplasty 1 year prior at an outside institution (Figure 4). The patient continued to have limited range of motion with dorsiflexion limited to 30 degrees and persistent, daily pain. This patient underwent implant removal, preparation of the first MTP fusion site, and a first metatarsal proximal osteotomy with external fixation application for lengthening. The fusion site was unable to be reduced acutely and needed to be gradually shortened creating a bone transport scenario. The first stage of distraction was initiated at postoperative day 5 at a rate of 0.5 mm per day, and the shortening at the fusion site was also carried out at 0.5 mm per day. The patient developed a premature consolidation of the lengthening site 6 weeks following the initial surgery which required operative osteoclasis. The first MTP fusion site (docking site) still had a gap so it underwent autologous bone grafting during the same revision surgery.

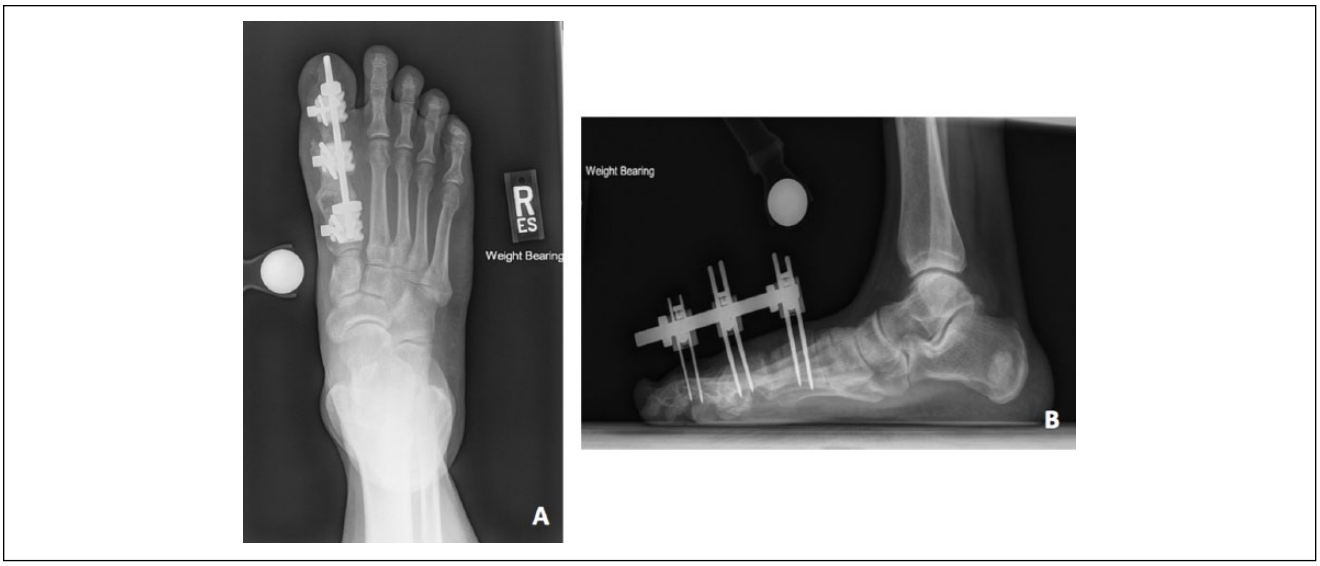

Figure 5. Case 3. (A) Anteroposterior and (B) lateral radiographs 2 months postoperation demonstrating the first metatarsal distraction.

Figure 6. Case 3. Lateral radiograph at 3 months postoperation at the time of external fixator removal demonstrating consolidation at both the distraction site and arthrodesis site.

The second surgery consisted of the first MTP bone grafting from the calcaneus and acute docking, and a first metatarsal osteotomy revision through a closed, rotational osteoclasis using the external fixator pins to control both segments. Repeat intraoperative cultures were taken and were negative. At neither surgery was a K-wire transfixing the arthrodesis site left in situ temporarily because of the concern for infection. The osseous distraction was initiated at postoperative day 5 at a rate of 0.5 mm/d and continued for 14 days. The first metatarsal was lengthened a total of 24 mm. Length restoration was clinically determined with the first metatarsal head at the same level clinically as the third metatarsal head and similar to the contralateral side, which we used as a template (Figure 5). The patient was maintained at partial heel weightbearing in a rigid postoperative shoe for 3 months. The external fixator frame was removed at 3 months postoperation and the patient was progressed to partial weightbearing at 50% body weight (Figure 6). At 3.5 months postoperation, the patient was progressed to full weightbearing as tolerated. The patient achieved full weightbearing without an assistive device by 6 months postoperation. The patient returned to full duty work as a heavy laborer by 9 months postoperation. Radiographic union of both the arthrodesis site and lengthening site were achieved by 3.5 months postoperation and the first metatarsal length restored (Figure 7). This patient continued to have mild pain with activity postoperatively that was managed with wearing a rocker bottom–type shoe. He was able to return to walking and his job. There were no issues with first toe IP joint stiffness noted postoperation.

Discussion

There are very few cases reporting the long-term results of failed first MTP arthroplasty, and even fewer describing revision procedures following these failures. The commonly accepted plan of treatment after a failed first MTP arthroplasty is conversion to arthrodesis, using bone graft.[2] When considering how to repair the bone defect in these patients, the most common option is to restore the length of the patient's metatarsal using autogenous bone graft from either the iliac crest or the tibia.[9] When a significant amount of bone loss is present, the bone graft is traditionally taken from the iliac crest. However, procedures that involve harvesting a large amount of bone graft have complications associated with them. Iliac crest bone grafting can lead to

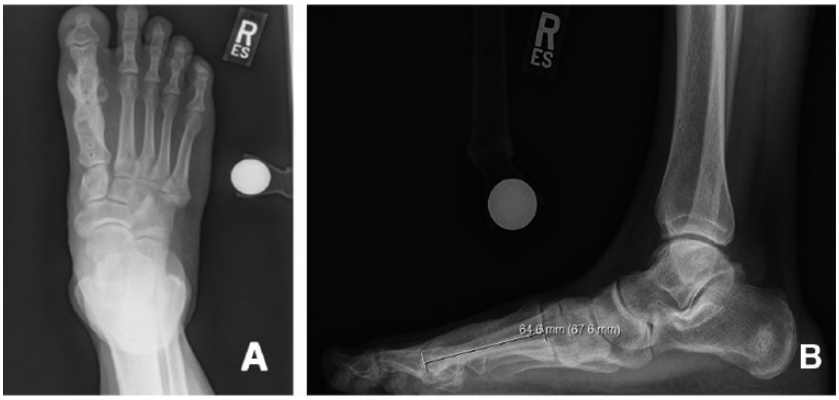

Figure 7. Case 3. (A) Anteroposterior and (B) lateral radiographs at 6 months postoperation demonstrating healing to union at both the distraction site and arthrodesis site with restoration of metatarsal length.

iliac fractures, increased pain in the site of the harvest, and increased length of postoperative hospital stays. The rate of complications following iliac bone grafting for use in foot and ankle surgery has been reported to be as high as 13.1%.[9]

Given the difficult nature of this revision procedure and the amount of bone loss after the removal of the implant, these revision arthrodesis procedures leave the patient at an increased risk of nonunion or malunion.[2] Garras et al reported on 6 of 18 patients that required structural bone grafting to restore length due to extensive bone loss.[5] However, they were unable to restore full length in 1 patient because of the size of the defect, limiting the degree of lengthening that could be achieved as a result of poor soft tissue integrity and vascularity. This patient required the additional procedure of lesser metatarsal shortening osteotomies.[5] Because of the high morbidity of using large bone grafting procedures, we chose to use limited bone grafting only to improve the fusion potential. We used a distraction technique to fix the majority of missing length in these 3 patients in order to minimize the chance of failure and increased morbidity associated with using bone grafts alone to fill substantial defects. Another benefit of this technique is the ability to control the amount of length restored. By stretching soft tissues, additional length can be added easily. It needs to be mentioned that we do not advocate overlengthening the metatarsal to compensate for shortening of the proximal phalanx. The temptation is to match the length of the contralateral great toe clinically, but this would require overlengthening the metatarsal, which will make the plantar aspect of the first MTP fusion too prominent. The metatarsal is lengthened in the anatomic axis, so it moves distally and plantar. Overlengthening could produce metatarsalgia of the first ray, whereas dorsiflexion can lead to metatarsalgia of lesser rays.

Conclusion

In this case series, we present 3 patients who all underwent first MTP reconstruction surgery with minor bone grafting in addition to a lengthening procedure. All patients achieved successful arthrodesis. This technique allowed for appropriate first metatarsal length and avoided transfer lesions to the second and other lesser metatarsals. We believe that this novel operative technique may lead to better results with fewer complications than just arthrodesis with bone graft in patients in need of revision first MTP surgery.

Author Note

The study took place at the Hospital for Special Surgery and was approved by the institution's Foot and Ankle Registry, which is approved by our Institutional Review Board.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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