

Distraction osteogenesis for treatment of iatrogenic shortening of the first ray

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The purpose of this study is to present a surgical treatment option following iatrogenic shortened first ray pathology and report the postoperative outcomes. Retrospective analysis of two surgeon's patients (N=5) who underwent gradual distraction osteogenesis following previously failed first ray surgery was conducted. Surgical outcomes were measured including time in the external fixator and amount of distraction achieved. Complications measured included neurovascular complications, non-union, mal-union, infections, mal-alignment, pain, wound dehiscence, stiffness and transfer metatarsalgia. The average time spent in an external fixator was 78.8 (34-108) days. Average distraction achieved was 12.2 (2-22) mm. Four of the 5 patients experienced at least one of the following postoperative complications: pin site infections, wound dehiscence, non-union and postoperative pain. This study suggests that distraction osteogenesis may be a feasible surgical treatment option for iatrogenic shortened first ray with the right patient selection, but needs further evaluation.

Keywords: callus distraction, deformity, external fixation, iatrogenic shortening first ray

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Failed arthrodesis or arthroplasty of the first ray can be a problematic complication with issues of non-union, deformity and decreased metatarsal length. Significant shortening can alter weight bearing mechanics causing iatrogenic metatarsalgia leading to pain and decreasing quality of life [1]. Common surgical interventions include shortening the lesser metatarsals or deformity correction osteotomies. However, these can come with their own set of complications including floating-toe deformity, persistent metatarsalgia, and significant forefoot shortening [2]. When significant shortening is present, treatment options include acute correction with interpositional bone grafting, or gradual distraction with external fixation. Gradual distraction can offer several advantages over acute correction including the ability to achieve greater overall length, avoidance of bone grafting, no donor site morbidity, and the ability for patients to weight-bear earlier in the postoperative period. Additionally, gradual distraction can reduce the chances of neurovascular compromise since it allows soft tissues to adapt gradually as bone

lengthens [3-6]. Few reports exist in the literature of distraction osteogenesis to correct for shortening of the first ray [7-10]. The purpose of this case series is to present surgical outcomes following distraction osteogenesis with use of a monolateral external fixator for correction of shortened first ray pathology.

Materials and Methods

A retrospective review was performed on patients who underwent gradual distraction osteogenesis as a revision surgery to the first ray from January 2016 to December 2018. Inclusion criteria were patients who had previously failed first ray surgery leading to iatrogenic shortened first ray with greater than one year follow-up. Exclusion criteria were patients who underwent distraction osteogenesis as the primary procedure. After inclusion and exclusion criteria were considered, five patients were eligible to participate in this study. Patient charts were reviewed and objective data gathered. The objective data included age, sex, body mass index, medical comorbidities, smoking

history, length of follow-up and follow-up surgical procedures. Complications and outcomes were assessed primarily with chart review. Clinical notes were used to determine the time in the external fixator and total length obtained. Complications measured included neurovascular complications, non-union, mal-union, infections, mal-alignment, pain, wound dehiscence, stiffness and transfer metatarsalgia.

Operative Technique

If previous hardware was present it was removed with appropriate instrumentation. An osteotomy was performed at the metaphysis of the first metatarsal. If a plantarflexion deformity was present, a closing dorsal wedge osteotomy was made. Two half-pins were placed in a bicortical fashion both proximal and distal to the osteotomy site for a total of four half-pins. The external fixator was then applied to the pins. In two of the patients, two additional half-pins were placed in a bicortical fashion proximal and distal to the first metatarsophalangeal joint and a second external fixator was applied to the pins spanning the first metatarsophalangeal joint. The joint was then slightly distracted to prevent stiffness and jamming of the first metatarsophalangeal joint during the lengthening process. In three of the patients, a first metatarsophalangeal joint fusion procedure was performed with internal fixation including dorsal plating and screws or a steinman pin. The consolidation period was 10 days. After that time, patients were instructed to advance the device by 0.5 mm per day for 21 days.

Postoperatively, throughout the consolidation and distraction periods, patients were kept non-weight bearing for 8 weeks, followed by weight bearing in a walking boot for approximately 4 weeks (Figure 1). The external fixation device was removed three months postoperatively and patients returned to normal shoe gear at that time.

Results

Review of the records indicated a total of five patients eligible for this study. There were a total of 3 female and 2 male patients. Average age of patients was 57.8 (ranging from 44-77) years of age. The mean BMI was 27.2 (ranging from 22.3-33.6) kg/m².

Characteristic	
Age (yr)	57.8 (21-56)
Sex (M:F)	3:2
BMI (kg/m2)	27.2 (22.3-33.6)
Comorbidities	
HTN	2
DM	2
HLD	1
CHD	2
Current Smoker	3

Table 1 Patient demographics (N = 5 patients). *Abbreviations: BMI, body mass index; CHD, coronary heart disease; HTN, hypertension; DM, diabetes mellitus; HLD, hypercholesterolemia.*

There were a total of 3 active smokers. Two patients were identified with diabetes mellitus, 2 with hypertension, 2 with coronary heart disease and 1 with hypercholesterolemia (Table 1). All 5 patients underwent revision surgery due to a shortened first ray due to previously failed surgery. The mean follow-up duration was 21.8 (12-42) months. The average time spent in an external fixator was 78.8 (34-108) days. Average distraction achieved was 12.2 (2-22) mm. Four of the 5 patients experienced at least one postoperative complication (Table 2). One patient had a monolateral external fixator applied with an additional steinman pin across the joint and experienced delayed healing of the first metatarsophalangeal joint. This patient underwent revision arthrodesis with a dorsal locking plate and screws and then developed a wound dehiscence which was resolved with local wound care. Five months postoperatively, CT imaging was ordered showing partial osseous bridging with diffuse soft tissue swelling, the hardware was then removed and a bone biopsy was obtained revealing negative results for osteomyelitis. The patient developed a stable non-union with no interest for further surgical intervention and was last seen ambulating with normal shoes at last follow-up. One patient developed a half-pin infection which resolved with a ten-day course of oral antibiotics.

Patient	Mean Follow-up (months)	Time spent in External Fixation (days)	Average Length (mm)	Complications
1	27	87	10	Pin site infection
2	19	34	2	Infection
3	42	81	13	Pain
4	15	84	22	Non-union MTPJ Wound dehiscence
5	12	108	14	None
Average	21.8	78.8	12.2	

Table 2 Patient outcomes and complications (N=5).

One patient reported postoperative pain at the hallux and went on to a hallux interphalangeal joint arthroplasty. The pain resolved after treatment of physical therapy and over-the-counter orthotics. Lastly, one patient consolidated early due to noncompliance during the distraction protocol. The patient missed multiple postoperative appointments, stopped turning the external fixator and requested it to be removed 34 days postoperatively. The patient experienced a minor infection, which resolved with a 10 day course of antibiotics, and went on to a hardware removal with shortening of metatarsals two and three.

All five patients, at their last follow-up appointment, were ambulating in normal shoe-gear without complications. There were no cases of neurovascular complications, metatarsophalangeal joint stiffness, subluxation, or angulation.

Discussion

Acquired shortening of the first ray can lead to a variety of complications. Surgical treatment options are limited for a significantly shortened first ray and include acute correction with or without bone/metal graft interposition or gradual bone lengthening. Metatarsal lengthening applying acute correction techniques has been well described in the literature, however there are few reports regarding the use of distraction osteogenesis as a treatment option for the first ray [7-10]. Jones, et al., performed a systematic

review of postoperative outcomes following single stage lengthening versus distraction osteogenesis. The mean length achieved was 17.5 mm in the callus distraction group versus 13.2 mm in the single stage group. The complication rate was 12.62% in the bone distraction group versus 3.72% in the single stage lengthening group. The study concluded bone distraction allows greater amount of lengthening but can result in higher complication rate with longer healing times [10].

Common complications of distraction osteogenesis include pin site infections, metatarsophalangeal joint stiffness and subluxation [10-13]. To prevent some of these complications, current literature recommends the amount of length should not exceed 40% of the bone and additional pin fixation should be applied to the distal joints to prevent subluxation of the distal joints and to provide an axis guide for the bone regenerate [12-15]. Lamm proposed positioning an additional half-pin into the proximal phalanx and placing the osteotomy further from the joint where there are less forces at play to cause subluxation [16]. Mather, et al., applied this technique in a series of five patients with first ray shortening secondary to hallux valgus correction and experienced no postoperative complications or incidence of metatarsophalangeal joint stiffness. The study concluded good outcomes should be based on proper technique, patient selection and patient compliance [8].

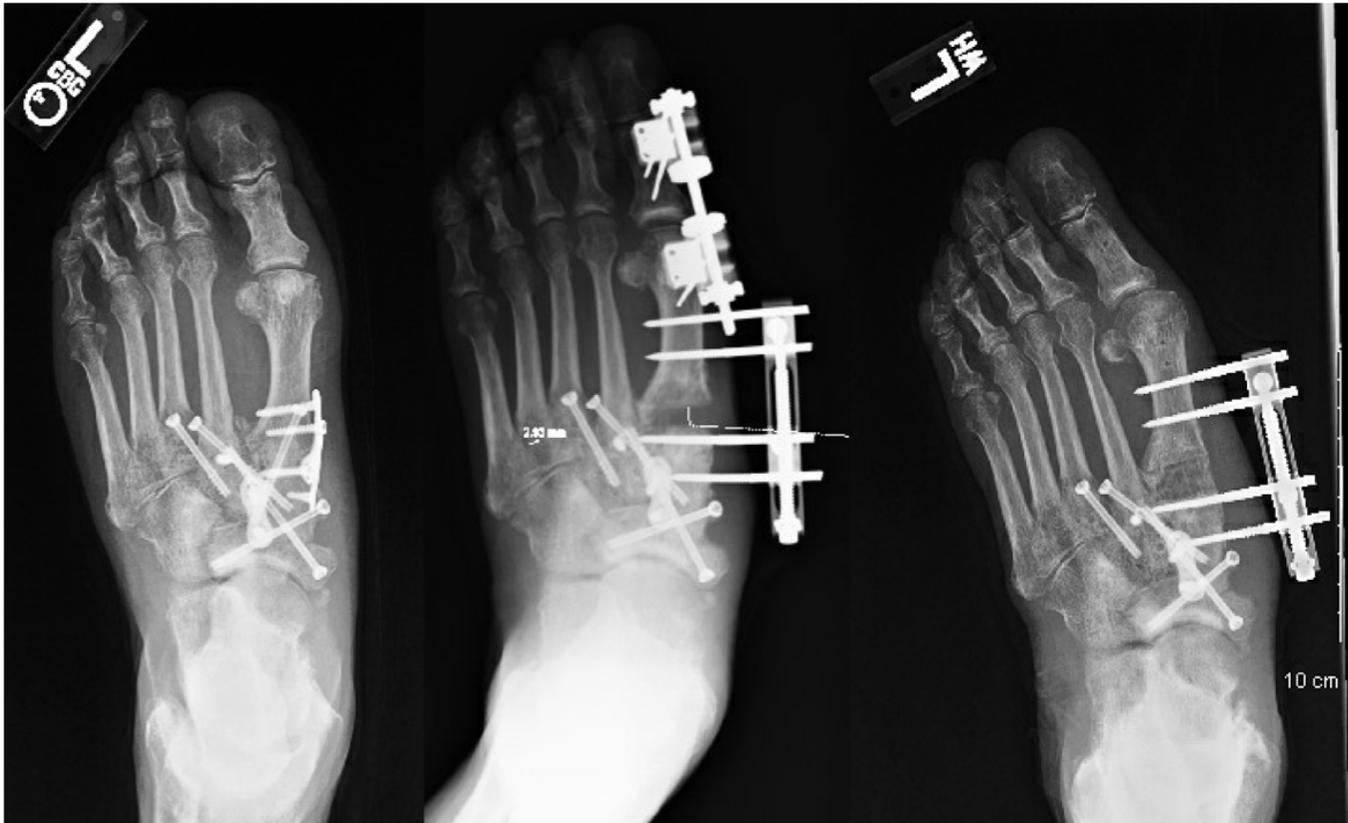


Figure 1 Radiographs of patient with short first ray following Lisfranc open reduction internal fixation. Preoperative (left), postoperative during distraction period (center), and postoperative with consolidation of final length (right).

In our study, the average distraction achieved was 12.2 mm, which is less than the average described in the literature. Part of the decrease in average distraction achieved can be attributed to patient selection and patient non-compliance. Patient selection is important as many of the potential complications are the result of patient co-morbidities and non-compliance. One of the patients did not strictly adhere to the recommended postoperative rehabilitation program and had the external fixator removed 34 days postoperatively with only 2 mm of length gained. Attempts to accelerate the distraction phase can be associated with fracture, deformity, and shortening [17]. Another patient achieved 22 mm of distraction after 84 days in the external fixator, but experienced a non-union of the first metatarsophalangeal joint. This patient continued to actively smoke despite smoking cessation recommendations by the surgeon. Success in bone distraction can be influenced by factors such as age, comorbidities, smoking, bone quality and osteotomy location.

Three of the five patients were also current everyday smokers during their distraction procedures and smoking is well-documented in the literature as a

significant risk factor for decreased healing potential in the lower extremity [18]. Smoking is a modifiable risk factor and improved results with our study may have been able to be achieved if these three patients discontinued smoking prior to their surgery. The literature supports that smoking cessation for as few as 4 weeks prior to the surgical intervention can decrease postoperative complications when compared to smokers who continue to smoke [19].

One patient developed a half-pin site infection which resolved with a ten-day course of oral antibiotics. Pin tract infections range in the literature from 8.5% up to 100%. The majority of these resolve with a short course of oral antibiotics, but approximately 4% go on to osteomyelitis [20]. Pin site care is largely surgeon dependent and the literature lacks any high quality evidence to provide recommendations for decreasing pin site infections and for pin site care [20]. Making sure the external fixator is stable with minimal to no movement at the pin sites and ensuring that thermal necrosis does not occur when inserting the pins are discussed in the literature as accepted techniques to decrease pin site infections [20].

Notably, there were no cases of neurovascular complications, metatarsophalangeal joint stiffness, mal-union, mal-alignment or transfer metatarsalgia, indicating this study was able to reproduce the previously described benefits in the literature of gradual distraction when applying proper technique. All five patients at their last follow-up appointment were ambulating in normal shoe gear without complication.

As with the majority of studies, the design of the current study is subject to limitations with its retrospective nature, small sample size, no patient reported outcomes, and varying in surgical procedures and postoperative protocol. A larger sample size, prospective study, patient reported outcomes with uniform surgical technique and postoperative protocol would be needed to obtain more definitive study results.

In conclusion, gradual metatarsal lengthening is a surgical treatment option for an iatrogenic shortened first ray. However, patient selection, smoking cessation, patient compliance, a consistent surgical technique and postoperative protocol is key in order to obtain successful reproducible results. This case series supports the limited current literature that distraction osteogenesis is a viable option for treatment for iatrogenically shortened first rays as we were able to obtain 12.2 mm of distraction on average and all patients were ambulating in regular shoes at final follow up. Distraction osteogenesis is a feasible surgical treatment option for iatrogenic shortened first ray, but better quality studies are needed for further evaluation.

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