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# A Two-Stage Percutaneous Approach to Charcot Diabetic Foot Reconstruction

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ABSTRACT

The goals of Charcot deformity correction are to restore osseous alignment, regain pedal stability, and prevent ulceration. Traditional reconstructive surgical approaches involve large, open incisions to remove bone and the use of internal fixation to attempt to fuse dislocated joints. Such operations can result in shortening of the foot and/or incomplete deformity correction, fixation failure, incision healing problems, infection, and the long-term use of casts or braces. We recommend a minimally invasive surgical technique for the treatment of Charcot deformity, which we performed on 11 feet in 8 patients. Osseous realignment was achieved through gradual distraction of the joints with external fixation, after which minimally invasive arthrodesis was performed with rigid internal fixation. Feet were operated on at various stages of Charcot deformity: Eichenholtz stage I (1 foot), Eichenholtz stage II (6 feet), and Eichenholtz stage III (4 feet). When comparing the average change in preoperative and postoperative radiographic angles, the transverse plane talar-first metatarsal angle ($P = .02$), sagittal plane talar-first metatarsal angle ($P = .008$), and calcaneal pitch angle ($P = .001$) were all found to be statistically significant. Complications included 3 operative adjustments of external or internal fixation, 4 broken wires or half-pins, 2 broken rings, and 11 pin tract infections. Most notably, no deep infection, no screw failure, and no recurrent ulcerations occurred and no amputations were necessary during an average follow-up of 22 months. Gradual Charcot foot correction with the Taylor spatial frame plus minimally invasive arthrodesis is an effective treatment.


The consequences of Charcot neuroarthropathic joint dislocation and subluxation and osseous destruction are a perplexing challenge to the foot and ankle surgeon. Although several disease processes are associated with Charcot deformity, the most common cause in the United States is diabetes mellitus. The prevalence of Charcot deformity is variable, ranging from 0.15% of all patients with diabetes to as high as 2% in a population of neuropathic diabetic patients (1). The resultant osseous deformities produce abnormal pedal pressures that increase the risk for foot ulceration, osteomyelitis, and ultimately amputation.

Treatment of Charcot neuroarthropathy often is based on the stage at which the deformity presents. The most common classification system, the Eichenholtz system, divides Charcot neuroarthropathy into 3 stages: developmental, coalescent, and reconstructive (2). Moreover, acute Charcot events historically have been treated with non-weight-bearing immobilization by using total contact casting until the foot has calmed down (1, 3). Subsequently, the feet collapse and are difficult to accommodate, even with custom molded shoes and orthotics. Ulceration and osteomyelitis commonly occur, resulting in the need for surgical reconstruction or amputation (3). More recently, surgical reconstruction of the Charcot foot and ankle has gained increasing popularity (4–10). In clinical practice, Charcot reconstructive surgery typically is performed during Eichenholtz stages II or III. Historically, large, open incisions were used to remove the excess bone and perform open reduction with internal fixation (4, 5, 7, 8). Screw fixation and/or plantar plating were performed in an attempt to fuse and stabilize the joint. Those procedures often resulted in nonanatomic correction with occasional neurovascular and soft tissue compromise, infection, and prolonged casting or bracing.

During the last decade, important advances have been made in external fixation, especially regarding its use in deformity correction. The improved technology of gradual deformity correction with use of the Taylor spatial frame (TSF) (Smith & Nephew, Memphis, TN) has tremendously expanded the applications of external fixation in the foot and ankle (11–13). External fixation allows for early weight bearing, joint range of motion, decreased disuse osteoporosis, and

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access to the soft tissues for wound care. Many authors have advocated open Charcot reconstruction for Eichenholtz stage II or III and then application of a static (holding) external fixator (with or without internal fixation, with or without arch wire tension) (5, 9, 10, 14). Recently, it has been reported that Eichenholtz stage I also has been successfully treated with static external fixation (10). We have developed a new minimally invasive 2-stage surgical technique that uses gradual deformity correction with external fixation for reduction of the dislocated and subluxed Charcot joints and then percutaneous arthrodesis.

## Surgical Technique

We prefer gradual deformity correction with external fixation for large deformity reductions of dislocated Charcot joint(s). Gradual external fixation correction allows for multiplanar deformity correction with distraction to realign the dislocated osseous segments. We have found great benefit in distraction/lengthening of the collapsed/dislocated Charcot bones and joints to accurately gain osseous realignment. A stable or coalesced Charcot deformity requires an osteotomy and then gradual correction with external fixation. The osteotomy can be performed with a percutaneous Gigli saw technique. Midfoot osteotomies can be performed across 3 levels (i.e., talar neck and calcaneal neck, cubonavicular osseous level, and cuneocuboid osseous level) (12) (Figure 1). We do not perform a proximal osteotomy across multiple metatarsals with a Gigli saw because we want to avoid additional disturbance to the interossei, the risk of neurovascular injury, and the need to stabilize multiple bones. For an unstable or incompletely coalesced Charcot foot, correction can be obtained by performing gradual distraction and realignment with external fixation through the Charcot joint(s). Despite the radiographic appearance of coalescence, the majority of Charcot deformities can undergo distraction without osteotomy to realign the pedal anatomy. A TSF is applied to gradually distract and realign the Charcot foot; the correction is then maintained by creating minimally invasive arthrodesis of the Charcot joint(s) with rigid internal fixation that is inserted percutaneously. This 2-stage correction is a new technique that was developed by the senior author.

The first stage consists of osseous realignment achieved by performing ligamentotaxis. A TSF forefoot $6 \times 6$ butt-frame (i.e., 2 U-plates connected together at 90° to create a butt joint) construct is applied and provides gradual relocation of the forefoot on a fixed hindfoot. The distal tibia, talus, and calcaneus are fixed with 2 U-plates joined (butt frame) and first mounted orthogonal to the tibia (i.e., 90° to the mid-diaphyseal axis of the tibia) in both the anteroposterior and lateral planes. The U-plate is affixed to the tibia with 1 lateromedial 1.8-mm wire and 2 to 3 other points of fixation (combination of smooth wires or half-pins). For additional stability, a second distal tibial ring can be added, creating a distal tibial fixation block (i.e., 2 tibial rings joined by threaded rods). It is essential to fix the hindfoot in a neutral position; an Achilles tendon lengthening typically is required to achieve a neutral hindfoot position. Each patient is assessed with the Silfverskiöld test before choosing the type of posterior muscle group–lengthening procedure (15). Severe cases of gastrocnemius-soleus equinus required a Z-lengthening of the Achilles tendon to obtain maximum length. The Z-lengthening of the Achilles tendon affords a greater amount of lengthening than a gastrocnemius-soleus or gastrocnemius recession (16). For less severe cases of gastrocnemius-soleus equinus, a gastrocnemius-soleus recession was performed. With the hindfoot manually held in a neutral position, the U-plate is fixed to the calcaneus with 2 crossing 1.8-mm wires. A 1.8-mm medial-lateral talar neck wire also is inserted and fixed to the U-plate. Next, two 1.8-mm stirrup wires are inserted through the osseous segment just proximal and distal to the Charcot joint(s). Stirrup wires are bent 90° just outside the skin to extend and attach but are not tensioned to the respective external fixation rings distant from the point of fixation. The stirrup wires capture osseous segments that are far from an external fixation ring, thereby providing accurate and precise Charcot joint distraction. A full external fixation ring is then mounted to the forefoot with two 1.8-mm crossing metatarsal wires and the aforementioned distal stirrup wire. Digital pinning often is required, whereby the digital wires (1.5 or 1.8 mm) are attached to the forefoot ring. Finally, the 6 TSF struts are placed and final radiographs obtained (anteroposterior and lateral views of the foot to include the tibia). Orthogonal anteroposterior and lateral-view fluoroscopic images are obtained of the reference ring; the images provide the mounting parameters that are needed for the computer planning. The decision as to which ring (distal or proximal) to use as the reference ring is a matter of the surgeon's preference; typically, a distal reference is chosen for foot deformity correction. Superimposition of the reference ring on the final films is critical for accurate postoperative computer deformity planning (www.spatialframe.com). TSF planning is beyond the scope of this article but is critical to fully comprehend before attempting this procedure. In brief, the surgeon enters the deformity and mounting parameters into an Internet-based software that produces a daily schedule for the patient to adjust each of the 6 struts. The rate and duration of the patient's schedule are controlled by the surgeon's data entry. The patient is clinically and radiographically followed up in the office weekly or biweekly.

Creative frame construction is required because of the small pedal anatomy, which renders it difficult to apply external fixation. When applying the forefoot $6 \times 6$ butt frame, it is important to mount the U-plate on the hindfoot and the full ring on the forefoot as posterior and anterior as possible, respectively. The greatest distance of forefoot and hindfoot ring separation is critical to accommodate the TSF struts. Bone segment fixation is important; otherwise, failure of osteotomy separation or incomplete anatomic reduction occurs. Small wire fixation is preferred in the foot because of the size and consistency of the bones. When treating patients with neuropathy, construction of extremely stable constructs is of great importance. External fixation for Charcot deformity correction should include a distal tibial ring with a closed foot ring.

After gradual distraction with the TSF has realigned the pedal anatomy, the second stage is performed. The second-stage surgery consists of 2 parts: minimally invasive arthrodesis of the affected Charcot joints with percutaneous insertion of internal fixation followed by removal of the external fixation. Gradual distraction for realignment of the dislocated Charcot joint(s) is obtained in approximately 1 to 2 months. Before frame removal, small transverse incisions (2-3 cm in length) overlying the appropriate joint(s) are made to perform cartilage removal and joint preparation for arthrodesis. Minimally invasive arthrodesis is easily performed because the Charcot joint(s) are already distracted. The risk of infection is a concern because the fixator is still mounted. However, if the fixator is removed before applying internal fixation, the correction will be lost. To minimize the risk of infection, an alcohol and Betadine solution (Purdue Pharma, Stamford, CT) is sprayed on the external fixator and skin and then a sterile towel is draped over the rings and pins. Under fluoroscopic guidance, the guide wires for the large-diameter cannulated screws are inserted percutaneously through the plantar skin into the metatarsal head by dorsiflexing the metatarsophalangeal joint. After the medial and lateral column guide wires are inserted to maintain the corrected foot position, the frame is removed and the leg and foot are re-prepped. Typically, 3 stainless-steel, cannulated, intramedullary metatarsal screws with an 8-mm or 7-mm diameter are inserted: medial and lateral column partially threaded screws for compression of the arthrodesis site and 1 central fully threaded screw for


**Fig. 1.** Gradual Charcot realignment through osteotomy. Case of midfoot Charcot neuroarthropathy deformity (Eichenholtz stage III, stable, with superficial ulceration and previous malaligned Lisfranc arthrodesis). Lateral-view radiograph shows rocker-bottom and equinus deformities (*A*). Anteroposterior-view radiograph shows midfoot adduction deformity (*B*). Clinical photograph shows a superficial plantar lateral ulceration (*C*). Note the rocker-bottom and equinus deformities shown in the lateral view standing photograph (*D*). Percutaneous Achilles tendon Z-lengthening was performed to realign the hindfoot to a neutral position before applying the external fixator. The lateral view still image, obtained by using video fluoroscopy, confirms the acute hindfoot correction. Complete equinus correction was therefore achieved acutely (*E*). Gigli saw was passed across the cuneiforms and cuboid through 4 percutaneous incisions (*F*). Osteotomy was then performed. To ensure completion of the osteotomy, manual forefoot traction was applied. Note the two 1.8-mm wires placed just adjacent (1 distal and 1 proximal) to the osteotomy; these are called *stirrup wires*. Stirrup wires are then bent 90° back to their respective ring and fixed to ensure focused distraction (*G*). Taylor spatial frame (forefoot 6 × 6 butt) was applied and used for gradual distraction and realignment of the forefoot on a fixed hindfoot. The postoperative anteroposterior-view radiograph shows the stirrup wires adjacent to the osteotomy (*H*). Lateral view postoperative radiograph shows the midfoot osteotomy with the external fixator in place (*I*). Lateral-view radiograph obtained after gradual distraction shows complete consolidation of the osteotomy. The fixator was ready to be removed (*J*). Note the corrected foot position just before removal of the fixator. Immediately after removal of the external fixator, a minimally invasive fusion of the midtarsal joint was performed to prevent future Charcot foot collapse (*K*). Weight bearing lateral view (*L*) and anteroposterior view (*M*) postoperative radiographs show 3 percutaneous intramedullary metatarsal screws that were inserted for stabilization of the osteotomy and fusion of the midtarsal joint. Note the accurate anatomic reduction. Lateral view postoperative photograph of the patient during weight bearing shows a plantigrade foot (*N*). Clinical photograph shows no plantar ulceration (*O*). The patient has not experienced recurrence of ulceration or deformity during a 3-year follow-up. (Figure and legend reprinted with permission. © 2010, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Baltimore, MD)

stabilization. These screws span the entire length of the metatarsals to the calcaneus and talus, provide compression across the minimally invasive arthrodesis site, and stabilize adjacent joints. The intramedullary metatarsal screws cross an unaffected joint, the Lisfranc joint, thereby protecting the Lisfranc joint from experiencing a future Charcot neuroarthropathic event. We prefer to maximize screw diameter and length to fill the metatarsal canal. We insert the land of the screw at the distal metaphyseal-diaphyseal junction (neck) of the metatarsal. By maximizing both the diameter and the length of the intramedullary screw, we feel this maximizes stability and follows intramedullary fixation principles. The minimally invasive incisions are then closed, and a well-padded U and L splint is applied. Before hospital discharge (length of hospital stay ranges from 1-4 days), the patient's operative splint and dressing are removed and a short leg cast applied. Incisions are evaluated before application of the short leg cast. The non-weight-bearing short leg cast is maintained for 2 to 3 months, and then gradual progression to weight bearing is achieved. Therefore, the entire treatment is completed in 4 to 5 months (Figure 2).

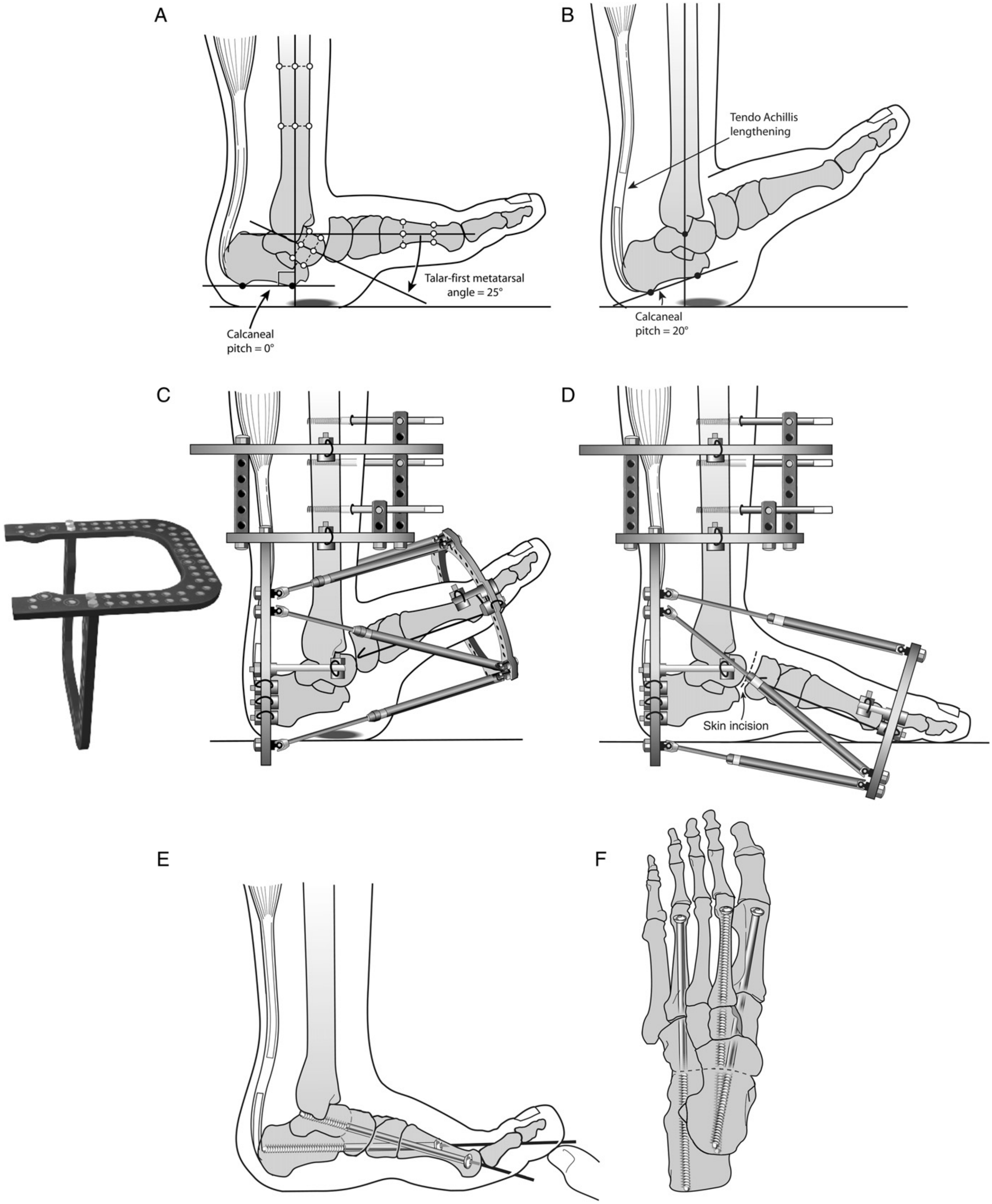


**Fig. 2.** Gradual Charcot realignment through joint distraction. Illustration of a midfoot Charcot neuroarthropathy with equinus deformity (Eichenholtz stage II or III, with ulceration). Lateral view shows equinus (calcaneal pitch, 0°) and rocker bottom (talar-first metatarsal angle, 25°) (*A*). Percutaneous Achilles tendon Z-lengthening is performed to acutely correct the equinus deformity. (*B*). The hindfoot and ankle are then fixed in the corrected position with the Taylor spatial frame (forefoot 6 × 6 butt). Then the forefoot is fixed to the distal foot ring. Note the initial forefoot position (*C*). Gradual distraction (5-15 mm) and realignment of the forefoot to the hindfoot are performed with the fixator. Just before fixator removal, a minimally invasive fusion of the midtarsal joint is performed (*D*). After inserting the percutaneous guide wires for the large-diameter cannulated screws, the fixator is removed. Partially threaded intramedullary metatarsal cannulated screws are inserted beneath the metatarsal head percutaneously to compress both the medial and lateral columns of the foot (*E*). Anteroposterior view shows a third fully threaded screw inserted to increase midfoot stability. Note the accurate anatomic reduction, restoration of foot length, healed ulceration, and preservation of the subtalar and ankle joints (*F*). (Figure and legend reprinted with permission. © 2010, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Baltimore, MD)

**Patients and Methods**

We reviewed a series of 8 patients (11 feet) who underwent minimally invasive realignment surgery for reconstruction of Charcot foot deformity at the Rubin Institute for Advanced Orthopedics. Data regarding the patients were collected during a 3-year period (November 2003 to July 2006). The patients were diagnosed with peripheral neuropathy and Charcot foot. Eleven feet with midfoot Charcot deformity, with or without subtalar Charcot deformity, underwent minimally invasive realignment surgery via a 2-stage approach (gradual realignment with external fixation and then minimally invasive arthrodesis with rigid internal fixation). Patients with Charcot deformity of the Lisfranc and ankle joints were excluded because these deformities result in different pathologies. We do not typically treat Lisfranc Charcot with this method because it does not require treatment with external fixation.

A complete review of the medical charts and radiographic angular measurements was conducted preoperatively and postoperatively. In addition to demographic information, the following data were recorded: stage and location of Charcot deformity, time in external fixation, time to fusion (via radiographic evaluation of one senior author), time to return to normal shoe gear, and complications. Anteroposterior, lateral, and oblique views of the foot or ankle and long leg calcaneal axial and Saltzman views were obtained. Postoperative radiographs were reviewed to assess osseous union. Radiographic angular measurements were recorded, including calcaneal pitch, talar-first metatarsal (sagittal and transverse planes), hindfoot alignment, and Kite's angles. The preoperative and postoperative angles were averaged and compared by using the paired samples *t* test. The level of significance was defined at the 5% ($P \leq .05$) level. The prevalence of complications (nonunions, additional surgery, pin tract infections, deep infections, recurrent ulceration, and hardware failure) was calculated.

## Results

A statistical description of the case series is shown in Table 1. Eight patients with an average age of 61 years (range, 41-79 years) underwent minimally invasive Charcot realignment surgery of 11 feet. The case series consisted of 5 (62.5%) women and 3 (37.5%) men with an average height of 1.1 m and average weight of 93 kg. The average body mass index was 33.6 kg/m$^2$. Three (27.3%) feet had Charcot deformity of the midtarsal joint and the subtalar joint, and 8 (72.7%) feet had Charcot deformity of the midtarsal joint only. All patients were preoperatively diagnosed with gastrocnemius-soleus equinus. Three (27.3%) extremities underwent gastrocnemius-soleus recession, and 8 (72.7%) extremities underwent percutaneous Z-lengthening of the Achilles tendon. The following complications were observed in the operated extremities: 0 nonunions, 3 (27.3%) additional operations (2 [18.2%] for adjustment of intramedullary metatarsal screws and 1 [9.1%] for exchange of an external fixation half-pin), 4 (36.4%) broken wires or half-pins, 2 (18.2%) broken rings, 0 deep infections, and 11 (100%) pin tract infections. The average time in external fixation was 12 ± 8 weeks (range, 5-30 weeks). Time for radiographic fusion averaged 16 ± 9 weeks (range, 6-28 weeks) after the minimally invasive arthrodesis (second-stage surgery). The average time to return to normal shoe gear (custom molded shoes with orthosis) was 22 ± 11 weeks (range, 8-37 weeks) after the second-stage surgery. Follow-up time averaged 22 ± 10 months (range, 6-36 months). Antibiotics were orally administered to all patients during the distraction with the TSF (first stage) as needed. No patients required intravenous antibiotics or admission into the hospital for a pin site infection. Typically, the oral antibiotic used was 500 mg of cephalexin 4 times per day for a 10-day course. For patients with penicillin allergies, 300 mg of clindamycin 3 times per day was prescribed.

The average preoperative and postoperative radiographic angular measurements are shown in Table 2. The average changes shown by the preoperative and postoperative radiographs were 18° ± 22° in the transverse talar-first metatarsal angle, 21° ± 21° in the sagittal talar-first metatarsal angle, 15° ± 12° in the calcaneal pitch angle, and 4° ± 18° in the hindfoot alignment angle. Paired *t* tests compared the preoperative and postoperative radiographic angular measurements. The radiographic angles found to be statistically significant included the transverse plane talar-first metatarsal angle ($P = .02$), sagittal plane talar-first metatarsal angle ($P = .008$), and calcaneal pitch angle ($P = .001$).

**Table 1**
Statistical description* of the case series (N = 11 feet in 8 patients)

| Risk factor or exposure | Result |
|---|---|
| Age (years) | 61 ± 12 (range, 41-79) |
| Sex | |
| Male | 5 (62.5) |
| Female | 3 (37.5) |
| BMI (kg/m$^2$) | 33.6 ± 13 |
| Eichenholtz category of Charcot foot | |
| I | 1 (9.1) |
| II | 6 (54.5) |
| III | 4 (36.4) |
| Location of Charcot breakdown | |
| Midtarsal and subtalar | 3 (27.3) |
| Midtarsal only | 8 (72.7) |
| Preoperative gastrocnemius-soleus equinus | 11 (100) |
| Adjunctive procedures | |
| Gastrocnemius recession | 3 (27.3) |
| TendoAchilles lengthening | 8 (72.7) |
| Complications | |
| Nonunion | 0 |
| Adjust metatarsal screw | 2 (18.2) |
| Exchange half pin | 1 (9.1) |
| Broken wire or half pin | 4 (36.4) |
| Broken ring | 2 (18.2) |
| Deep infection | 0 |
| Pin tract infection | 11 (100) |
| Time in external fixation (weeks) | 12 ± 8 (range, 5-30) |
| Time to radiographic fusion (weeks) | 16 ± 9 (range, 6-28) |
| Time to return to normal shoes (weeks) | 22 ± 11 (range, 8-37) |
| Duration of follow-up (months) | 22 ± 10 (range, 6-36) |

BMI, body mass index.
* Results depicted as mean ± standard deviation for continuous numeric data, or count (%) for categorical data.

## Discussion

With acute correction achieved by using internal fixation or static external fixation, precise deformity correction must be obtained at the time of surgery and cannot be altered during the postoperative period. However, gradual distraction with external fixation allows for adjustments during the postoperative course to ensure accurate realignment for the large Charcot deformity. Our new minimally invasive gradual deformity correction technique avoids previous incisions, limits neurovascular compromise (in that the correction occurs slowly over time), reduces the risk of infection because the technique is minimally invasive, allows for accurate anatomical correction without loss of foot length or bone mass, provides the ability to be partial weight bearing, and offloads wounds.

Our new technique follows the surgical principle of first obtaining correction and then maintaining correction. The first stage of our technique obtains correction through gradual distraction and realignment with external fixation, namely the TSF in the patients described in this report. The second stage maintains correction with

**Table 2**
Radiographic angular measurements (N = 11 feet in 8 patients)

| Angular measurement (°) | Preoperative | Postoperative | *P* value* |
|---|---|---|---|
| Transverse plane | | | |
| Kite's angle | 19 ± 7 | 16 ± 4 | .105 |
| Talar-first metatarsal | 19 ± 21 | 1 ± 6 | .02 |
| Sagittal plane | | | |
| Calcaneal pitch | 0 ± 12 | 16 ± 8 | .001 |
| Talar-first metatarsal | 21 ± 21 | 0 ± 6 | .008 |
| Frontal plane | | | |
| Hindfoot alignment | –4 ± 20 | 0 ± 3 | .468 |

* Paired samples *t* test.

fusion at the time of fixator removal by using minimally invasive arthrodesis techniques. Percutaneous Achilles tendon lengthening or gastrocnemius-soleus recession almost always is performed in conjunction with the initial operation.

The most notable results of this study were that none of the 11 feet experienced recurrent ulceration after undergoing the outlined surgical technique. In addition, all feet were plantigrade with no deep infections at an average follow-up of 22 months. No amputations were performed in our series. Additional surgery was performed on 3 feet for minor adjustment of internal or external fixation. Although intramedullary metatarsal screws look simple to insert, they can be challenging when multiple screws are used. Despite frequent hardware failure in this patient population, no intramedullary metatarsal screw failure occurred in our series. Radiographic time to fusion was 16 weeks in our study, which is comparable with times reported in the literature (reported range, 12-18 weeks) (5, 10). The average time to return to normal shoe gear was 22 weeks after arthrodesis (second-stage surgery), which is less than the literature reports (48 weeks) (3).

The radiographic angles found to be statistically significant were the talar-first metatarsal angle in the transverse plane and the talar-first metatarsal angle and calcaneal pitch angle in the sagittal plane. These significant radiographic angular changes represent the presence of ankle equinus, rocker-bottom foot, and transverse forefoot deformity in all Charcot feet studied.

Our current protocol has evolved to limit the patient's total treatment time. Typically, we allow for gradual distraction for realignment of the dislocated Charcot joints during a period of 1 to 2 months. During the second-stage surgery, minimally invasive Charcot joint arthrodesis is performed by using rigid percutaneously inserted internal fixation (intramedullary metatarsal screws) followed by removal of the external fixation. A short leg cast and non-weight-bearing are maintained for 2 to 3 months, and then progression to weight bearing is achieved. Therefore, the entire treatment is completed in 4 to 5 months.

Currently, the literature is devoid of gradual realignment correction of the Charcot foot with external fixation. This novel, minimally invasive surgical approach to Charcot foot deformities has been used for 8 years at our institute. This study of the early results (2003-2006) of this method provides evidence that our new minimally invasive realignment surgery, consisting of gradual osseous correction with external fixation and then maintenance of correction via arthrodesis with rigid internal fixation, is an accurate and reliable treatment modality for Charcot foot deformities. This technique allows for anatomic reduction, rigid internal stabilization, and restoration of the foot position (plantigrade foot) and foot length for improved shoeing and prevention of ulceration, infection, and subsequent amputation, as shown in the short term (2 years). Our short-term results are very encouraging considering that neither recurrent ulceration nor deep infection has occurred. We anticipate that this minimally invasive technique will also enhance patients' quality of life for the long term.

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