# Computer-Assisted Gradual Correction of Charcot Foot Deformities: An In-Depth Evaluation of Stage One of a Planned Two-Stage Approach to Charcot Reconstruction


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## Statement of Purpose

The surgical treatment of Charcot foot deformities is a widely debated topic with issues ranging from when to operate to how to properly correct an abnormality. Historically, correction of a severe deformity was attempted in one acute surgical procedure that frequently required open reduction and internal fixation through large incisions. This one-time procedure would often result in complications including under or over correction of the deformity, neurovascular injury, or incision dehiscence leading to possible soft tissue infection or osteomyelitis. This retrospective case series aimed to evaluate stage one of a planned two-stage approach to Charcot deformity correction, consisting of gradual modification with the use of computer-assisted external fixation.

## Introduction

Charcot neuroarthropathy is a systemic disease that generates pathological changes in the musculoskeletal system and can lead to breakdown of the bones, joints, and soft tissues of the foot and ankle[1,2]. If left untreated, Charcot can become a limb threatening condition. The goal of surgical treatment for severe Charcot deformities is to obtain a stable, plantigrade foot free of ulcerations[3,4]. Reportedly, however, 50%-80% of Charcot reconstructions fail[5]. Nevertheless, recent literature describes a potentially successful two-stage approach to Charcot reconstruction involving gradual correction of large, complex deformities followed by internal fixation[6-8]. This staged method allows for more accurate deformity correction while providing less risk to neurovascular and soft tissue structures, considering there is a roughly 40% prevalence of peripheral arterial disease in patients with CN[9].

This study focuses on stage one, the gradual correction phase. The primary aim of the investigation is to evaluate the ability to correct the Meary's and calcaneal inclination angles radiographically to within a normal range with few postoperative complications using gradual correction. The secondary goal is to evaluate ulceration healing during this stage.

## Case Series

*Methods*

A retrospective chart review was performed to obtain patient information and radiographic data. From 2011 to 2018, eighteen patients (18 feet) with severe, complex Charcot foot deformities underwent a planned, two-stage surgical reconstruction at a single institution. The use of computer-assisted external fixation was employed in stage one followed by the implementation of rigid internal fixation during stage two.

Digital radiographic measurements of Meary's and calcaneal inclination angles were performed using preoperative lateral weight-bearing x-rays[10,11]. Post-correction radiographs contained external fixation devices holding the foot in a static position with no ability to obtain a standard weight-bearing radiograph. Measurements could still be taken appropriately, however, following adequate correction (**Fig. 1**). Detailed descriptive statistics were calculated for each angle measurement, and a two-tailed t-test was performed to evaluate for possible statistical significance regarding the mean change of the Meary's and calcaneal inclination angles preoperatively compared to post-correction.

Existence of ulceration was determined clinically and found to be present on the feet of 13 of the 18 patients prior to undergoing the procedure.

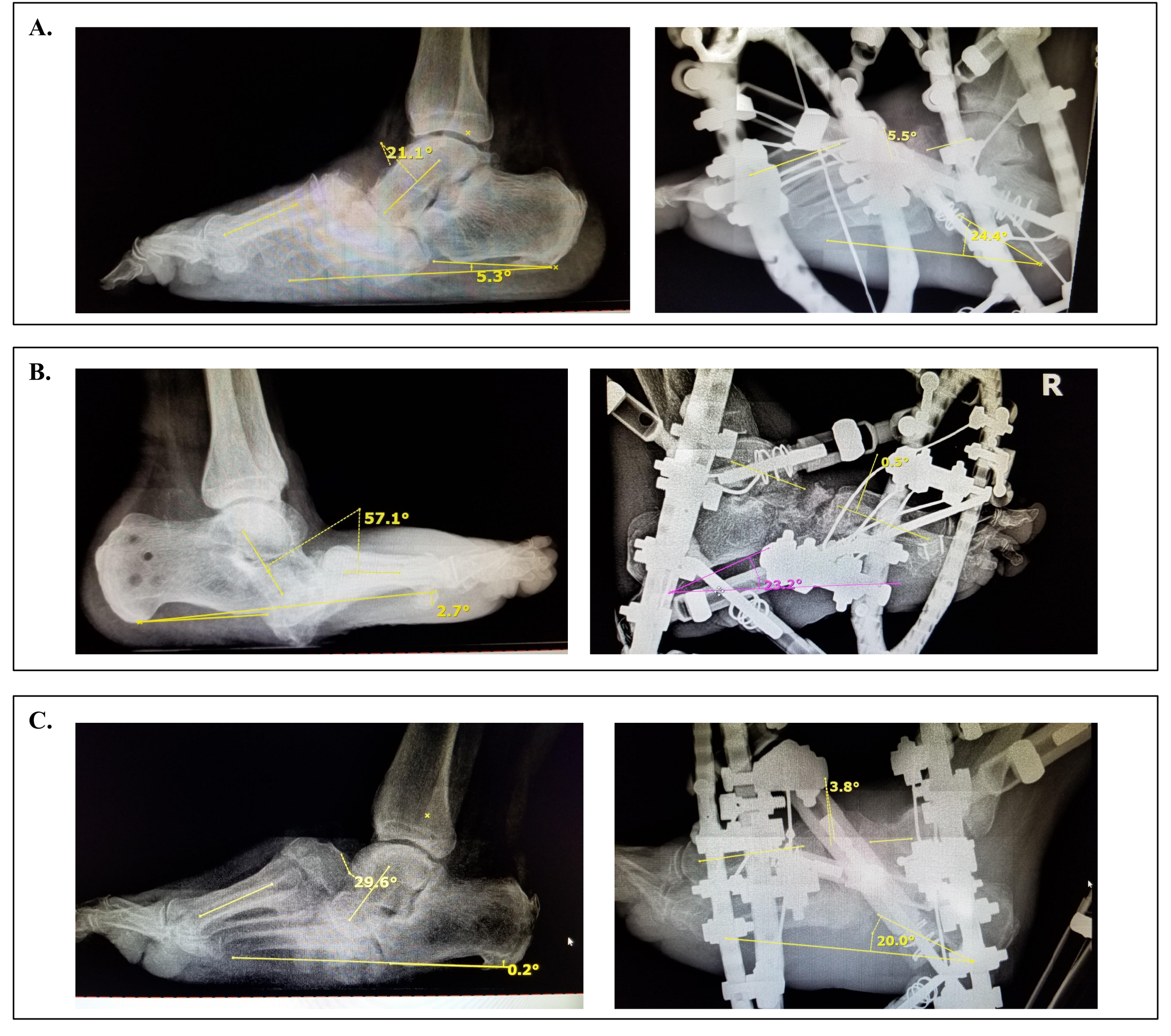


**Figure 1** A-C: Preoperative and post-correction Meary's and calcaneal inclination angle measurements shown on digital lateral weight-bearing radiographs before and after computer-assisted gradual deformity correction was employed using external fixation. Preoperative radiographs show severe, rigid joint subluxation and foot shortening.

*Surgical Technique*

The senior author (PW) performed the planned, two-stage reconstruction procedures as described by Lamm et al. with stage one consisting of the application of a Hexapod external fixation device for computer-assisted gradual correction[5]. The frame constructs were built intraoperatively, specific to each patient's deformity.

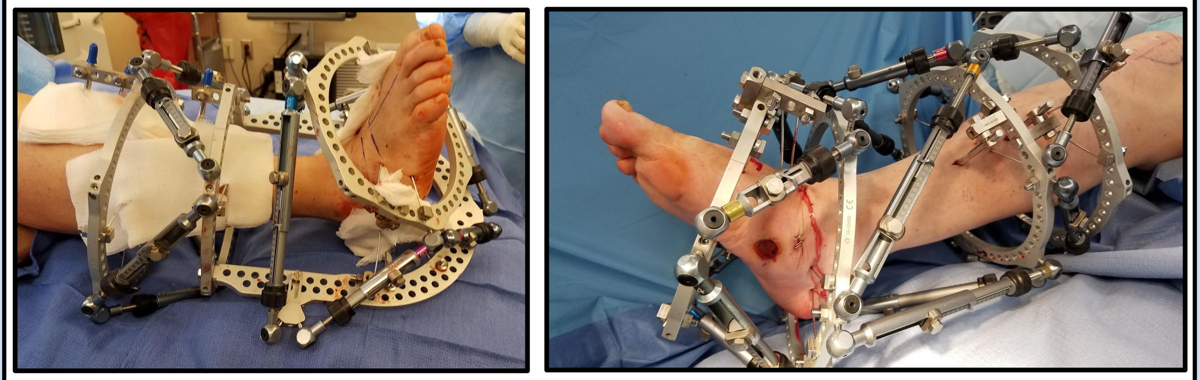

**Figure 2** External Fixation Constructs. Examples of hexapod frame constructs for computer-assisted gradual correction of severe Charcot foot deformities.

Moderate to severe deformities limited to the midfoot received a butt frame configuration, and more complex deformities with multiple rearfoot and/or midfoot irregularities received a miter frame[11] (**Fig. 2**).

Patients were placed in the supine position and underwent general anesthesia for the procedure. Posterior heel cord lengthening was achieved prior to the application of the external fixation device by performing a percutaneous triple hemi-section tendo-Achilles lengthening on all patients, secondary to gastrocnemius-soleal equinus. The external fixation device was then applied[12,13].

For patients with a severe bony coalescence, an osteotomy was necessary. This was performed with a gigli saw following application of the external fixation device[14] (**Fig. 3**). The use of a hexapod device was paramount, as its unique design and accompanying software enabled adjustments to be made in all three axes simultaneously using the intricate concept of projective geometry. Following each device application, the deformity parameters, the relationship of the Hexapod to the deformity or osteotomy, and the size of the hexapod and struts were input into the software program. This helped to determine the speed of correction based on the structures at risk and calculate the necessary daily strut adjustments required for accurate correction[15,16] (**Fig. 4**).

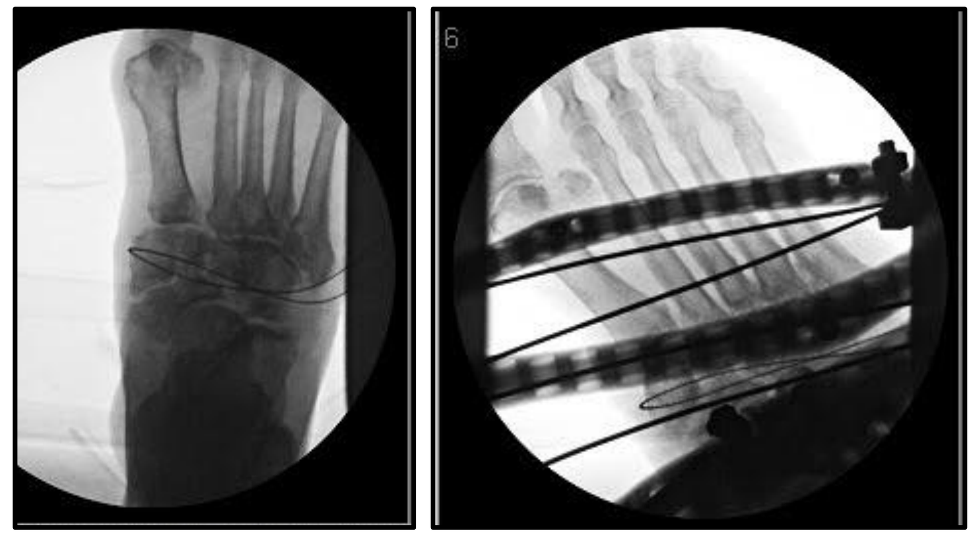

**Figure 3** Percutaneous Gigli Saw Technique. The saw is inserted percutaneously through four 1-centimeter incisions around the midfoot prior to application of the external fixation device. The osteotomy is performed following stabilization of the limb with external fixation.

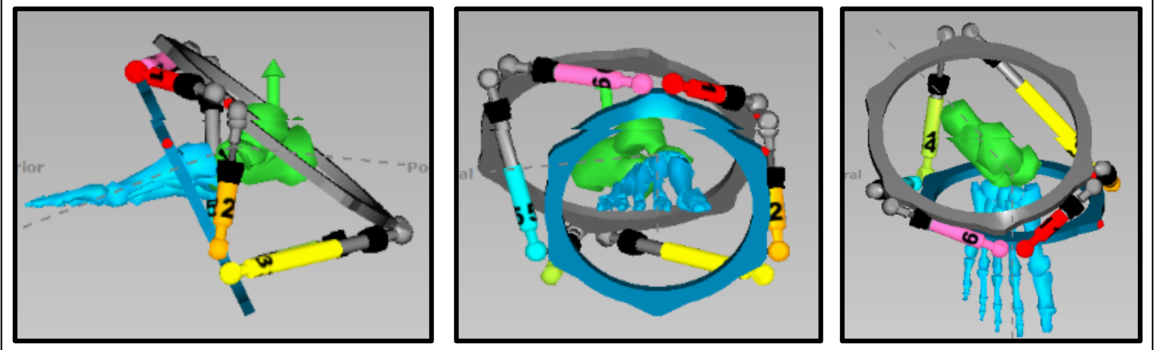

**Figure 4** Computer-Assisted Gradual Correction. Example of internet-based software program that allows the surgeon to calculate an accurate rate of correction for each specific deformity. This gradual correction takes place in all three planes (x,y,z) simultaneously following data input.

Complete correction was defined as Meary's and calcaneal inclination angles that were within a normal range. For Meary's angle, this range was 0-15 degrees and for the calcaneal inclination angle the range was 8.5-30 degrees[11,17]. Following sufficient correction, the hexapod device was left in place for an additional 4-6 weeks in order for the bone to coalesce and for the soft tissues to acclimate to their new position. The device was then removed, and rigid internal fixation was implanted in stage two of the two-stage approach.

*Results*

**Table 1**

Patient Demographics and Information (N=18 patients, 18 feet)

| Mean Age (years) | Sex | Laterality | Ulceration Present | Gastroc-Soleal Equinus[18] | Charcot Deformity Location | Eichenholtz Classification Stage[19] |
|---|---|---|---|---|---|---|
| 60.0 | 77.8% Male | 55.6% Right | 72.2% | 100% | 88.9% Midfoot<br>11.1% Rearfoot | Stage 1: 0%<br>Stage 2: 16.7%<br>Stage 3: 83.3% |

**Table 2**

Perioperative Findings (N=18 patients, 18 feet)

| Mean Days in Ex-Fix | Problems | Complications | Ulceration Healed | Mean Follow-up (Months) |
|---|---|---|---|---|
| 66.0 | 22.2% (pin tract infections) | 0% | 100% | 39.6 |

**Table 3**

Mean Comparison of Preoperative vs. Post-Correction Angles (N=18 patients, 18 feet)

| | Pre-op Meary's Angle (Degrees) | Post-correction Meary's Angle (Degrees) | Pre-op Calc Inclination Angle (Degrees) | Post-correction Calc Inclination Angle (Degrees) |
|---|---|---|---|---|
| Mean | -27.9 | 2.4 | 4.5 | 23.1 |
| Standard Deviation | 13.5 | 2.0 | 8.4 | 5.3 |
| Range | -55.0 to 0.0 | 0.0 to 6.0 | -19.0 to 14.6 | 10.0 to 31.0 |
| Median | -29.0 | 2.5 | 4.9 | 24.5 |
| Two-tailed Distribution | p-value = << 0.05 | | p-value = << 0.05 | |

## Analysis & Discussion

This case series aimed to demonstrate reproducibility of stage one of Lamm's previously described two-stage approach to Charcot reconstruction, to show correction of the Meary's and calcaneal inclination angles to within a normal range, and to illustrate ulceration healing. To this point, outcomes have been shown to be similar in regards to complete ulceration healing, few postoperative problems, no complications, and statistical significance of the mean correction of the Meary's and calcaneal inclination angles to within a normal range.

To our knowledge, the present case series is the largest to date focusing on gradual Charcot deformity correction with the use of computer-assisted external fixation. Stage two of the procedure will need to be examined in detail, and subsequent studies will need to be performed to determine if these corrections were maintained over time and the frequency in which limb salvage was able to be achieved (**Fig 5**).

**Figure 5** Clinical Correction Goal. Left: Preoperative photo emphasizing severe valgus deformity. Right: Postoperative photo following gradual correction with computer-assisted external fixation followed by implantation of rigid internal fixation showing significant amount of correction to achieve a stable, plantigrade foot.

This series shows that stage one of a two-stage approach to Charcot reconstruction can be accomplished successfully by gradual deformity correction with the use of computer-assisted external fixation. These results not only build on the work of Lamm et al., but they indicate that gradual deformity correction may be the safest and most effective approach when it comes to Charcot reconstruction. We hope to ultimately find a consensus gold standard method for correction of complex Charcot deformities.

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