
Treatment of Charcot Midfoot Deformity by Arthrodesis Using Long Axial Screws

10

V. James Sammarco

Introduction

Management of Charcot foot deformity in diabetics is particularly challenging because of the effects that diabetes mellitus has on multiple organ systems. There is a “perfect storm” of mechanical and biologic problems, which often leads to poor outcome in these patients. Peripheral neuropathy leads to loss of protective sensation and autonomic dysfunction, which can lead to ulceration. Even minor trauma can lead to fracture and dislocation in the foot, which may go unnoticed by the patient until a severe deformity occurs. Once the normal weight bearing architecture of the foot is lost, bony prominences increase local pressures and cause a breakdown of the soft tissue envelope. Impaired immune capability due to decreased macrophage function in glycosylated tissues makes infection more likely and also more difficult to eradicate. Atherosclerosis of both large and small vessels often accompanies diabetes and significantly complicates matters by decreasing arterial perfusion. These factors combined with poor cardiac function, venous stasis, obesity and the patients’ inability to remain non-weight bearing, combine to make complications

frequent. For these reasons, diabetes and related complications continue to be the leading cause of amputation in the United States with an estimated 70,000 amputations per year [1].

Conservative care of the Charcot foot consisting of offloading of ulcers with contact casting and accommodative bracing remains the mainstay of treatment. Traditionally, surgery was reserved for those cases that presented with recurrent ulceration and usually consisted of an exostectomy. Early surgical series, where surgical correction of severe deformity was done with midfoot arthrodesis, provided little evidence that a more aggressive surgical approach provided better long-term results than nonoperative care. These series used standard fixation techniques such as crossed screws, Kirschner wires, and simple neutralization plates. Complications were frequent including loss of fixation, hardware failure, and recurrence of deformity [2].

More recently, studies have questioned the validity of delaying surgical correction of progressive neuroarthropathic deformity. Saltzman and colleagues retrospectively evaluated 115 patients treated over a twenty year period [3]. One hundred and twenty seven limbs were treated with a standardized clinical protocol that emphasized nonsurgical care. Forty-seven percent of patients required extensive bracing that lasted more than 18 months and the risk of recurrent ulceration was 40 %. These authors concluded that even diligent nonsurgical treatment

V.J. Sammarco, M.D. (✉)
Reconstructive Orthopaedics and Sports Medicine,
Cincinnati, OH, USA
e-mail: vjsammarco@gmail.com

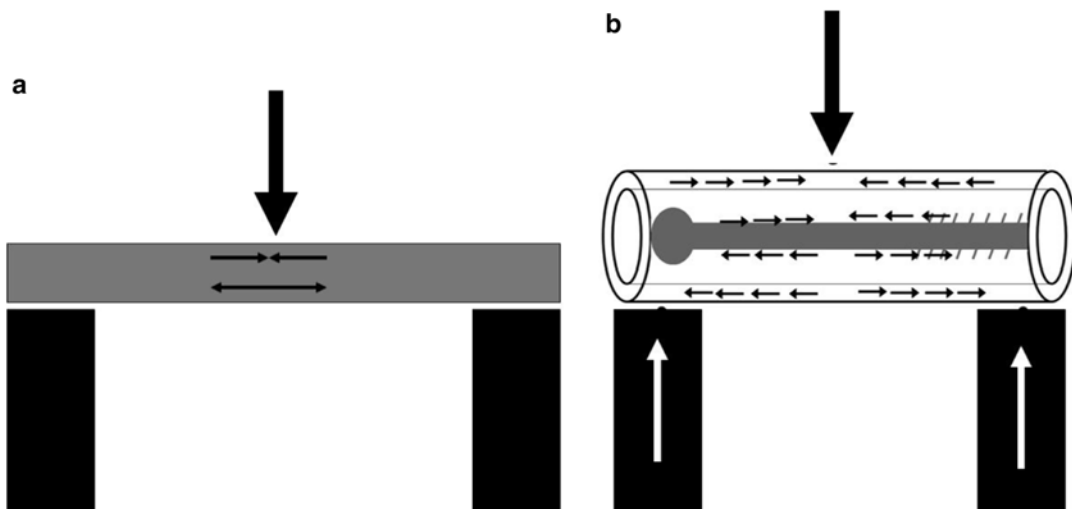


Fig. 10.1 (a) In a beam model of the foot, force applied centrally in the beam will generate tensile forces plantarly and compressive forces dorsally. (b) Screws applied axially will share compressive and tensile forces to resist deformation

can be associated with poor outcome and that better methods of treatment were necessary. Simon and colleagues reported on early surgical intervention in patients with Charcot midfoot neuroarthropathy in Eichenholtz stage I disease [4]. Fourteen patients were treated with midfoot arthrodesis. Successful results were reported for all patients. All patients returned to functional ambulation with standard diabetic and off-the-shelf shoe wear. No recurrent deformity or ulceration was reported. These and other studies suggest that corrective surgical treatment may be associated with better functional outcome than a plan which emphasizes nonsurgical care [5].

Techniques have evolved to correct Charcot midfoot deformity: plantar plating, locked plating, and axial screw fixation. The axial screw technique was developed as a method to improve fixation and stability in patients undergoing reconstruction for Charcot midfoot disease. We coined the term “superconstruct” to describe fixation techniques specifically designed for these challenging Charcot midfoot cases [6]. A superconstruct is defined by four factors: (1) fusion is extended beyond the zone of injury to include joints that are not affected to improve fixation,

(2) bone resection is performed to shorten the limb to allow for adequate reduction of deformity without undue tension on the soft tissue envelope, (3) the strongest device is used that can be tolerated by the soft tissue envelope, and (4) the devices are applied in a position that maximizes mechanical stability.

Axial screw fixation involves the placement of intraosseous screws which span the area of deformity and fix the proximal and distal fusion segments. Screws are placed such that they bridge the zone of dislocation from the intramedullary canals of the metatarsals and extending into the less compromised bone proximally. Larger diameter screws can be used without creating stress risers in the metatarsal shafts as occurs when transcortical screws are used. The intraosseous position of the screws aids in realignment of the foot. The procedure can be done through a more limited approach with less osseous stripping than is needed for plating, and the intraosseous position diminishes the risk of exposed hardware in the event of poor wound healing compared to other techniques. Biomechanically, the screws act as load sharing devices similar to steel rebar in concrete (Fig. 10.1).

Indications

The indications for surgical reconstruction of the Charcot foot are relative and must be balanced with the patient's overall health, circulatory status, their ability to control blood glucose levels, and in their ability to comply with extended periods of non-weight bearing. Diabetic medical comorbidities including cardiac disease, renal disease, and peripheral edema can contribute to poor wound healing and infection. Therefore, medical optimization by the patient's internal medicine physician is necessary prior to proceeding with surgery. In addition, peripheral arterial disease, in particular, is problematic and warrants formal evaluation with arterial Doppler examination if pulses are weak or absent. Transcutaneous oxygen perfusion can be measured as an excellent indicator of wound healing potential. If there is poor perfusion of the foot, the patient should be evaluated for revascularization by a vascular interventionist or surgeon.

Charcot midfoot deformity has been classified by Sammarco and Conti [7] and by Schon et al. [8]. Both classifications are anatomic and are based on the level of dislocation with some variation between the two. The Schon classification is subdivided with a separate designation (Beta) for cases where the deformity is severe, or where the midfoot is dislocated (Table). Schon also presented a clinical classification system with Grade C being a rocker bottom foot deformity.

We consider the indications for surgical correction of neuropathic foot deformity by midtarsal osteotomy and arthrodesis to be: (1) Patients with a non-plantigrade foot (Schon Type C) who have recurrent ulcerations despite conservative management, (2) Radiographs demonstrating a Schon type beta severity, and (3) Patients with gross instability or progression of deformity despite immobilization and casting. Ideally, patients undergoing an arthrodesis with internal fixation should be infection and ulcer free. Often Wagner Grade 1 and 2 ulcers can be effectively resolved with a period of contact casting and/or non-weight bearing. If osteomyelitis is present, or if ulcers do not show signs of healing with simple off-weighting, we prefer a staged procedure with external fixation. In the absence of

ulceration, surgery can be done once medical clearance has been obtained. In the presence of significant edema, reduction of swelling by off-weighting the foot, immobilization in a cast or boot walker, and judicious use of an Unna boot wrap can improve the soft tissue envelope preoperatively.

Surgical Technique

The minimal equipment needed to perform this technique includes: (1) An image intensifier, (2) A microsagittal saw, for bone resection, and (3) Reduced head or headless cannulated screws. Multiple long length screws (up to 120 mm) should be available. A variety of diameter screws should also be available ranging from 4.0 to 8.0 mm.

The patient is positioned supine on a beanbag to allow the operative leg and the body to be supported to correct for external rotation of the leg so that foot is perpendicular to the operating table. This allows better access to the lateral aspect of the foot. A pneumatic tourniquet is placed around the proximal thigh. The leg is prepped and draped above the knee. The ankle can then be supported by stacked towels or a bump under the leg to facilitate fluoroscopy.

An equinus deformity is invariably present and must be aggressively corrected prior to performing the midfoot correction. An intraoperative Silfverskiold's test is performed and if positive, a gastrocnemius recession is done. Alternately, a three-step tendo Achilles lengthening can be performed of the deformity if equinus is present with the knee in knee flexion and extension. However, both procedures may be necessary if the equinus deformity is rigid and fixed. The goal is to achieve 10°–15° of ankle dorsiflexion with the knee in full extension.

Approach

The approach is tailored to the level of the dislocation. Longitudinal incisions are made medially, dorsally, and laterally as needed (Fig. 10.2).

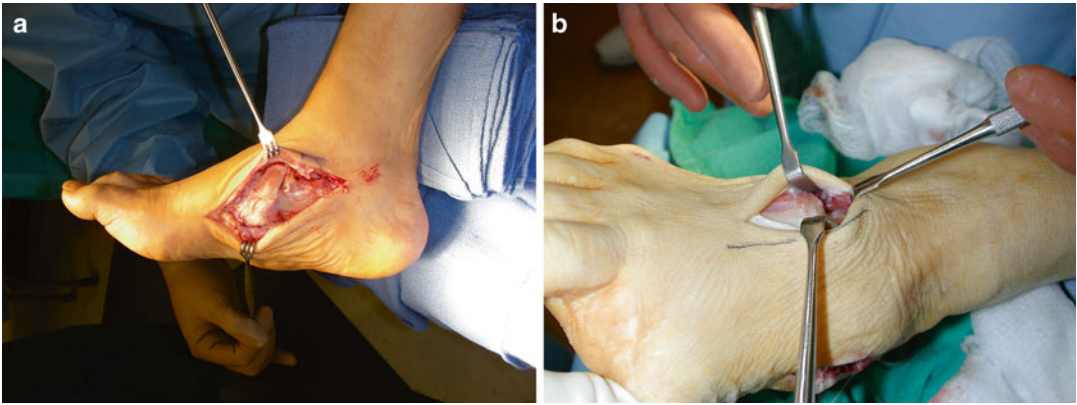


Fig. 10.2 (a) An extended medial approach demonstrates excellent exposure of the dislocation. Note the tibialis anterior tendon which is a deforming force causing dorsal

dislocation of the midfoot. (b) The midline approach to the central columns demonstrating dislocation at the tarsometatarsal joint

The medial column is approached through a long medial incision centered at the apex of the deformity. The abductor hallucis is elevated as a single layer and reflected plantarly. This muscle is used as a full-thickness layer for closure at the end of the case. In most cases, the tibialis anterior tendon will need to be detached and reattached at the end of the procedure. This resolves a significant deforming force holding the forefoot dorsiflexed, which can prevent reduction if not addressed. If the navicular is fragmented, it may also be necessary to detach and tag the posterior tibial tendon for later repair.

Approaching the middle column may require a separate incision, particularly if the tarsometatarsal joints are dislocated. Typically, a longitudinal dorsal incision is made centered at the apex of the deformity. The dorsal neurovascular bundle is elevated subperiosteally and is preserved. The lateral column is often exposed through a dorso-lateral incision, elevating the extensor digitorum brevis muscle as necessary. Care should be taken to create full-thickness fasciocutaneous flaps for closure, and to aid in wound healing.

Resection of Bone and Correction of Deformity

As the midfoot breaks down, one often encounters a dislocation due to the deforming forces of the tibialis anterior tendon, the posterior tibial

tendon, and the Achilles tendon. These tendons cause the forefoot to sublux dorsally, which may result in the forefoot sitting in bayonet apposition on top of the hindfoot (Fig. 10.3). The apex of the dislocation will usually correspond to the most prominent area plantarly on the patient's foot. Often this is the medial cuneiform or the cuboid.

When planning a correction to the midfoot, it is helpful to think of the foot as two distinct segments, the forefoot and hindfoot. The goal of the surgery is to realign both segments and create a stable arthrodesis at the mid-tarsus.

Bone resection must be done to allow a tension-free reduction of the foot deformity. Bone resection is also done to remove articular cartilage in order to create the arthrodesis bed. It is acceptable to bridge non-involved joints without preparing them for fusion in order to preserve their vascularity and the structural properties of the bone. Bridging unprepared joints, however, increases the risk of hardware failure and screw migration. Inadequate bone resection will result in undue tension on the arterial structures and may also result in recurrence of the deformity. To correct the deformity an aggressive osseous resection is performed which incorporates a wedge resection at the apex of the deformity. This usually involves removing more bone plantarly and medially. The wedge resection of bone can be preoperatively planned by radiographs or alternately by using intraoperatively placed Kirschner wires and checking fluoroscopic

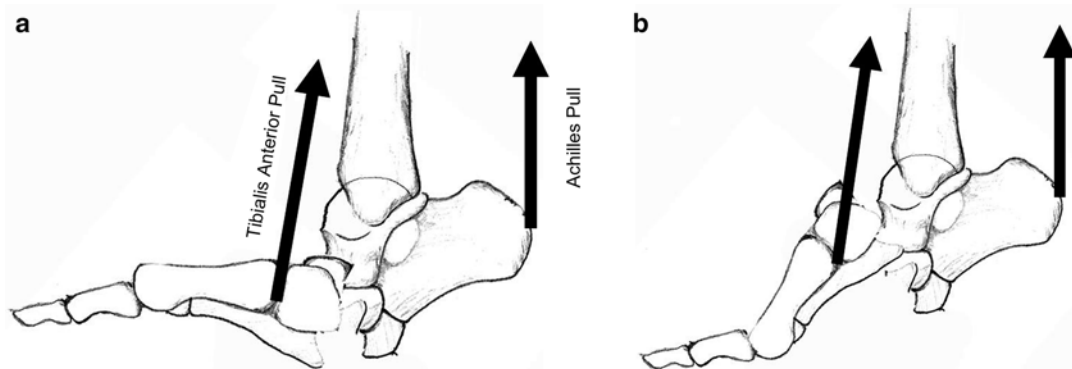


Fig. 10.3 (a) Forces of the tibialis anterior and Achilles act to induce deformity at the midfoot. (b) Dislocation may occur as the deformity progresses. Correction of

these forces must be addressed at the time of surgery or reduction may not be possible

images. The medial column typically has more fragmentation than the middle and lateral columns and is therefore approached first (Fig. 10.4). Once an adequate amount of bone has been removed, a balanced resection extending laterally can be done. Care must be taken not to over-resect bone in the middle and lateral columns of the foot so to avoid gapping of the arthrodesis bed. The soft tissues must be protected during the bony resection in order to avoid transection of the arterial supply to the forefoot. This can be accomplished by placing Hohmann retractors superiorly and inferiorly to prevent excursion of the saw into the soft tissues.

Bone resection starts medially to correct the medial column first, then proceeds towards the middle and lateral columns as necessary. Resection is done in small steps, through 2 or 3 incisions, gradually removing bone until the desired foot position is achieved. A microsagittal saw and set of sharp osteotomes or chisels are ideal for this resection. The goal is to match the resection so that good opposition of the proximal and distal segments can be achieved. Once the foot can be realigned, without significant soft tissue tension, attention is directed towards fixation of the arthrodesis.

Fixation with Long Axial Screws

The goal of fixation using the axial screw technique is to span the area of Charcot dissolution and fracture, achieving fixation proximally and distally in more normal bone (Fig. 10.5). I prefer

to use cannulated screws because the guidewires which are placed through the intramedullary canals of the metatarsals are used to guide overall alignment of the foot. The reduction is held temporarily with the intramedullary guidewires before placement of the final hardware.

The guidewires can be applied antegrade (from proximal to distal) or retrograde through the metatarsal heads. The antegrade technique has the disadvantage that the wires, drills, taps, and screws are passed blindly in close proximity to the neurovascular bundle. The retrograde technique is only appropriate in patients with sensory neuropathy since the technique involves passing large diameter cannulated screws through the articular surface of the metatarsal head.

My own preference is to cannulate all of the desired metatarsals retrograde to the level of the dislocation. The deformity is then reduced manually and the guidewires are advanced across the deformity into the foot proximally. The wire is checked fluoroscopically and advanced to the level of the desired correction. Once the deformity is corrected, the guidewires will hold the deformity reduced while positioning is verified radiographically. A cannulated depth gauge is used to gauge the length of the screw. The medial column is reduced first, followed by the middle and lateral columns. The fifth metatarsal can usually not be secured with axial screws because the trajectory dictated by the fifth metatarsal shaft will be lateral to the cuboid. Obliquely applied screws are used for the fifth metatarsal cuboid fusion.

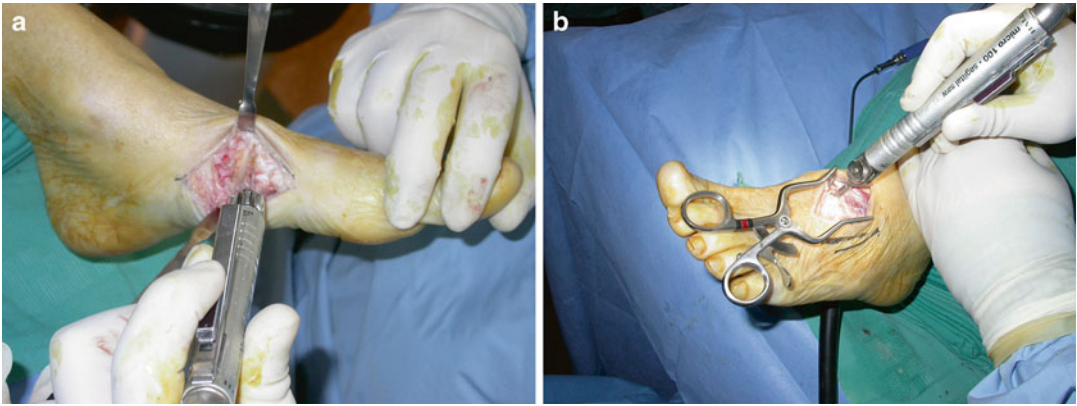


Fig. 10.4 (a) Resection of bone at the level of dislocation is necessary to achieve reduction. Bone resection is typically done with a plantar and medial closing wedge con-

figuration at the apex of the deformity. (b) Further resection may be necessary through a dorsal or lateral incision depending on the degree of deformity

The largest diameter screw which will fit into the metatarsal shaft is used. This can be gauged by sequentially reaming the metatarsal with cannulated drills. The metatarsal shaft should be radiographically visualized during the reaming procedure to gauge the fit of the drill bit within the metatarsal. When the intramedullary canal is filled radiographically and the drill is meeting resistance, larger drills should not be applied or the metatarsal may fracture. The shaft is then tapped to prevent fracture during passage of the final hardware. The size of the tap will often dictate the size of the screw that can be used in the metatarsal shaft, and this should also be gauged radiographically. Attempting to place a screw with too large a diameter can lead to splitting or fracture of the metatarsal. Typically, the medial column will accept a screw diameter of 6.5–8.0 mm. The lesser metatarsals will accept screw diameters from 4 to 5 mm. Initial series used screws with standard heads, however at times these proved to be difficult to countersink. I have now switched to using headless screws for most procedures. It is important that the screw length should be selected so that the head is well countersunk below the level to the articular surface.

The medial column is typically fixed by passing the screw through the metatarsophalangeal joint and extending it into the tarsal navicular. If the navicular is fragmented and the transverse

tarsal joint must be included in the fusion, the medial column screw can usually be advanced into the talar neck and body. The middle column is typically secured through the second and third metatarsals and is also placed into the navicular. If the transverse tarsal joint is to be fused, the second metatarsal screw can also be advanced into the talar neck. The lateral column can be secured with a screw traversing through the fourth metatarsal into the cuboid and extended into the calcaneus if necessary. This can be passed antegrade or retrograde if the calcaneocuboid joint is to be included in the fusion. The fifth metatarsal will usually not align axially with the cuboid, and can be secured with obliquely placed screws from the fifth metatarsal metaphysis into the cuboid.

Primary apposition with compression is desirable; however, if there are gaps in the fusion site, these should be bone grafted. Often local graft obtained during the osseous resection can be used; however, I have found that demineralized allograft bone matrix is also effective for small defects. If a large amount of bone graft is required, cancellous autograft from the proximal tibia or iliac crest can be harvested.

At the time of closure, the tibialis anterior and posterior tendons, if detached for exposure, should be reattached directly to bone by suturing them through small drill holes. The fascia of the

abductor hallucis is then closed over the dorsal deep fascia to cover the medial column. A layered closure of the skin is then performed.

Postoperative Management

The patient is placed into a posterior splint with a Robert-Jones type cotton wadding to allow for swelling. The splint is removed 2–5 days

postoperatively and a non-weight bearing short leg cast is applied. The frequency of follow-up visits needs to be tailored to the clinical course; patients exhibiting signs of poor wound healing, excessive swelling, and those with poor compliance with weight bearing restrictions typically need more careful supervision than those that are healing without incident. The cast is changed and X-rays obtained every 2–4 weeks, until osseous consolidation is apparent radiographically.



Fig. 10.5 Case study of midfoot fusion for Charcot deformity in a 56-year-old woman with diabetes mellitus: (a) The patient presented with a recurrent Wagner Grade 1 Ulceration medially and gross instability through the midfoot. (b, c) A/P and lateral X-rays showing chronic neuroarthropathic dislocation of the midfoot. (d–f) Realignment is obtained and held with guidewires for cannulated screws

after resection of bone at the level of dislocation. (h, i) Long axial screws are applied through the metatarsophalangeal joints over guidewires to bridge the zone of neuroarthropathic dislocation. (j) Two-year postoperative clinical photograph of foot and weight bearing X-rays showing restoration of alignment and successful arthrodesis



Fig. 10.5 (continued)

At 3 months, casting is discontinued and immobilization is changed to a removable cam walker boot. Physical therapy may be necessary to aid with ambulation and gait training. Non-weight bearing is maintained until osseous consolidation is apparent on X-rays, typically 4–5 months from surgery. The boot walker can be used for initial weight bearing and is discontinued after 6 months. When the boot is discontinued, the patient may return to appropriate shoe wear with a custom molded diabetic type orthotic.

Pitfalls and Complications

Early complications include wound breakdown and infections. To avoid this, it is important to have a well-vascularized foot, before proceeding with surgery, and to have the patient's blood glucose and medical issues optimized as much as possible. Ensuring that the patient complies with the strict non-weight bearing protocol is also

necessary for success, but is often difficult to accomplish. The patient should be assessed pre-operatively by a physical therapist and accommodative aids need to be available when the patient returns home. Many patients may benefit from admission to an extended nursing facility.

In the event that wound breakdown occurs, treatment is tailored to the severity of the problem. Wounds typically heal slowly and nylon sutures may be left in place up to 4 weeks. If partial thickness skin loss or marginal necrosis of the wound edge occurs, local, non-aggressive wound care with dressing changes and minimal debridement in the office is usually all that is necessary to encourage granulation and secondary healing. Usually, these patients are treated with more frequent cast changes with close observation of the wound. If the patient is referred to wound center, it is important to communicate with those treating the patient not to perform aggressive debridement of marginal tissue. In the event of complete dehiscence, or deep infection, return to the operating

room for formal incision and debridement is necessary. We will often use negative pressure wound therapy for secondary closure in conjunction with suppressive antibiotics. Often removal of hardware and application of an external fixator are necessary.

Nonunion, hardware failure and recurrence of the deformity are more common in cases where the talonavicular joint is incorporated into the fusion. If hardware failure occurs, but the foot remains plantigrade, further surgery is not indicated. In the event that deformity recurs, the surgery can be revised by replacing the intramedullary hardware and bone grafting the nonunion site.

Long-Term Results

We reported retrospectively on 22 patients who had undergone surgical reconstruction and arthrodesis with multiple intramedullary screws, to treat Charcot midfoot deformity, using the above described techniques. Axially placed intramedullary screws, inserted either antegrade or retrograde across the arthrodesis sites, were used to restore the longitudinal arch. Radiographic measurements were recorded preoperatively, immediately postoperatively, and at the time of the last follow-up and were analyzed in order to assess the amount and maintenance of correction. Patients were evaluated clinically and radiographically at an average of 52 months. Complete osseous union was achieved in 16 of the 22 patients. There were five partial fusions and there was one nonunion with recurrence of deformity. There were eight cases with hardware failure. All patients returned to an independent functional ambulatory status without above ankle bracing using standard diabetic shoe wear and custom multidensity foam diabetic type orthotics [9].

Conclusions

Charcot midfoot deformity is a difficult disease to treat effectively. While most patients can be managed effectively with bracing, a subset of patients with significant deformity and instability exists who cannot be managed effectively without surgery. Good results have been reported with corrective arthrodesis although standard fixation techniques are often inadequate in patients with neuroarthropathy. The technique described here where fixation is achieved with long axial screws has shown successful long-term results.

References

1. National Diabetes Statistics Report. (2014). <http://www.diabetes.org-basics/statistics/>.
2. Munson ME, et al. Data mining for identifying novel associations and temporal relationships with Charcot foot. *J Diabetes Res.* 2014;2014:214353.
3. Saltzman CL, et al. How effective is intensive nonoperative initial treatment of patients with diabetes and Charcot arthropathy of the feet? *Clin Orthop Relat Res.* 2005;435:185–90.
4. Simon SR, et al. Arthrodesis as an early alternative to nonoperative management of Charcot arthropathy of the diabetic foot. *J Bone Joint Surg Am.* 2000;82A(7):939–50.
5. Hastings MK, et al. Progression of foot deformity in Charcot neuropathic osteoarthropathy. *J Bone Joint Surg Am.* 2013;95(13):1206–13.
6. Sammarco VJ. Superconstructs in the treatment of Charcot foot deformity: plantar plating, locked plating, and axial screw fixation. *Foot Ankle Clin.* 2009;14(3):393–407.
7. Sammarco GJ, Conti SF. Surgical treatment of neuroarthropathic foot deformity. *Foot Ankle Int.* 1998; 19(2):102–9.
8. Schon LC, et al. The acquired midtarsus deformity classification system—interobserver reliability and intraobserver reproducibility. *Foot Ankle Int.* 2002; 23(1):30–6.
9. Sammarco VJ, et al. Midtarsal arthrodesis in the treatment of Charcot midfoot arthropathy. *J Bone Joint Surg Am.* 2009;91(1):80–91.