SYMPOSIUM: RECENT ADVANCES IN FOOT AND ANKLE SURGERY

Should One Consider Primary Surgical Reconstruction in Charcot Arthropathy of the Feet?

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Abstract Charcot neuroosteoarthropathy of the feet can induce severe instability and deformity with subsequent plantar ulceration leading to substantial disability or even amputation. Traditionally, nonoperative treatment is regarded as the primary option of treatment while surgery is restricted to treating complications or failure of nonoperative treatment. Failed nonoperative treatment essentially prolongs treatment period. We retrospectively reviewed 22 patients (26 feet) with midfoot (n = 9) or hindfoot (n = 17) neuropathy who underwent primary surgical reconstruction and reorientation arthrodesis due to manifest instability, nonplantigrade foot position, and deformity with overt (n = 8) or what we judged was impending ulceration (n = 9). The minimum followup was 0.5 years (mean, 2.7 years; range 0.5–7 years). All eight ulcers healed without recurrence of ulceration or manifestation of new ulcers during the followup period. We observed complications leading to further surgery in nine patients:

five with perioperative hematoma and four with instability. AOFAS scores rose from a preoperative mean of 39 to 70 points (hindfoot cases) and from 51 points to 84 (midfoot cases). Early surgical reconstruction in high-risk patients can provide timely restoration of a plantigrade and stable foot and improved quality of life of the patient at complication rates comparable to those after secondary surgery following failed nonoperative treatment; however we emphasize we had no control group in this small case series for which we could compare nonoperative treatment.
Level of Evidence: Level IV, therapeutic study (case series). See Guidelines for Authors for a complete description of levels of evidence.

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Introduction

Charcot neuroosteoarthropathy represents a devastating process that today is mostly observed in diabetic patients [2, 5, 7, 12, 22, 23]. Quality of life is seriously impaired in patients with Charcot arthropathy more than in the average diabetic patient including a more profound limitation of physical activity than most severe medical illnesses [5, 9]. Charcot foot arthropathy increases the risk of skin breakdown, recurrent ulceration, and amputation secondary to foot deformity more than any other single condition [1, 5, 29]. At least 30% to 50% of patients with Charcot neuroosteoarthropathy are estimated to develop a recurrent ulceration [1–4]. Limbs with open ulceration at the initial presentation and limbs with recurrent ulceration have decreased limb survival rate compared to feet without ulcers, adding to an annual limb amputation rate of approximately 1% to 5% [21, 23, 29]. The goals of treatment should not be merely to save the limb [10, 19–22]: Pinzur proposed the goal include a long-term infection- and

ulcer-free plantigrade and stable foot that allows the patient to walk with commercially available depth-inlay therapeutic footwear [21].

Due to the scarcity of valid data and the difficulties in accomplishing a prospective randomized trial due to the strong opinions held by treating experts [21], evidence-based recommendations for treatment are lacking [21]. However, during the last decade various expert-based algorithms of treatment have been proposed [24, 26, 29]. Traditionally, the Eichenholtz stage relying on clinical and standard radiographic examination [11] and the site of the disease [32] provide the key determinants for selecting the primary therapeutic strategy [7, 21]. Nonoperative immobilization techniques using specific orthoses or total contact casts still represent the mainstay for the initial phases of Charcot neuroarthropathy, while surgery is reserved for patients with infection, recurrent ulceration, and substantial deformity or joint instability not manageable by casting or orthotic devices [3, 20, 29]. As most Charcot feet manifest in the midfoot, the majority of studies describe lesions in the midfoot area [8, 10, 16, 18, 33, 34, 36]. However, the success of total contact casting even in the hands of a single experienced physician may result in subsequent ulcerations in 30% of the patients during the treatment [13]. Recurrence of ulceration means prolonged disability and the requirement for recasting, long-term use of ankle-foot orthoses, or possible secondary surgery [29]. In particular, unstable deformities in these frequently obese patients are difficult to brace with a high inherent risk of ulceration in the insensate feet [19, 21]. Late institution of immobilization and unloading runs a high risk of permanent deformity after healing [6, 14]. An underlying fixed deformity or osseous prominence is one of the main reasons for recurrence of ulceration [35]. As such, more than 40% of the patients with midfoot disease who had been managed primarily nonoperatively may require surgery in the further clinical course [21, 23]. While formerly corrective arthrodesis of nonplantigrade neuroarthropathic feet has been regarded as a salvage procedure and an alternative to amputation [20], more recent reports relying on bio-mechanically sound stabilization techniques have demonstrated maintenance of walking independence using commercially available therapeutic footwear and an infection-free foot [26] despite a high complication rate varying from 10% to more than 30% [3, 19]. One study of 14 patients with Stage I Charcot arthropathy at the midfoot level reported successful healing of the primary corrective arthrodesis without immediate or long-term complications or any recurrent ulceration during a mean followup period of 41 months [35].

Rearfoot and ankle Charcot deformities, though less common than midfoot disease, tend to be more unstable than midfoot disease and more likely to undergo subsequent surgery [5, 36]. Identification of patients at-risk who already present with manifest ulceration or who are more likely to have skin ulceration over plantar bony prominences due to a nonplantigrade deformity or severe instability appears beneficial for timely decision-making in favor of surgical reconstruction [24, 26]. Early arthrodesis in the very unstable cases with a reduced period of total contact casting reportedly provides comparable results to patients treated nonoperatively [5, 36].

We therefore asked whether primary surgery in patients judged at high risk for secondary surgery would (1) provide a stable plantigrade ulcer-free and infection-free foot in patients with advanced mechanical instability of the foot and/or the ankle; (2) allow increased physical activity level; and (3) do so at complication rates not higher than those reported for secondary surgery.

Materials and Methods

We retrospectively reviewed all 22 patients with 26 affected feet treated primarily surgically for Charcot neuroarthropathy from January 2001 to December 2007 (Table 1). The criteria included: (1) Charcot neuroarthropathy manifest at the midfoot (Sanders and Frykberg Type 2) [32] (n = 9 feet) and/or the hindfoot (Sanders and Frykberg types 3 and 4) (n = 17 feet); (2) a high degree of instability manifest joint subluxation and/or a clinical and radiographic nonplantigrade foot position (Fig. 1A) based upon the assessment of two coauthors (KK, TM); (3) either existing superficial skin ulceration (Wagner grades 1 and 2 [37]) (n = 8 feet) or impending plantar ulcers (Wagner grade 0, ie, preulcer) [37] at local bony prominences or local plantar hyperkeratoses due to bone deformity (Fig. 1B); we presumed a preulcerative situation in the non-plantigrade foot where non-plantar skin is subjected to weight bearing or there is delayed recapillarization time after manual pressure. We excluded patients with acute deep infection that led to radical débridement and secondary reconstruction or amputation. Four patients had bilateral involvement. Four patients presented with Stage I Charcot arthropathy according to the classification of Eichenholtz, seven had Stage II, and 11 had Stage III arthropathy. Stage I corresponds to the stage of development when the patient presents with a swollen erythematous and hyperemic foot with progressive osteolysis and deformity, Stage II represents the stage of coalescence when the swelling subsides and remineralization and callus formation occurs, Stage III is the stage of consolidation when the clinical picture of inflammation has resolved while joint collapses, ankylosis and deformity have occurred [22]. Twenty of the 22 patients had diabetes for more than 5 years and 17 of the 20 required insulin to

Table 1. Demographic data of study patients and surgical intervention

Patient	Gender, Age	Bilateral	Ulcus	Procedure	Fixation method	Followup (years)	Revision
1	M, 54			TC	Blade plate + plate	0.7	
2	M, 64		x	TC	Blade plate	0.7	x
3	M, 73			TA	Screws	1	
4	M, 46	B		TA	Plate + screws	5	x
5	F, 51		x	TT + TA	Screws	1.3	
6	F, 52			TT + ST	Imn	2.5	
7	M, 49		x	CA + LA	Plate + screws	3.3	x
8	F, 60			CA + LA	Plate + screws	4.6	x
9	F, 38			TC	Blade plate	7	x
10	M, 59			TA	Plate + screws	1.8	x
11	F, 69		x	TA	Plate + screws	1.8	x
12	M, 49			CA + LA	Plate + screws	1.6	
13	M, 51	B		CA + LA	Screws	1	
14	F, 51	B		CA + LA	Screws	2	
15	F, 50	B		CA + LA	Plate + screws	3	x
16	M, 73			CA + LA	Screws	0.5	
17	M, 56		x	CA + LA	Screws	2	x
18	F, 68			LA	Screws	5	
19	M, 60	B		LA	Screws	3	
20	M, 60	B		LA	Screws	2.5	
21	M, 64			LA	Screws	4.5	
22	F, 29		x	LA	2 plates	1.4	
23	M, 53			LA	Screws	6.5	
24	F, 56		x	LA	Screws	3	
25	F, 63	B	x	LA	Screws	3	
26	F, 64	B		LA	Screws	2	

B = bilateral manifestation, Ulcus = manifest ulcus at surgery, procedure: TC = tibiocalcanear arthrodesis, TT = tibiotalar arthrodesis, ST = subtalar joint arthrodesis, TA = triple arthrodesis, CA = Chopart joint arthrodesis, LA = Lisfranc and innominate joint arthrodesis; Imn = intramedullary interlocking nail.

control their diabetes. Two patients of the 22 included in the study group had been immobilized in a bivalved custom-fit orthosis or an orthotic walker for less than 6 weeks with documented progress of the deformity and plantar ulceration prior to presentation at our institutions. The remaining 20 patients who presented without previous attempt of nonoperative treatment were considered as patients at-risk with nonbraceable and noncastable deformities. The mean age of the 22 patients was 56.2 years (range, 29–73 years). The minimum followup was 6 months (mean, 32 months; range, 6–84 months). None of the 22 patients was lost to followup.

The vascular status of each patient was assessed clinically by palpation of peripheral pulses. In patients with major soft tissue swelling, clinical examination was supplemented by color-coded duplex sonography. We routinely obtained weight-bearing radiographs of both ankles and feet including Saltzman views [28] of the hindfoot. CT scanning with multiplanar reconstruction was obtained in two cases where complex deformity or major osseous defects were visible on standard radiographs and the surgeons wanted better preoperative spatial imaging for planning of the reconstruction.

The indications for surgery included (1) a nonplantigrade foot position; (2) a high degree of hindfoot or midfoot instability not amenable to bracing or total contact casting based on expert opinion (KK, TM); and (3) manifest or impending ulcerations at bony prominences due to noncompensated deformity with nonlinear talar-first metatarsal axes on lateral (Fig. 1C) and anterior-posterior weight-bearing radiographs (Fig. 1D). The mean duration from the first presentation of the patient to the surgical procedure was 1.7 months (range 0.5–5 months).

We attempted to limit the extent of corrective arthrodesis and the number of surgical incisions to the minimum needed to achieve a plantigrade and stable foot position.

Fig. 1A–H (**A**) A 50-year old female diabetic patient (Sanders/ Frykman type III Eichenholtz stage III) with bilateral non-plantigrade foot deformity is shown. (**B**) The podogram shows bilaterally a pathological weightbearing area at the plantar midfoot in the same patient. (**C**) A weight-bearing radiograph of the left foot in the same patient is shown. (**D**) A weight-bearing radiograph of the left foot (AP view) in the same patient is shown. (**E**) Clinically asymptomatic nonunion and partial implant breakage after triple arthrodesis of the left foot is shown (lateral view in the same patient). A revision was not performed as the patient declined further surgery. (**F**) Clinically asymptomatic nonunion and partial implant breakage after triple arthrodesis of the left foot is shown (AP view in the same patient). (**G**) The clinical view 1.8 years after triple arthrodesis of both feet is shown. Bilateral maintenance of correction is demonstrated despite partial nonunion at the left side in the same patient. (**H**) The podogram shows a plantigrade foot position without pathological weight-bearing at the midfoot area.

With isolated midfoot neuroarthropathy (n = 9), we maintained the talonavicular joint and with hindfoot involvement we performed triple arthrodesis (n = 5) (Table 1). When we performed arthrodesis of the ankle and the subtalar joint (n = 2) or tibiocalcaneal arthrodesis (n = 3), the talonavicular and the calcaneocuboid joints

were preserved in four of five feet to avoid the generation of a completely stiff foot. A plantigrade foot position was achieved either by osteotomy or excision of bone at the apex of the deformity or by resection of necrotic and destroyed bone and reorientation of the foot axes. Residual osseous defects after obtaining a plantigrade foot position were filled with autologous iliac crest grafts. The corrected foot position was preliminarily maintained with K-wires. We simulated partial weight bearing intraoperatively by manually pressing a plate against the plantar surface and obtained fluoroscopy prior to definitive stabilization to verify an adequate reduction. We stabilized the midfoot or the Chopart joint either by noncannulated 7-mm fully threaded screws or by 7.3-mm cannulated screws supplemented by 3.5-mm plates. If the ankle was fused, we inserted a retrograde interlocking nail (n = 1) or a 4.5-mm cannulated blade plate (n = 3). Lengthening of the gastrocnemius-soleus complex either by open gastrocnemius recession or by percutaneous Achilles tendon lengthening was an integral procedure in the 11 cases with an equinus deformity. We locally débrided ulcers in eight feet and covered them with dry postoperative dressings for secondary healing.

Postoperatively, we applied a nonweight-bearing total contact cast. We reviewed patients and obtained radiographs at 6 weeks and every 3 to 4 weeks until osseous healing. Casts were routinely replaced every second or third week until signs of osseous consolidation (bony bridges at the correction site, no signs of bone resorption around implants) with maintenance of the corrected foot position became visible on all three radiographic views. The mean postoperative casting period in a nonweight-bearing cast was 10.6 weeks (range 6–16 weeks). Partial weight bearing was allowed when the first signs of callus formation became visible on radiographs. Weight-bearing radiographs were performed prior to allowing full weight bearing in usually commercially available therapeutic footwear or customized orthopaedic shoes. The mean period from surgery to full weight bearing was 3.5 months (range 3–5 months).

Two of us (KK, one of the treating surgeons, and PH) assessed the pre- and postoperative clinical status employing the AOFAS ankle-hindfoot scale and the midfoot scale, respectively [15] (Tables 2–5).

Results

We achieved a stable and plantigrade foot in all feet, even in those cases with incomplete osseous healing or the need for secondary surgery. We observed no recurrence of ulceration or the development of new ulcers during the observation

Table 2. Preoperative AOFAS ankle-hindfoot score

Patient	Gender, age	Pain	Activity limitations support requirement	Maximum walking distance	Walking surfaces	Gait abnormality	Sagittal motion	Hindfoot motion	Ankle hindfoot stability	Alignment	Total
1	M, 54	20	4	2	0	0	4	0	0	0	30
2	M, 64	30	0	0	0	0	4	3	0	0	37
3	M, 73	30	0	2	0	0	8	0	0	0	40
4	M, 46	20	4	2	0	0	4	3	0	0	33
5	F, 51	30	4	2	0	0	8	0	0	0	44
6	F, 52	30	4	0	0	0	0	0	0	0	34
7	M, 49	30	4	2	0	0	4	0	0	0	40
8	F, 60	20	0	2	0	4	4	0	0	5	38
9	F, 38	20	4	2	0	0	4	0	0	0	30
10	M, 59	30	4	2	0	4	4	3	0	0	47
11	F, 69	20	0	2	3	0	4	6	6	10	51
12	M, 49	20	4	2	0	0	4	3	0	0	33
13	M, 51	30	4	2	0	0	4	3	0	0	43
14	F, 51	20	4	2	0	0	4	3	0	0	33
15	F, 50	20	0	0	3	0	8	3	8	5	47
16	M, 73	0	0	0	3	0	8	6	8	10	35
17	M, 56	20	4	2	0	4	8	3	0	0	41
Mean											38.6
SD											6.1

Table 3. Preoperative AOFAS midfoot score

Patient	Gender, age	Pain	Activity limitations support requirement	Footwear requirement	Walking distance	Walking surfaces	Gait abnormality	Alignment	Total
18	F, 68	20	0	0	4	5	5	0	34
19	M, 60	20	4	0	7	10	5	15	54
20	M, 60	20	4	0	7	10	5	15	54
21	M, 64	40	7	0	4	0	0	0	51
22	F, 29	40	10	0	4	5	0	8	67
23	M, 53	20	0	0	7	0	5	0	32
24	F, 56	30	7	0	4	5	5	0	51
25	F, 63	20	0	0	7	5	10	15	50
26	F, 64	30	7	0	7	5	10	15	67
Mean									51.1
SD									12.1

Table 4. Postoperative AOFAS ankle-hindfoot score

Patient	Gender, age	Pain	Activity limitations support requirement	Maximum walking distance	Walking surfaces	Gait abnormality	Sagittal motion	Hindfoot motion	Ankle hindfoot stability	Alignment	Total
1	M, 54	40	7	4	0	4	4	0	8	10	77
2	M, 64	30	7	5	5	4	0	0	8	10	69
3	M, 73	30	4	2	3	4	4	0	8	10	65
4	M, 46	40	7	5	3	4	4	0	8	10	81
5	F, 51	30	7	4	3	4	0	0	8	10	70
6	F, 52	30	7	4	5	4	0	0	8	10	68
7	M, 49	40	7	5	5	8	4	0	8	10	87
8	F, 60	20	7	4	0	4	4	3	8	10	60
9	F, 38	40	10	5	5	4	4	0	8	10	94
10	M, 59	30	4	4	3	4	4	3	8	10	70
11	F, 69	30	0	2	0	0	4	3	8	10	57
12	M, 49	30	7	2	0	4	4	0	8	10	65
13	M, 51	40	7	5	3	4	4	0	8	10	81
14	F, 51	30	4	4	3	4	8	0	8	10	71
15	F, 50	30	4	4	3	4	8	0	8	5	66
16	M, 73	20	0	0	3	0	8	6	8	10	55
17	M, 56	30	4	4	3	4	8	0	8	5	66
Mean											70.0
SD											9.2

period. Twenty-five of the 26 feet had no sign of deep or recurrent infection. In one diabetic patient with systemic lupus erythematosus on permanent cytostatic medication, a chronic fistula developed after revision for nonunion and implant breakage; the patient, who nonetheless had improved activity level and walking distance compared with the preoperative status, declined further

surgery. In no foot did the podogram show pathological midfoot contact (Fig. 1H). We observed no patient with recurrence of deformity in the presence of osseous healing.

Mean postoperative AOFAS scores were increased compared with preoperative values both in the hindfoot and the midfoot subgroup, respectively (Tables 2–5). Activity level and maximum walking distance rose in 19 patients

Table 5. Postoperative AOFAS midfoot score

Patient	Gender, age	Pain	Activity limitations support requirement	Footwear requirement	Walking distance	Walking surfaces	Gait abnormality	Alignment	Total
18	F, 68	30	7	3	10	5	10	8	73
19	M, 60	40	7	3	10	10	10	15	95
20	M, 60	40	7	3	10	10	10	15	95
21	M, 64	40	7	3	4	0	0	15	69
22	F, 29	40	7	3	7	10	10	15	92
23	M, 53	40	10	5	10	5	10	15	95
24	F, 56	30	7	3	7	10	10	8	75
25	F, 63	30	7	3	7	5	10	15	77
26	F, 64	30	7	3	10	10	10	15	85
Mean									84.0
SD									10.6

and remained unchanged in three patients comparing the pre- and postoperative level.

Perioperative and postoperative complications resulted in nine surgical revisions during the observation period. Perioperative wound complications necessitated revision of hematoma formation and local débridement in five patients during the primary hospital stay. All of them went on to uneventful wound healing. Incomplete osseous union of the arthrodesis could be confirmed radiographically in six feet with hardware complications (implant loosening, implant breakage). This led to surgical revision due to recurrence of instability in four cases. In one of the latter cases, a clinically asymptomatic implant failure due to fibrous nonunion became manifest during a routine radiograph control 6 months after revision (Fig. 1E–F) without loss of correction (Fig. 1G) without further reintervention. None of the operated feet developed wound healing problems that could directly be related to ulceration manifest at the time of surgery.

Discussion

Charcot neuroosteoarthropathy of the feet is a major risk factor for foot deformity and ulceration with a subsequent rate of lower extremity amputation [3, 5, 29]. Nonoperative measures such as total contact casting are regarded as treatment of choice for a majority of patients if the treatment is likely to provide a plantigrade foot without major bony destruction and deformities [6, 7, 31]. According to some series, however, 40% to 50% of these patients may have secondary surgery due to recurrent ulcers or residual deformity [3, 5, 12, 23, 29]. This two-step approach may be associated with prolonged immobilization and increased morbidity, diminished quality of life, and increased costs [3, 21, 26]. We therefore asked whether primary surgery would (1) provide a stable plantigrade ulcer-free and infection-free foot in patients with advanced mechanical instability of the foot and/or the ankle and at high risk for secondary surgery; (2) allow increased physical activity level; and (3) do so at complication rates not higher than those reported for secondary surgery.

We note several limitations of our study. First, knowing which degree of instability and deformity will be at high risk of failure with nonsurgical treatment relies on judgment [21, 23] and the risk factors are not well understood. Expert assessment of these key parameters represents the basis for most treatment protocols from centers with wide experience in Charcot feet [18, 19, 21, 23, 24, 29]. On the other hand, we believe decision making for surgery in Charcot feet on the basis of any given algorithm requires assessment by someone with considerable experience with Charcot feet and it should not be left to the inexperienced [21]. Second, our single cohort was heterogeneous, making generalizations more difficult. All major studies on the topic published during the last 15 years (Tables 6, 7) are retrospective with limited numbers of patients [27]. The authors are not aware of any prospective comparative study or any high-quality randomized controlled trial of primary nonoperative versus primary surgical treatment of Charcot feet. The need for such studies has been repeatedly mentioned [21, 27, 29] as has the difficulty in conducting such a trial owing to the heterogeneity of the deformities and instability [21]. Nevertheless, our data suggest a subset of patients with advanced instability and deformity benefit from primary surgical reconstruction comparable to patients who have secondary surgical reconstruction.

Table 6. Retrospective clinical series on corrective arthrodesis in Charcot feet (last two series refer to primary surgical intervention)

Author (Year)	Patients (n)	Feet (n)	Followup (months, mean and range)	Preop feet with ulcers	Postoperative period until full weight bearing (months)
Papa et al. (1993) [20]	29	29	43 (23–68)	15	5
Early and Hansen (1996) [10]	18	21	28 (6–84)	10	5
Pinzur and Kelikian (1997) [25]	20	21	NS (12–31)	8	5.3 (−20)
Sammarco and Conti (1998) [30]	26	27	27 (18–51)	6	7
Schon et al. (1998) [33]	NS	59	NS	4	NS
Myerson et al. (2000) [17]	30	30	48 (19–112)	13	4
Stone and Daniels. (2000) [36]	10	10	24 (11–37)	NS	> 3
Pakarinen et al. (2002) [19]	5	5	21 (1–81)	0	> 4
Pinzur (2004) [21]	60	60	> 12	NS	NS
Saltzman et al. (2005) [29]		14	46 (NS)	8	NS
Pinzur and Sostak (2007) [26]	51	51	33 (12–NS)	NS	NS
Sammarco et al. (2009) [31]	22	22	52 (24–137)	9	5.8
Simon et al. (2000) [35]	14	14	41 (25–77)	NS	4
Mittlmeier et al. (current study)	22	26	32 (6–84)	8	3.5

As such, in the present study with two-thirds of the feet having hindfoot manifestation of neuroosteoarthropathy and a high risk for a potential failure of nonoperative treatment none of the patients was assigned to primary nonoperative treatment. All our patients, whether they achieved bony or fibrous union, achieved a plantigrade and stable foot that remained ulcer-free during the observation period (Table 7). This compares quite favorably with the results after secondary surgery, where the recurrence rate of ulceration varied between 0% and 20% (Tables 6, 7).

Our patients accomplished full weight bearing within a mean of 3.5 months after surgery, which is longer than in nondiabetic patients but compares well with the only series of primary arthrodesis in Eichenholtz Stage I patients [35] and shorter than reported following secondary arthrodesis (4–7 months, Table 7). The high rate of patients being mobilized in accommodative shoewear after primary arthrodesis favorably compared to that of other series after secondary reconstruction where a substantial number of patients permanently use ankle-foot orthoses (Table 7). Functional outcome has rarely been analyzed in patients after surgical reconstruction of Charcot feet employing the AOFAS scores while most authors have expressed the functional result in a more descriptive manner (Table 7). A substantial increase in AOFAS scores occurred in our cohort within a relatively short time mainly due to functional improvement and better realignment both in our midfoot and hindfoot groups. The results exceed the AOFAS scores given for a limited series of 10 patients with mostly hindfoot involvement [36].

The deep infection rate after primary arthrodesis was also low compared with secondary arthrodesis where the infection rate ranged from 0% to more than 30% (Table 7). While almost one-third of our patients had preoperative ulcers in combination with instability or deformity (eight of 26 feet, Table 6), none of our patients had progressive deformity or subsequent amputation. All of these ulcers in our study healed uneventfully following corrective arthrodesis. In contrast, a number of authors advocate postponing surgery until a concomitant ulcer has definitely healed [8, 30, 31] or rely on alternative techniques of fixation as external fixators [24]. Despite the fact that an open wound may increase the risk for complications [4], we observed no major infectious complications. Other complications in our series were high when compared to studies with secondary intervention strategy [3, 10, 16, 17]. Hardware failure often coincides with the nonunion rate which was substantially high in our (23%) as in other series (0–30%, Table 7). Despite this, a stable fibrous nonunion in good position does not necessarily require surgery. Choice of implants or implant combinations was adapted to the underlying biomechanical requirements preferably using large-size internal implants. We believed none of the observed implant failures could directly be related to improper selection of implants. This even holds true for the single patient with chronic fistula who denied revision as she was satisfied with the functional level achieved.

In the light of the recent literature our outcomes fulfill the definition of a favorable outcome that includes "the ability to remain free of ulcer and infection and to maintain

Table 7. Retrospective clinical series on corrective arthrodesis in Charcot feet (Last 2 series refer to primary surgical intervention. Display of the essential outcome parameters (NS not specified, AFO ankle-foot-orthosis)

Author (year)	Recurrency of ulcers (n)	Deep infection (n)	Hardware failure (n)	Reoperation (n)	Nonunion (n)	Amputation (n)	Accommodative shoeware	Function
Papa et al. (1993) [20]	3	2	4	5	10	1	All AFO	25/29 walking
Early and Hansen (1996) [10]	2	2	2	2	2	3	13/15	13/15 walking
Pinzur and Kelikian (1997) [25]	NS	6	?	9	2	1	NS	NS
Schon et al. (1997) [33]	NS	15	NS	19	2	4	13 AFO all but one regular or orthopaedic shoewear	NS
Sammarco and Conti (1998) [30]	0	3	2	5	5	0	All but 1	No limit of activity
Myerson et al. (2000) [17]	2	0	2	1	2	0	All AFO	All community walker
Stone and Daniels (2000) [36]	1	0	0	0	4	0	6 walking aids one wheelchair	Mean AOFAS score 52
Pakarinen et al. (2002) [19]	1	2	0	NS	1	2	NS	NS
Pinzur (2004) [21]	NS	NS	NS	NS	NS	8	NS	NS
Saltzman et al. (2005) [29]	NS	NS	NS	NS	NS	0	NS	NS
Pinzur and Sostak (2007) [26]	3	NS	NS	8	NS	3	44/51	NS
Sammarco et al. (2009) [31]	3	1	8	9	6	0	NS	All ambulatory
Simon et al. (2000) [35]	0	0	NS	0	0	0	14	Level of walking ability similar to preop state
Mittlmeier et al. (current study)	0	1	6	9	6	0	All but 2	AOFAS (midfoot) 84 AOFAS (hindfoot) 70

walking independence using commercially available depth-inlay shoes and custom accommodative orthoses" [24, 26]. Early surgical intervention in high-risk patients may allow shorter periods of treatment at lower costs with an improved quality of life. We believe surgical reconstruction in Charcot feet should not be limited to a salvage procedure and an alternative to amputation in failed nonoperative care [20, 30]. Amputation may be the more expensive option compared with reorientation arthrodesis [4]. Selected patients with nonplantigrade feet, instability, and manifest or impending ulcers may benefit from early surgical reconstruction with long-lasting functional improvement and without recurrence of instability or ulceration. Based on former reports [35] and our data a prospective randomized study should be performed to further elucidate the role of primary surgical versus nonsurgical treatment in patients with early diabetic Charcot feet.

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