



## Treatment of Charcot foot and ankle with a prefabricated removable walker brace and custom insole

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### Abstract

**Background:** Removable walker braces have been used successfully to treat acute and chronic foot and ankle conditions including diabetic foot ulcers. We hypothesized that a removable walker brace may be successfully used in the management of the Charcot foot and ankle. **Methods:** Twenty-five feet and ankles with Charcot arthropathy in 21 patients (bilateral in 4 patients) were treated with a prefabricated, pneumatic removable walker brace fitted with a custom orthotic insole. Follow-up data were collected from patient interview, examination, and radiography.

**Results:** Brace fitting was accomplished usually with a single visit to the prosthetist or pedorthist/orthotist. At the most recent evaluation, 17 (68%) feet and ankles had consolidation (stage III) of the Charcot arthropathy (average duration of brace use,  $29 \pm 19$  weeks) and were subsequently treated with rocker sole shoes, insoles, and ankle foot orthoses; 8 (32%) feet and ankles had ongoing brace treatment. Three feet developed new deformity during brace treatment, but average radiographic parameters of hindfoot to forefoot alignment had minimal change between initial and final radiographs at an average of  $36 \pm 24$  weeks after initial radiographic evaluation.

**Conclusions:** The prefabricated, pneumatic removable walker brace fitted with a custom insole was successful in the management of the Charcot foot and ankle and had a high satisfaction rate and safety profile despite frequent, albeit usually minor, complications.

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### 1. Introduction

Charcot arthropathy is a syndrome consisting of fractures and dislocations in the diabetic and non-diabetic neuropathic foot and ankle that may result in deformity, ulceration, and risk of amputation [1]. Initial treatment of the Charcot foot and ankle includes immobilization with limited or protected weightbearing [2] until sufficient healing and stability are achieved.

Total contact casting, an effective method for the treatment of neuropathic ulcers [3–7], is also useful in treating the Charcot foot [8,9]. The total contact cast immobilizes the affected foot and ankle, reduces plantar foot pressures and swelling, protects from additional trauma, limits shear stresses on the skin, and maintains patient mobility [10]. However, the utility of total contact casting may be limited by the need for specially trained personnel, provider time for application, and high cost [11]. In addition, cast changes are required every 1–2 weeks to maintain proper fit and permit wound inspection [10]. Casting limits patient bathing and daily wound inspection. Furthermore, complications of total contact casting are frequent, including

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skin maceration, ulceration, and progression of deformity [12,13]. These issues may be particularly problematic for patients who live in rural or underserved communities that are distant from specialized diabetic foot care clinics [14–17].

Removable walker braces have been used successfully to treat acute and chronic foot and ankle conditions [18]. Furthermore, removable walker braces have been effective in reducing plantar foot pressures and treating diabetic foot ulcers [3,10,11,19]. Advantages of the removable walker brace include one time application [11], relatively low cost compared with multiple total contact casts [10,11], and ability to monitor wounds daily and provide hygiene [10,11]. Furthermore, braces based on an air bladder design have the advantages of lightweight construction [11], absence of medial and lateral metal uprights that may cause malleolar skin ulceration, and adjustability of air bladder inflation to maintain close calf contact [11] and proper fit, especially with changes in swelling [10]. Disadvantages of removable walker braces include inability to fit the brace in feet with severe deformity and potentially limited compliance [10].

We hypothesized that a prefabricated, removable walker brace may be successfully used in the management of the Charcot foot and ankle. The purpose of this study was to evaluate the efficacy, safety, patient satisfaction, and complications of a removable walker brace with a custom orthotic insole for treatment of a series of patients with Charcot foot and ankle.

## 2. Materials and methods

### 2.1. Subjects

Twenty-five feet and ankles with Charcot arthropathy in 21 patients (bilateral in 4 patients) were treated in a tertiary care multidisciplinary diabetic foot and ankle clinic during a 33-month period with a removable walker brace. The majority of the patients had type 2 diabetes and were on insulin for glycemic control (Table 1). All 21 patients included in the study had both clinical and radiographic evidence of Charcot arthropathy [1]. All other patients with Charcot arthropathy evaluated during this period were excluded if they had abscess, infection, or gross instability that was managed with surgical débridement or stabilization. One additional patient who was treated with a removable walker brace was excluded because attempts to contact her were unsuccessful.

### 2.2. Removable walker brace treatment

The walker brace used in all patients was a prefabricated, air-cell, full-shell pneumatic walker brace (PneumaticWalker™, Aircast® Inc., Summit, NJ). The brace included rigid ankle support and a rocker sole to immobilize the foot and ankle. Size was selected to optimize comfort. Patients were

Table 1

Characteristics of 21 patients with Charcot arthropathy (25 feet and ankles) treated with removable walker brace<sup>a</sup>

Characteristic	
Age at treatment onset (years)	52 ± 12
Gender	
Male	10 (48)
Female	11 (52)
Side	
Right	14 (56)
Left	11 (44)
Weight (kg)	85 ± 19
Height (cm)	174 ± 11
BMI <sup>b</sup> (kg/m <sup>2</sup> )	28 ± 4
Diabetes	
Type 1	8 (38)
Type 2	12 (57)
Non-diabetic	1 (5)
Diabetes duration (years)	21 ± 10
Diabetes treatment <sup>c</sup>	
Insulin	14 (70)
Oral hypoglycemic	6 (20)
Diet alone	0 (0)
Comorbidities <sup>d</sup>	
Renal	7 (33)
Peripheral vascular	6 (29)
Retinopathy	5 (24)
Other <sup>d</sup>	6 (29)

<sup>a</sup> Reported as mean ± standard deviation or number (percent of total).

<sup>b</sup> BMI: body mass index.

<sup>c</sup> At beginning of treatment with cast brace. One patient that was on oral hypoglycemic at beginning of foot treatment was on insulin at the time of follow-up evaluation.

<sup>d</sup> Some patients had 2 or 3 comorbidities. Other: myocardial infarction, hypertension, rheumatoid arthritis, hereditary neuropathy, cardiovascular disease with congestive heart failure and stroke, and cataracts.

instructed to wear the brace 23.5 h per day (both in and out of bed) and to limit standing and walking to the minimum required for daily living needs. The brace was fitted in all patients by a certified prosthetist or pedorthist/orthotist who adjusted the brace as needed to accommodate deformity by heat molding the plastic shell of the brace (Winnipeg Prosthetics & Orthotics Specialty Company Ltd., Winnipeg, Manitoba and the FootHealth Centre, Canadian Footwear, Ltd., Winnipeg, Manitoba). Furthermore, a dual layer, custom fitted, full foot length, polyethylene foam (Pink or Black Plastazote®, Zotefoams Inc., Walton, Kentucky) orthotic insole was fabricated for all patients by direct heat molding to fit the plantar aspect of the foot during full weightbearing in the brace (Fig. 1). Patients were instructed to check the brace fit manually and adjust the air pressure in the air-cells several times daily to decrease the risk of the brace becoming too loose or too tight. Patients were reevaluated within 1 week of obtaining the brace to confirm satisfactory fit and to adjust the brace and insole as needed. Subsequent patient reevaluation was done at monthly intervals until consolidation of the Charcot arthropathy



Fig. 1. Posterior shell of the removable walker brace with heat-molded, Plastazote<sup>®</sup> (pink or black), custom orthotic insoles used in this study. The anterior shell of the walker brace is not shown.

was noted clinically (resolution of swelling, erythema, and increased warmth) and radiographically (bony consolidation). After consolidation was confirmed, patients were fitted with diabetic shoes with a full length steel shank, an anterior rocker bottom, and another custom fitted, full foot length, polyethylene foam orthotic insole. Other orthoses, such as an ankle–foot orthosis or a custom molded leather ankle brace, were used as needed.

### 2.3. Medical record review and patient interview

A questionnaire was developed to standardize data collection. Medical records were reviewed, and patients were interviewed and examined. Patients who could not be interviewed in person were contacted by telephone. Patients consented to inclusion in the study. Information was recorded from the medical records and interviews including demographics, diabetes history, foot and ankle history including ulcers and Charcot arthropathy (anatomic type [1,20] and natural history stage [21]), and any deformity present. Features of treatment with the removable walker brace were documented including treatment duration, progression of healing, patient compliance (as reported by the patient), subjective impression, complications, and subsequent treatment including footwear, orthoses, and surgery. Radiographs from initial and most recent evaluations (available in all except one foot in one patient; average time between initial and most recent radiographs,  $34 \pm 24$  weeks) were reviewed for anatomic Charcot type [1,20],

consolidation of fractures, and changes in alignment; talo-first metatarsal angles were determined from the lateral and anteroposterior weightbearing radiographs of the foot.

### 2.4. Data analysis

Average values are reported as mean  $\pm$  standard deviation. There was no control group for comparison.

## 3. Results

The majority of the patients had type 2 diabetes and were treated with insulin (Table 1). Comorbidities were frequent, including renal, peripheral vascular, and eye disease (Table 1). Charcot arthropathy had been present for an average of approximately 3 months, and had been treated with a variety of modalities before beginning treatment with the brace (Table 2). The Charcot feet and ankles were of all three stages at the onset of brace treatment, and the majority involved the midfoot and tarsometatarsal (Lisfranc) region (Table 2). Deformity was varied among study participants at the onset of brace treatment and included rockerbottom deformity from midfoot or hindfoot collapse, flatfoot deformity, forefoot abduction, forefoot varus, ankle–hindfoot varus or valgus, and toe deformities.

Brace fitting was accomplished usually with a single visit to the prosthetist or pedorthist/orthotist, and the majority of braces could be fitted without heat molding of the plastic

Table 2

Characteristics of Charcot arthropathy and treatment with removable walker brace in 25 feet and ankles (21 patients)<sup>a</sup>

Characteristic	
Duration of Charcot arthropathy before brace use (weeks) <sup>b</sup>	12 ± 9
Treatment prior to removable walker brace <sup>c</sup>	
Cast <sup>c</sup>	15 (60)
Half-cast	5 (20)
Brace	1 (4)
Non-weightbearing	9 (36)
Partial weightbearing	5 (20)
Surgery	4 (16)
No prior treatment	8 (32)
Other <sup>c</sup>	5 (20)
Charcot stage when removable walker brace started	
I - Fragmentation	8 (32)
II - Coalescence	11 (44)
III - Consolidation	6 (24)
Anatomic location of Charcot arthropathy when removable walker brace started <sup>d</sup>	
	Type                      Region involved
1 Lisfranc	13 (52)                      20 (80)
2 Hindfoot	2 (8)                         7 (28)
3A Ankle	1 (4)                         1 (4)
3B Posterior calcaneus	1 (4)                         2 (8)
4 Combined	7 (28)                      –
5 Forefoot	1 (4)                         4 (16)
Treatment after removable walker brace <sup>e</sup>	
Rocker sole shoe and insole	13 (52)
Ankle foot orthosis	5 (20)
Surgery <sup>f</sup>	3 (12)
Cast <sup>g</sup>	2 (8)
Removable walker brace (ongoing)	8 (32)
Charcot stage at end of study	
I - Fragmentation	0 (0)
II - Coalescence	0 (0)
III - Consolidation	17 (68)
Removable walker brace ongoing (stage varied)	8 (32)
Deformity when removable walker brace discontinued	
Same as when brace started	14 (56)
Worse than when brace started	0 (0)
New deformity during brace treatment <sup>h</sup>	3 (12)
Removable walker brace ongoing	8 (32)

<sup>a</sup> Reported as mean ± standard deviation or number (percent of total) of feet and ankles.

<sup>b</sup> Three patients excluded from mean duration who had chronic Charcot for 78, 79, and 192 weeks before starting treatment with removable walker brace.

<sup>c</sup> Total is greater than number of feet because some feet had several forms of treatment. Cast = total contact cast or short leg walking cast. Other: U-splint in 2 feet, hinged walker brace in 1 foot, crutches for 1 foot, and comfortable shoes in 1 foot.

<sup>d</sup> Type as described previously [1,20]. Combined, 7 feet and ankles: 5 feet and ankles with two regions involved; 2 feet and ankles with three regions involved.

<sup>e</sup> Total is greater than number of feet and ankles because some had more than one treatment.

<sup>f</sup> Surgery consisted of osteotomy for recurrent ulcer in two feet and debridement for abscess in one foot.

<sup>g</sup> Cast: one was postoperative and one was in a patient with a recurrent ulcer and rocker bottom foot.

<sup>h</sup> New deformities during treatment: 1 foot with hindfoot collapse and forefoot varus, 1 foot with Lisfranc collapse, and 1 foot with forefoot abduction and crossover toe deformity.

Table 3

Removable walker brace parameters for treatment of Charcot arthropathy in 25 feet and ankles (21 patients)<sup>a</sup>

Parameter	
Number of visits to prosthetist	1 ± 1
Insurance coverage that paid for brace	
Fully paid by insurance	23 (92)
Partial (80%) paid by insurance	1 (4)
Not covered	1 (4)
Removable walker brace heat molded/stretched	
No	19 (76)
Yes <sup>b</sup>	4 (16)
Unknown	2 (8)
Duration of use of removable walker brace (wk) <sup>c</sup>	29 ± 19 (range, 6–73 weeks)
Standing and walking activity (h per day)	
Before Charcot diagnosis	9 ± 4
During treatment with removable walker brace	3 ± 3
Compliance with removable walker brace	
Full time (23.5 hr/day)	7 (28)
Out of bed only, not in bed	17 (68)
A few hours per day	1 (4)
Patients' subjective impression of removable walker brace	
Greatly helpful	21 (84)
Moderately helpful	2 (8)
Minimally helpful	0 (0)
Not helpful at all	1 (4)
Aggravated condition	1 (4)

<sup>a</sup> Reported as mean ± standard deviation or number (percent of total).

<sup>b</sup> Removable walker brace was stretched at medial malleolus and hindfoot in 1, fifth toe in 1, posterolateral heel in 1, and undocumented in 1 brace.

<sup>c</sup> N = 17 feet and ankles for which brace treatment was completed; brace treatment was ongoing for the other 8 feet and ankles.

shell (Table 3). The majority of patients had full insurance coverage for the costs of the brace. Patients decreased the average amount of standing and walking during the treatment course and used the brace for an average of 7 months (Table 3). The majority of patients did not wear the brace in bed at night and found the brace greatly helpful (Table 3).

At the most recent evaluation, almost one third of feet and ankles still were using the brace for ongoing treatment (Table 2); no further follow-up information was available for these 8 feet because the orthopedist moved from the region and care was transferred to another physician. The majority that had completed brace treatment reached stage III with no progression of initial deformity and were subsequently treated with rocker sole shoes, insoles, and ankle foot orthoses (Table 2). Three feet developed new deformity during brace treatment, noted on both clinical (Table 2) and radiographic examination. However, average radiographic parameters of hindfoot to forefoot alignment had minimal change between initial and final radiographs (Table 4).

The most frequent complication was pain from direct pressure from the brace and musculoskeletal pain in the back, hip, and knee (Table 5). Two new ulcers developed during brace use (Table 5).

Table 4  
Radiographic comparison of Charcot feet and ankles before and after treatment with removable walker brace<sup>a</sup>

Parameter	
Time between initial and final radiograph (weeks)	36 ± 24
Lateral talo-first metatarsal angle (degrees)	
Initial	13 ± 17
Final	15 ± 11
Change	1 ± 6
Anteroposterior talo-first metatarsal angle (degrees)	
Initial	7 ± 18
Final	9 ± 16
Change	2 ± 5

<sup>a</sup> Weightbearing radiographs only; non-weightbearing radiographs excluded.

#### 4. Discussion

The data support the hypothesis that a prefabricated, removable walker brace fitted with a custom insole may be successfully used in the management of the Charcot foot and ankle. The brace was effective in immobilizing the foot and ankle during healing and had a high satisfaction rate and safety profile despite frequent, albeit usually minor, complications.

In a previous study of total contact cast treatment for Charcot arthropathy, the average duration of cast treatment for unilateral cases was 19 weeks, with an additional average of 28 weeks after cast treatment until patients resumed footwear [8]. A more recent study of stage I Charcot

arthropathy in 10 patients reported an average of 6 weeks of total contact cast treatment and 12 weeks to achieve stability for therapeutic footwear [9]. Therefore, the current average duration of 29 weeks of brace treatment (Table 3) was longer than that reported for total contact casting.

A possible explanation for the longer duration of brace treatment compared with cast treatment is the issue of patient non-compliance. There is a low compliance rate among diabetic patients with prescribed footwear [22]. Compliance with the recommended full-time use of the brace was low (Table 3), and it is possible that some patients may have removed the brace more than admitted or walked without the brace. This may have prolonged the duration of healing. Furthermore, some patients in the current study lived great distances from the clinic, making frequent follow-up visits impractical. Therefore, it was judged best in this setting to avoid premature discontinuation of brace treatment and, thus, minimize the potential risk of relapse or swelling-related footwear complications. This cautious approach in these patients might also have contributed to a longer average treatment duration.

The pneumatic walker brace may be more economical over the course of treatment than total contact casting; however, a formal comparative economic analysis was not done. Total contact casting is labor intensive and is associated with frequent complications [12]. In addition, the cost of casting includes technical time for cast application, cast supplies for multiple casts, and frequent (weekly or biweekly) clinic visits for cast reapplication and adjustment; this total cost seems greater than the one time cost of the prefabricated brace and custom orthotic insole and cost of monthly follow-up clinic visits. Furthermore, the removable walker brace provides a distinct advantage in the care of patients from rural and underserved regions; whereas a total contact cast requires specially trained staff for application and maintenance, the brace required less frequent follow-up and only occasional adjustment.

It is important to note that there are several available designs of removable walker braces. Double-upright braces were not used because of potential for pressure irritation and ulcer at the malleoli against the double-uprights or hinges, a problem which had been observed prior to a previous study that included double-upright braces [18] and which may result in infected ulcers and amputation in the diabetic neuropathic foot and ankle. The pneumatic design appeared to provide a more uniform distribution of support around the foot and ankle without localized areas of pressure from a double-upright or hinge, and had the adjustability of the air bladders to accommodate deformity or changes in swelling. The plastic material provided a lightweight brace compared with braces made of metal uprights and hinges, and could be heat molded to accommodate major deformity. A standard height brace (short leg cast height) was used because it was felt that a low top brace (top of the brace just above the

Table 5  
Complications of removable walker brace in treatment of Charcot arthropathy

Complication	Number (%) feet
Pain from direct pressure from brace	12 (48)
Musculoskeletal pain	
Back	5 (20)
Hip	4 (16)
Knee	2 (8)
Ulcer development <sup>a</sup>	
Present at beginning of brace use	5 (20)
Developed during brace use <sup>b</sup>	2 (8)
Ulcer status in removable walker brace	
Improved	5 (20)
Unchanged	0 (0)
Deteriorated <sup>c</sup>	2 (8)
Tripping/falls	3 (12)

<sup>a</sup> There was a history of ulcer prior to treatment with removable walker brace in 10 (40%) feet and ankles, 5 of which had healed before brace use. In 1 foot, an ulcer developed after the brace was discontinued.

<sup>b</sup> 2 new ulcers: 1 ulcer subsequently improved and 1 ulcer deteriorated, necessitating discontinuation of the brace.

<sup>c</sup> Ulcer deterioration during brace use occurred in 1 patient with a partial foot amputation and psychiatric disorder and 1 patient with non-diabetic idiopathic neuropathy and rockerbottom midfoot collapse.

malleoli) would not provide adequate immobilization of the ankle or distribution of pressure away from the foot. Therefore, the pneumatic walker brace with the custom insole had some of the advantages of the custom Charcot Restraint Orthotic Walker (CROW) [23] without the higher cost and expertise necessary for CROW fabrication and maintenance.

The custom fitted, polyethylene foam orthotic insole used in this study is similar to insoles that are commonly used for diabetic neuropathic patients as a protective measure for the plantar surface of the foot. The removable walker brace was not available with a protective insole specific for the diabetic foot. Therefore, the custom insole was used with the removable walker brace to reduce the potential risk of skin irritation and breakdown on the plantar aspect of the foot during treatment for Charcot arthropathy.

Limitations of the study include those inherent with a retrospective review, including incomplete history and radiographic studies of previous treatment in some cases. No direct comparison was done with other treatment methods, and a comparative study with other treatment methods such as total contact casting may be of interest to evaluate relative efficacy, cost, and patient satisfaction. The brace may be relatively contraindicated in patients with hypermobile instability. Nevertheless, since the simplicity and efficacy of brace treatment became evident, the amount of total contact casting done in the clinic has decreased (casting used primarily for ulcer treatment or treatment of Charcot arthropathy by other clinic physicians), with improvements of clinic efficiency and decrease in patient queues waiting for orthopaedic cast technicians.

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