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Healing rates of plantar ulcers in leprosy and diabetes

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Summary Comparison was made of wound healing time in a consecutive series of leprosy and diabetic patients with plantar ulceration. In the leprosy group, 66 of 70 (94%) ulcers healed in a mean time of 42·7 (±36·1) days, and in the diabetic group, 75 of 80 (94%) ulcers healed in a mean time of 39·7 (±32·1) days. Analysis of all healed ulcers using a general linear model found wound depth ($p < 0{\cdot}03$), and wound diameter ($p < 0{\cdot}05$) significantly related to ulcer healing time. Diagnosis, healing devices (cast, splint and cut-out sandal), age and sex were not significant. In diabetic subjects a regression model including depth, diameter and age explained 36% of the variation in healing time. A meaningful regression model was not found in leprosy patients.

Introduction

Plantar ulceration is a major cause of disability in patients with leprosy and diabetes mellitus. Sensory loss secondary to peripheral neuropathy and mechanical stresses (pressure) are considered the primary causes of plantar ulceration.[1–5] In patients with diabetes, angiopathy may also be a factor contributing to tissue breakdown and delayed healing.

Motor neuropathy results in atrophy and deformities in the feet which causes in abnormal patterns and increased stresses on the foot.[1] Autonomic neuropathy results in dry inelastic skin due to loss of sweating mechanisms, and abnormal blood flow due to alterations in vasomotor control.[6]

Based on animal studies and observational data, repetitive stresses are believed to be the most common mechanism of injury in the neuropathic foot.[7,8] Repetitive stress also contributes to delayed healing in plantar ulcers because patients with sensory loss will walk on an unprotected, ulcerated foot.

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AETIOLOGY OF FOOT PROBLEMS IN LEPROSY AND DIABETES MELLITUS

While neuropathy is the major complication of leprosy, generalized disease can also effect the respiratory tract, eyes, liver, testes, muscles and bones. Invasion of the nerve by *Mycobacterium leprae* can result in injury secondary to inflammation and/or compression. The deformities and ulcerations of the feet and hands that so heavily stigmatize leprosy patients are secondary to neuropathy.[9]

Diabetes mellitus is a metabolic disorder of uncertain aetiology characterized by hyperglycaemia resulting from diminished secretion or ineffective action of insulin. Neuropathy or angiopathy are frequent complications which together may be contributing factors to the delayed wound healing in diabetic patients.[10] Altered nerve metabolism associated with hyperglycaemia and nerve ischaemia may lead to the distal, symmetrical, primarily sensory polyneuropathy most commonly seen in diabetes.[11]

Patients with diabetes have a higher incidence of both microangiopathy and macroangiopathy than nondiabetics. Microangiopathy is characterized by thickening of the capillary basement membrane resulting from hyperglycaemia. This pathology may alter the capillary diffusion of cell nutrients and lymphocytes which could prolong healing and promote infection.[12] Macroangiopathy results from accelerated atherosclerosis commonly involving the tibial and peroneal arteries, but uncommonly the small vessels of the feet.[13–14] Angiopathy is the primary cause of painful ischaemic lesions or gangrene generally affecting the nonweightbearing areas of the feet, but is an unlikely cause of the painless lesions associated with callous formation which develop over the plantar surface of the foot.[3,12,15,16]

ULCER TREATMENT

Several methods of treatment which reduce the mechanical stress on the foot have been recommended for the treatment of plantar ulcers.[12,17–23] These include bedrest, crutches, walking casts, walking splints, prefabricated walkers and splints, patellar tendon braces, foam pads, cut-out sandals and healing footwear. The effectiveness of methods such as bedrest, crutches, and easily removable appliances is highly dependent on patient compliance.

Brand found the total contact cast (TCC) to be the most effective method of treating plantar ulcers in leprosy and recommended their use in both leprosy and diabetes mellitus. The TCC promotes healing by reducing mechanical stress on the foot.[18] Walking casts

Table 1. Ulcer grades

Grade	Definition
0	Intact skin
1	Superficial ulcer
2	Deep ulcer (involvement of tendon, bone, ligament, or joint)
3	Deep abscess or osteomyelitis
4	Gangrene of toes or forefoot
5	Gangrene of whole foot

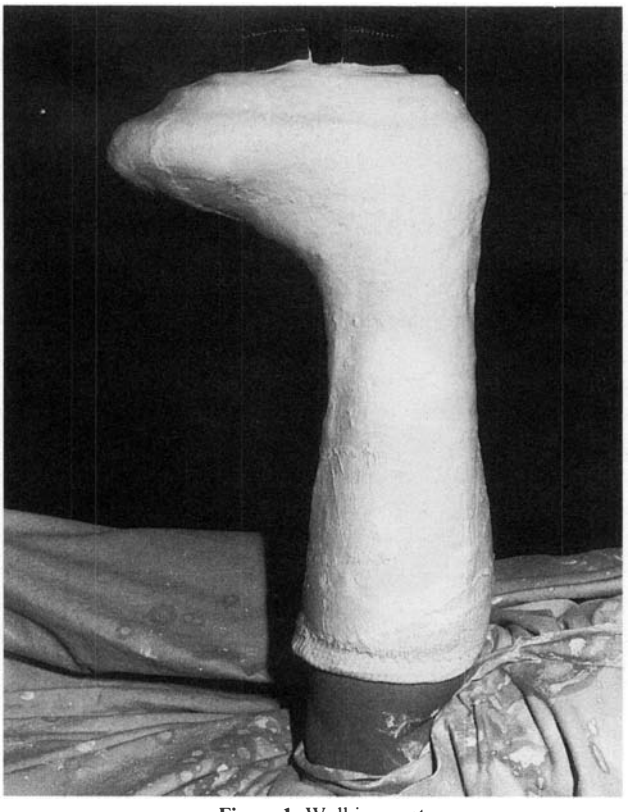

Figure 1. Walking cast.

have been shown to be effective in reducing pressure on the plantar surface of the foot during walking.[24–26] Novick *et al.*[27] found no meaningful differences in the reduction of plantar forces between walking casts and walking splints. Mooney & Wagner[28] proposed that the TCC promoted healing in the diabetic patients by reducing oedema and thereby improving the microcirculation.

The effectiveness of walking casts in the management of plantar ulcers in both leprosy and diabetic patients has been well reported.[29–36] The median and average healing time of these studies collectively is approximately 6 weeks. Several studies using control groups found a much higher percentage of the healed ulcers, as well as significantly decreased healing time of plantar ulcers using casting.[31,33,35] There is limited data on the effectiveness of other wound healing devices in leprosy and diabetic patients.

This study compares the healing rates of leprosy and diabetic patients utilizing several devices designed to reduce plantar stresses.

Method

Subjects included all patients with leprosy and diabetes treated for plantar ulcerations by the Foot Program of the Gillis W Long Hansen's Disease Center during a 2-year period.

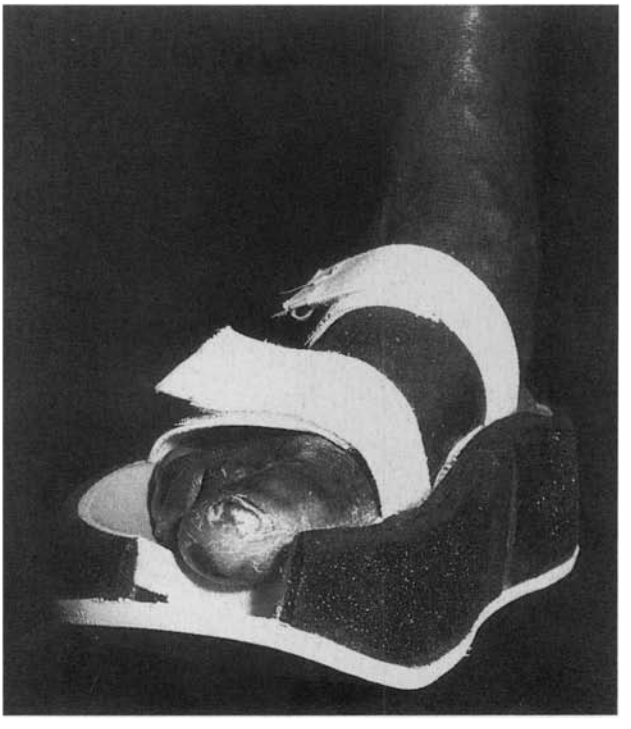

Figure 2. Cut-out sandal.

Patients with a history of both leprosy and diabetes mellitus were not included in the study.

Initial recordings were made on a tracking form including patient's age, sex, duration of ulcer, wound diameter and depth. Diameter was determined by tape measurement of maximum wound length. Depth was determined by measuring the depth with a sterile probe. Wound probing was also used to classify the wound into an ulcer grade as described by Wagner (Table 1).[37]

TREATMENT

Wounds were debrided of necrotic tissue unless such removal would result in further injury to underlying viable structures. Callous and overlying wound edges were cut back to expose the basal cell layer of the epidermis in order to promote epithelialization. Wound care following debridement included cleansing with hydrogen peroxide and flushing with saline. Povadine iodine solution was often used to clean intact skin areas but was not used topically on wounds. Antibiotic therapy was only used in the treatment of acute infection.

Wounds were protected from walking stresses using 1 of 3 devices (treatments 1–3): walking casts, cut-out sandals or walking splints (Figures 1–3). The fabrication technique for each device has been previously described by Birke *et al*.[38] Patients who were treated with more than one treatment device, or required surgical treatment were included in

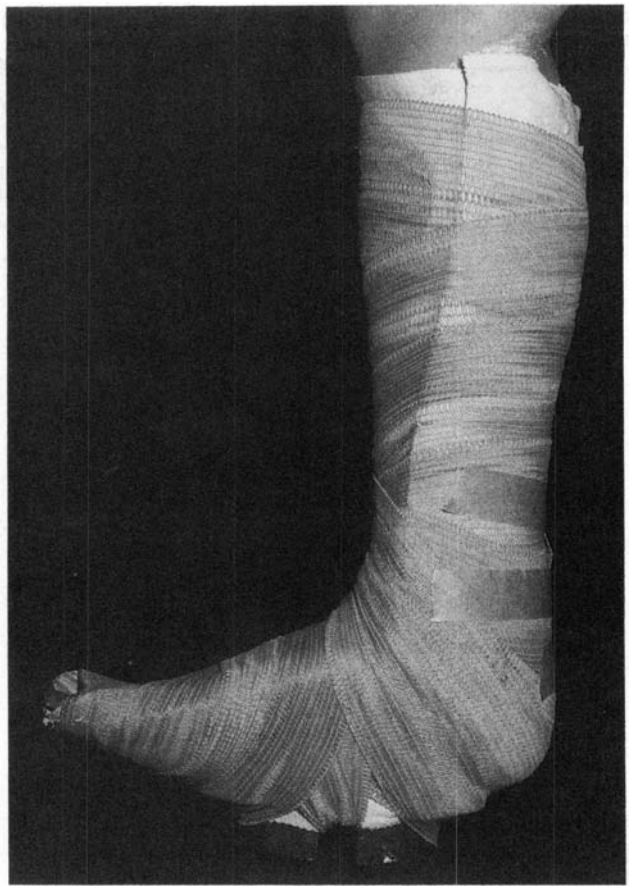

Figure 3. Walking splint.

treatment group 4. All patients were instructed in partial weightbearing ambulation using crutches or a walker.

Healing devices were selected in a nonrandomized manner based on ulcer grade, location and in some cases patient preference. Generally, walking casts were the recommended treatment for Wagner grade 1 and 2 ulcers. Deep abscess, purulent drainage, heavy drainage, systemic signs of infection and dermatosis were contraindications for casting in this study. Suspected Grade 3 ulcers were evaluated for surgery. Cut-out sandals were used for toe ulcerations. Walking splints were the alternate method when casting was not indicated or patients were not amenable to a cast.

Healing time (measured in days) was determined by clinical observation of wound closure. Wound closure was defined as complete epithelialization of the wound. Differences in healing time between diagnostic groups and the relationship of secondary variables including healing device, age, wound diameter, depth and duration on healing time were analysed using a general linear model (SAS System, SAS Institute Inc, Cary, NC, USA) and multiple regression.

Table 2. Mean healing rates and wound characteristics between diabetic and leprosy patients

	n	Rate (days)	Age (years)	Diameter (mm)	Depth (mm)	Duration (days)
Diabetic	75	39·7	51·8	17·4	7·4	328·6
Leprosy	66	43·2	54·8	11·4	6·1	244·1

Table 3. Data on ulcers not healed or lost to follow-up (LTFU)

	Not healed	LTFU
Diabetic	2	3
Leprosy	3	1

Table 4. Mean healing rates and wound characteristics for healing devices

	n	Rate (days)	Diameter (mm)	Depth (mm)	Age (years)
Walking cast	68	37·7	16·4	7·2	50·2
Cut-out sandal	25	34·8	7·7	4·1	55·9
Walking splint	27	43·0	20·0	7·0	55·6
Other*	21	58·7	10·0	8·5	56·5

* Includes surgery cases.

Results

In the leprosy group 66/70 ulcers (94%) healed in a mean time of 42·7 ($\pm$ 36·1) days and 75/80 ulcers (94%) in the diabetic group healed in a mean time of 39·7 ($\pm$ 32·1) days (Table 2). The number of cases which did not heal or were lost to follow-up were similar in both groups (Table 3). There was no significant difference in healing time between leprosy and diabetic patients ($p > 0{\cdot}05$).

Analysis of secondary variables using a general linear model showed a significant relationship between wound depth ($p < 0{\cdot}03$), and diameter ($p < 0{\cdot}05$) and the dependent variable healing time. Age, duration of ulceration, treatment devices (Table 4) and sex were not significant. A stepwise regression model including depth, diameter and age explained 36% of the variation in healing time for diabetics (Table 5). Depth was found to be a highly significant predictor of healing time. A meaningful prediction model ($p > 0{\cdot}15$) was not found for leprosy patients.

Table 5. Stepwise regression procedure for dependent variable rate

Step	Variable	Partial R2	Model R2	F ratio	Probability
1	Depth	0·3191	0·3191	34·208	0·0001
2	Diameter	0·0214	0·3404	2·332	0·1311
3	Age	0·0215	0·3619*	2·387	0·1268

* 36·19% is the total variation in rate explained by the model rate = −1·8337 + depth (2·32334) + diameter (0·34087) + age (0·35414).

Discussion

It has been thought that delayed healing of ulcers in diabetic patients may be the result of vascular disease. Since leprosy patients are at no greater risk of vascular disease than the general population, it might have been expected that the diabetic group in this study would have healed at a slower rate. The finding of no difference in healing time between leprosy and diabetic patients supports loss of protective sensation and mechanical stress as the primary aetiology for plantar ulceration in both groups.

Delbridge *et al.*[4] characterized neuropathic ulcers as being painless, circular, calloused, pink lesions and localized over bony areas on the plantar surface of the foot. In contrast he notes that vascular lesions tend to be painful, irregular, noncalloused, pale and nonplantar. Additionally, ulcers in leprosy and diabetic patients seem to be located at the same sites of the foot.[41,42] The first metatarsal head, the great toe, and fifth metatarsal head have been shown to be the most common sites of ulceration in both groups. These sites represent areas of highest pressure on the foot and ulceration has been shown to occur where pressure is highest.[1,39,40] The patients' inability to protect their feet due to sensory loss results in delayed healing of plantar ulcers.

Both leprosy and diabetes are major international health problems. Leprosy has an estimated 12 million cases and diabetes mellitus 100–120 million cases worldwide.[43,44] In the USA foot complications account for 20% of annual hospital admissions of diabetic patients, and foot injuries caused by neuropathy have been found to be 3 times more common than ischaemia.[45,46] Diabetes is the leading cause of lower extremity amputation in the USA (50,000 diabetic foot amputations yearly), and it has been reported that this rate could be significantly reduced by implementation of programme emphasizing preventive care of insensitive feet.[47–50]

There are limited resources to provide healing devices, protective footwear and orthotics for the tens of millions of leprosy and diabetic patients likely to develop foot problems in most parts of the world. Since there is a common aetiology in plantar ulceration in leprosy and diabetes, the pooling of resources could result in more effective management and reduction of disability in both groups.

This study shows that both leprosy and diabetic patients can obtain satisfactory ulcer healing with proper wound protection. While not randomly assigned, device selection showed no relationship to healing time between the 3 devices used. Also, the average healing time in this study (using the cast, sandal or splint) was similar to the cast groups in other studies where walking casts were shown to be more effective than traditional methods.[31,33,35]

Wound depth was found to be the strongest predictor of healing time. Deeper wounds may heal more slowly because of involvement of subdermal tissues such as tendon, joint, capsule and bone. These lesions may also be more septic. Wound diameter and age were also found to affect healing time. As expected, healing time was longer for larger diameter wounds and in older patients.

Of note is the absence of a meaningful prediction model for the leprosy patients, where ulcer size and age accounted for an insignificant percentage of the variation in healing time. In this study, leprosy patients were primarily residents of the Center, while the diabetic patients were exclusively outpatients. The treatment of ulcers should be easier in a controlled environment, but in this situation, familiarity of patients with both staff and treatment procedures may have had a negative impact on patient compliance. For example, in contrast to the diabetic group, leprosy patients were more likely to direct their treatment or miss appointments. We speculate that compliance, or lack of it, may have accounted for much of the unexplained variation in healing time in the leprosy group. Research has been lacking on the measurement of compliance, the effect of compliance on treatment outcome in neuropathic patients, and the benefit of patient education on improving treatment compliance.

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Taux de cicatrisation des ulcères plantaires dans la lèpre et le diabète

J A Birke, A Novick, C A Patout et W C Coleman

Résumé Nous avons comparé le temps de cicatrisation des plaies dans des séries consécutives de patients lépreux et diabétiques souffrant d'ulcération plantaire. Dans le groupe des lépreux, 66 des 70 ulcères (94%) se sont cicatrisés dans un temps moyen de 42,7 ($\pm$ 36,1) jours, et dans le groupe des diabétiques, 75 des 80 ulcères (74%) se sont cicatrisés dans un temps moyen de 39,7 ($\pm$ 32,1) jours. L'analyse de tous les ulcères cicatrisés, à l'aide d'un modèle linéaire général, a révélé que la profondeur de la plaie ($p < 0{,}03$), et son diamètre ($p < 0{,}05$) étaient en relation significative avec le temps de cicatrisation. Le diagnostic, les systèmes d'aide à la cicatrisation (plâtre, attelle et sandale découpée), l'âge et le sexe n'étaient pas significatifs. Chez les sujets diabétiques, un modèle régressif comprenant profondeur, diamètre et âge a expliqué 35% de la variation du temps de cicatrisation. Pour les lépreux nous n'avons pas trouvé de modèle régressif ayant un sens.

Velocidades de curacion de las ulceras plantares en la lepra y la diabetes

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Resumen Se realizó una comparación del tiempo de curación en una serie consecutiva de pacientes de la lepra y diabéticos sufriendo de ulceración plantar. En el grupo leproso, 66 de las 70 úlceras (94%) se curaron en un tiempo medio de 42,7 días ($\pm$ 36,1 días), y en el grupo diabético, 75 de las 80 úlceras (94%) se curaron en un tiempo medio de 39,7 días ($\pm$ 32,1 días). Un análisis de las úlceras curadas utilizando un modelo general lineal reveló una profundidad de herida ($p < 0{,}03\%$) y un diámetro de herida ($p < 0{,}05$) significativamente relacionados al tiempo de curación de la úlcera. El diagnóstico, dispositivos de curación (escayola, tablilla, sandalia recortada), edad y sexo not eran sifnificativos. En los pacientes diabéticos, un modelo de regresión que incluía profundidad, diámetro y edad explicó 36% de la variación del tiempo de curación. No se encontró un modelo de regresión válido para los pacientes leprosos.