

Efficacy of Diabetic Foot Ulcer Treatment and Possible Ways for Improvement: A Retrospective Cohort Study

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ABSTRACT **Background:** Diabetic foot (DF) is a dangerous complication of diabetes mellitus (DM). Modern treatment modalities and good organization of care can improve prognosis. **Objectives:** To analyze results of DF treatment in a tertiary care setting and the degree of implementation of international guidelines in practice. **Methods:** We conducted a retrospective analysis of 90 patients treated for DF ulcers/wounds in our center (May–December 2023). Thirty-five patients received only outpatient care. The median age was 65 (37–90) years, 96% had type 2 DM. **Results:** Median wound duration was 29 (1–1461) days. Previous treatment was conducted by a family doctor in 30%, at a local wound clinic in 7%, by other medical specialists in 27%, or by the patient/relatives in 29%. At this stage off-loading devices were prescribed for 37%, and 35% were referred to a vascular surgeon. Limb ischemia occurred in 44 patients (49%), revascularization was conducted for 16 patients. At 6 months, healing rates were 48%. Minor or major amputation rates were 4% and 5%, respectively; 6% died, 29% stayed unhealed, and 8% were lost to follow-up. Multivariable analysis revealed independent predictors of non-healing (ethnic group and impossibility of revascularization) and of amputation (previous major amputation, presence of osteomyelitis, and white blood cell count). **Conclusions:** To prevent diabetes-related amputations, healthcare professionals must prioritize preventive care, provide regular podiatry services for high-risk patients, ensure early specialist treatment for any foot ulcer, implement international guidelines at all levels of DF care, and increase the capacity of secondary wound clinics and access to revascularization.

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KEY WORDS: amputation prevention, diabetic foot ulcer (DFU), healing rate, off-loading device, revascularization

Diabetic foot (DF) is a serious and resource-consuming complication of diabetes mellitus (DM). It is characterized by slow healing of lower extremity ulcers/wounds and high risk of disability; however, modern treatment modalities and good organization of care can improve the situation.

Early and comprehensive treatment by a multi-disciplinary team (MDT) increases the probability of treatment success [1,2]. Multiple factors influencing the efficacy of DF treatment became the basis for the International Working Group on the Diabetic Foot (IWGDF) guidelines [3–6].

Effective multi-modal treatment of a diabetic foot ulcer (DFU) includes (besides topical treatment) systemic antibiotic therapy in case of wound infection, early reveal of limb ischemia and revascularization, if necessary, removal of pressure at the ulcer area with usage of off-loading devices, and surgical interventions in the foot/leg for removal of all necrotic/infected tissues (that can include minor or major amputation) in case of deep infection or necrotic process. Nevertheless, the implementation of the IWGDF guidelines in practice have not been widely studied, and for many countries such data are lacking. Accordingly, the aims of our study were to analyze efficacy of DF ulcer and wound treatment in our DF unit and to identify pitfalls in the implementation of the IWGDF guidelines and possible ways to improve the treatment results.

PATIENTS AND METHODS

We analyzed retrospectively medical records of 100 patients who started treatment for a DFU or wound in our tertiary care hospital center in May–December 2023. The study protocol was approved by the ethics committee of Hillel Yaffe Medical Center. Patients admitted with gangrene (n=10) were excluded due to evident treatment result

(amputation). We analyzed factors influencing treatment results in 90 patients with ulcers or wounds. Fifty-five patients (61%) were hospitalized with further outpatient treatment; 35 (39%) were only outpatients. We analyzed the treatment results 01 March 2024. Median follow-up time from the start of the treatment was 6.3 months. An ulcer or wound was considered healed after complete epithelialization of the lesion without drainage or requirement of dressings for at least 4 weeks [7]. All available information about amputations in the studied cohort was fixed (amputation was defined as resection of a segment of a limb through a bone or a joint: minor was amputation distal to the ankle joint; major was proximal to this joint).

DIAGNOSTIC ALGORITHM

Blood tests were conducted for all patients according to the hospital protocol. We accessed the ulcers and wounds according to the Texas University classification system [8]. Wound infection was diagnosed according to the IWGDF criteria [9] for focal clinical signs and clinical/laboratory signs of systemic (severe) infection. Wound culture was obtained and assessed in case of planned antibacterial therapy. Exclusion of foot ischemia was based on the clinical signs (pedal pulses, ulcer appearance, pain patterns) and confirmed with Doppler ankle-brachial index study where necessary. If there were signs of limb ischemia, a CT angiography was conducted before vascular intervention. A diagnosis of osteomyelitis was based on clinical signs (pathologic fracture, bone fragments in the wound, probe-to-bone [PTB] test) and X-ray imaging with CT if necessary. This diagnosis was considered as definite in case of a positive X-ray/CT and PTB test, according to results of meta-analysis by Calvo-Wright et al. [10]. The cases were considered as probable osteomyelitis with a positive PTB test only.

TREATMENT

Treatment was made according to the IWGDF guidelines [3-6] and included metabolic control, antibiotics (in case of wound infection), application of dressings to the wound, wound off-loading, and vascular intervention when necessary and possible.

STATISTICS

Descriptive statistics were used to summarize demographic and clinical characteristics. Continuous variables are presented as median and range. Comparisons between subgroups were performed using the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's

exact test (as appropriate) for categorical variables.

Variables that were significantly associated with the outcomes in univariate analyses were entered into multivariable logistic regression models to assess their independent association with three primary outcomes: non-healing of the ulcer at 6 months, amputation (minor or major), and all-cause mortality. Patients lost to follow-up ($n=7$) were excluded from analyses related to amputation and mortality. A two-sided P -value < 0.05 was considered statistically significant. All analyses were performed using Statistica for Windows version 29 (StatSoft Inc., Tulsa, OK, USA).

RESULTS

Characteristics of the groups are presented in Table 1. We also analyzed ulcer/wound treatment conducted before admittance and assessed it according to the IWGDF guidelines. Results of this analysis are presented in Table 2.

UTILIZATION OF THE MAIN TREATMENT MODALITIES BY OUR TEAM

Antibacterial therapy

Antibiotics were prescribed (in case of clinical signs of wound infection or osteomyelitis) in 69 patients (77%). Wound culture was technically possible and was taken in 51 patients (56%). The antibiotic therapy was adjusted according to the culture results.

Revascularization

We considered revascularization in 44 patients with signs of ischemia. Of this group, 16 interventions were made (13 endovascular, 3 bypass). In 10 patients, revascularization was not considered possible. In 7 patients, revascularization was not appropriate (non-functional limb), in 10 patients wound healing was active without revascularization, and one patient refused intervention.

Off-loading

The choice of off-loading devices depends on wound location, mobility, and the general condition (including walking stability) of the patient. Most of our patients ($n=71$) presented with ulcers in the areas affected by physical load (pressure) during walking or bed rest position. So, we used removable off-loading devices, restricted walking (in 10 patients), or wheelchair use (in 16 patients) until the wound was completely healed. Of the off-loading devices, a half-shoe with a forefoot platform

was prescribed in 29 patients, a knee-high off-loading walker in 5, or a soft heel boot for 7 patients confined to their bed. Nevertheless, only 26 patients (34%) who needed off-loading constantly and completely followed the recommendations. Healing rates were higher in patients who were compliant with off-loading treatments (62% vs. 40%), but the difference did not reach significance ($P = 0.08$), presumably due to the heterogeneity of the cohort. Although low compliance with removable off-loading devices is well known [11,12], we could not use non-removable devices (e.g., total contact cast) in the existing model of care organization.

Treatment results

Healing rate at 3 months was 24%, healing rate by the time of analysis (median 6.3 months) was 48%. Results of the treatment are presented in Figure 1 and Figure 2. We also calculated treatment results for all inpatients ($n=55$) to compare results with other hospital-based cohorts. In our cohort of 55 patients, 23 (42%) achieved complete healing: 12 (22%) within 3 months. Amputations were needed in 9 patients (16%) (5 minor, 4 major). Four patients (7%) died due to concomitant diseases, and 14 (25%) remained unhealed. Five patients (9%) were lost to follow-up. Some patients ($n=47$) discontinued

Table 1. Characteristics of the cohort studied ($n=90$)

Demographic characteristics	Values	Demographic characteristics	Values
Age in years	65 (37–90)	Functional status	
Sex		Mobile	66 (72%)
Male	66 (73%)	In bed or limited mobility in room	15 (16%)
Female	24 (27%)	Non-functional limb (contracture, paralysis)	7 (10%)
Ethnic origin		Smoking status	
Jewish/mixed	53 (59%)	Active	22 (32%)
Arab	37 (41%)	Past	15 (22%)
Mode of treatment		Never	31 (46%)
Outpatient only	35 (39%)	Body mass index, kg/m ²	27.8 (18.6–42.0)
Inpatient and outpatient	55 (61%)	Current case characteristics	
Background medical history and risk factors		Case type	
Diabetes type (1 / 2)		Ulcer (including necrotic plaque)	78 (87%)
Type 1	4 (4%)	Wound after minor amputation	8 (9%)
Type 2	86 (96%)	Combination	4 (4%)
Diabetes duration, years	20 (1–40)	Diabetic foot	
Treatment of diabetes		Neuropathic	47 (52%)
Oral/GLP1 agonists	18 (22%)	Neuro-ischemic	43 (48%)
Insulin	18 (22%)	Osteomyelitis	
Insulin + other	46 (56%)	Yes	38 (42%)
Previous diabetic foot ulcers	43 (48%)	No	34 (38%)
Previous amputations		Probable	18 (20%)
Major	5 (5%)	Laboratory data	
Minor	22 (24%)	HbA1c, %	8.1 (4.6–3.5)
Both	2 (2%)	WBC, $n \times 10^9$	9.8 (3.6–26.2)
No	61 (68%)	C-reactive protein, mg/l (reference 0–5)	38 (0.6–325)
Severe renal failure (CKD Stages 4–5)	3 (3%)	Presence of multi-drug-resistant bacteria (resistance to two or more classes of antibiotics) of all wound cultures ($n=51$)	32 (63%)

Figure 1. Treatment results in the whole cohort assessed at 3 months

DF = diabetic foot

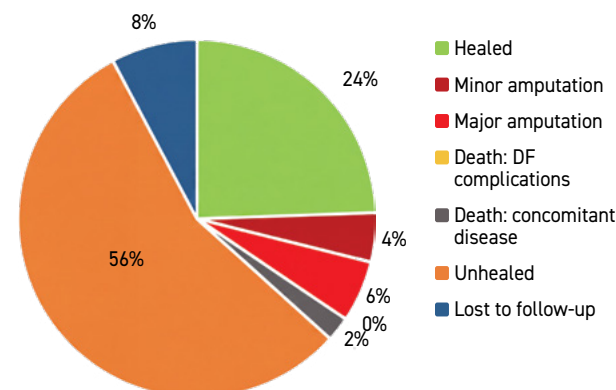


Figure 2. Treatment results in the whole cohort (n=90) assessed at the time of our study (median follow-up 6.3 months)

*The mortality rate did not differ significantly even after exclusion of patients lost to follow-up

DF = diabetic foot

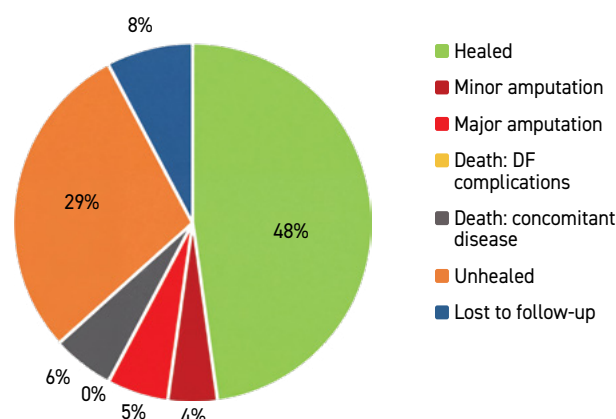


Table 2. Analysis of the treatment before visit or admittance to our team

Characteristic	Value
Ulcer/wound duration (before the start of our team's treatment), days	29 (1–1461)
Who treated the wound before our team	
Patient/relatives	26 (29%)
General practitioner	27 (30%)
Local wound clinic	6 (7%)
Other medical specialist	24 (27%)
Off-loading device / method prescribed in all cases where it was necessary and relevant	25 (37%)
Vascular surgeon consultation in all cases where it was necessary and relevant	17 (35%)

visits to the outpatient clinic, but medical information system contained data from telephone calls. We consider this information important for further analysis. In 40% of patients, the ulcers healed. In 2% a minor amputation was needed and 2% experienced a major amputation. In total, 11% died due to concomitant diseases, 30% stayed unhealed, and 15% did not respond to our telephone calls.

Factors related to poor treatment results

Table 1 presents the baseline characteristics of the study cohort and variables previously identified in the literature [1-4] as potentially associated with DF ulcer outcomes. Ulcer non-healing at 6 months was significantly associated with limb ischemia, inability to undergo revascularization, insulin-treated diabetes, Arab ethnicity, non-functional limb, and hindfoot ulcer location. In the multivariable logistic regression model, only Arab ethnicity and inability to undergo revascularization remained independent predictors of non-healing ($P < 0.05$). Amputation was significantly associated with prior major amputation, inability to undergo revascularization, presence of osteomyelitis, elevated white blood cell count (WBC), elevated C-reactive protein levels, limited mobility, and hindfoot ulcer location. In the multivariable model, prior major amputation, definite osteomyelitis, and WBC level remained independent predictors ($P < 0.05$). All-cause mortality was associated with older age, inability to undergo revascularization, non-functional limb, and limited mobility. However, in the multivariable analysis, none of these variables remained statistically significant, perhaps due to the low number of deceased patients in the cohort.

DISCUSSION

Our study was focused on a real-practice cohort. Few centers publish such data. For specialized DF care teams, it is important to analyze and publish these results because they show real situations and interventions that can be implemented to reduce diabetes-related amputation rates.

GROUP CHARACTERISTICS

We noted a high rate of osteomyelitis in our study cohort: 42% had X-ray positive osteomyelitis and 20% of X-ray negative or probable osteomyelitis (PTB only). According to our protocol, the first choice of treatment for osteomyelitis is conservative (a course of antibiotics for at least 6 weeks). Thus, only 13% of patients with osteomyelitis underwent amputation (7 of 56 patients; 3 lost to follow-up

were excluded). However, 7 of 9 patients who underwent amputation had osteomyelitis. Osteomyelitis was an independent risk factor for amputation but not for non-healing. In our opinion, non-healing was influenced more by the degree of ischemia, success of revascularization, and patient's adherence to off-loading recommendations.

TREATMENT CHARACTERISTICS

The delay between ulcer manifestation and involvement of the specialized MDT was high (median 29 days). This delay can be explained by the absence of obligatory referrals of DF patients. The cause of admission and outpatient visits to our center was often not a wound, but rather its deterioration. Low compliance with the IWGDF guidelines occurred. Off-loading devices were prescribed for 37% of patients who needed them, and referral to a vascular surgeon was made in only 35% of cases. We considered insufficient knowledge and treatment of DFUs by primary care physicians as the main causes of low implementation of IWGDF recommendations.

TREATMENT RESULTS

In our cohort, ulcer and wound healing in 48% (including 24% in 12 weeks) and all-level amputation rates of 9% was considered relatively good, but improvements are needed. We did not include 10 patients admitted with gangrene during the study period.

The treatment results of other DF care teams presented in the literature have limitations. In clinical practice, the healing rate of DF is approximately 30% to 40% at 12 weeks, and up to 67% at 1 year in MDT settings [7,13-14]. The American Heart Association [15] notes that only 25–50% of patients with DF heal in 12–20 weeks, but in specialized MDT the rates are up to 77% at 1 year.

A recent meta-analysis [16] investigated the efficacy of standard treatment of neuropathic DFs in control groups of 32 randomized control trials in 1996–2023. The healing rate was 33% (8–74%); by 12 weeks it was 25% and by 17–20 weeks it was 46%. Interestingly, in a similar meta-analysis [17], the results were only slightly worse, with a healing rate of 24% by 12 weeks, and of 31% by 20 weeks.

In Israel, the only available analysis of treatment results was published in 2021 [18]. This survey of hospital patients with DF infection showed no change in treatment results over 5 years. In that cohort 54% of the patients underwent amputation (25% major) and 6.2% died. The mortality rate within 1 year of discharge was 24.5%. Of

note, that cohort included more severe patients than ours and 19% received chronic hemodialysis.

Concerning our cohort, all-cause mortality rate of 6% in 6 months is high, although the median age of deceased patients was 82 (62–90) years. Nevertheless, high mortality rate of DF patients is common. Another recent meta-analysis [19] revealed mortality rates of 13% at 1 year, 33% at 3 years, 49% at 5 years, and 77% at 10 years, with cardiovascular disease and infection being the leading causes of death (47% and 25%, respectively). As cardiovascular complications represent the leading cause of mortality in DF patients, treatment of cardiovascular risk factors is very important in this group.

POSSIBLE WAYS TO IMPROVE TREATMENT RESULTS

Our findings confirmed the importance of revascularization in DF patients with limb ischemia. An increase in the revascularization rate may reduce the number of diabetes-related amputations. Chronic limb-threatening ischemia, even with minimal tissue loss, should be considered serious, and treated promptly with revascularization.

Surprisingly, isolation of multidrug resistant organisms (MDRO) in the wound did not affect treatment results. MDROs were defined as bacteria resistant to two or more classes of antibiotics. This finding confirms the efficacy of our hospital's antibacterial treatment protocol. Detection of MDRO led to changes in antibiotic regimens that, in turn, provided successful suppression of wound infection.

Low compliance with off-loading devices (34% in our cohort) was well demonstrated in previous studies [11,12]. One of the effective solutions is usage of non-removable off-loading devices in patients without significant ischemia and with controlled infection, which was underused in our cohort.

STUDY STRENGTHS AND LIMITATIONS

The strengths of our study include the description of real life situation concerning both treatment results and the degree of implementation of the IWGDF guidelines in the DF treatment.

Concerning the limitations, our study was retrospective; therefore, not all the possible parameters could be included in the risk factors model. The size of the cohort was relatively small. The cohort included both inpatients with follow-up outpatient treatment as well as just outpatient treatment. During the same period, 10 patients were admitted to our hospital with DF gangrene. They were not included in this cohort. Therefore, the total result of treatment may

not be reflected by this cohort. From the clinical point of view, this highlights the problem of proper pre-hospital care to reduce the rate of such admissions.

CONCLUSIONS

Treatment results in this inpatient/outpatient cohort were consistent with the results in previous research. Our study revealed incomplete implementation of the IWGDF guidelines in clinical practice. For prevention of diabetes-related amputations greater emphasis must be placed on preventive care aimed at preserving foot health, detecting patients at high risk for ulcer development for proactive referral to regular podiatry care and/or wound care clinics within their health fund (or hospital) system, educating patients to seek immediate evaluation by their primary care physician or a wound care specialist in case of any changes in the foot, referring patients with DF immediately to a specialized setting, and facilitating prompt acceptance of patients by specialized outpatient wound clinics. Implementing IWGDF guidelines at the primary and secondary levels of DF care is important as is increasing the capacity of secondary wound clinics and improving the availability of revascularization in tertiary care centers.

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References

- Musuuzza J, Sutherland BL, Kurter S, Balasubramanian P, Bartels CM, Brennan MB. A systematic review of multidisciplinary teams to reduce major amputations for patients with diabetic foot ulcers. *J Vasc Surg* 2020;1433-46 :(4) 71 .
- Valabhji J. Rapid access to multidisciplinary diabetes foot care teams. *BMJ* 2020; :368 m773.
- Senneville E, Abbas Z, Albalawi Z, et al. IWGDF/IDSA guidelines on the diagnosis and treatment of diabetes-related foot infections. *Diab Metab Res Rev* 2024; :(1) 40 e3687.
- Bus SA, Armstrong DG, Crews RT, et al. Guidelines on offloading foot ulcers in persons with diabetes (IWGDF 2023 update). *Diab Metab Res Rev* 2024; :(3) 40 e3647.
- Chen P, Vilorio NC, Dhatariya K, et al. Guidelines on interventions to enhance healing of foot ulcers in people with diabetes (IWGDF 2023 update). *Diab Metab Res Rev* 2024; :(3) 40 e3644.
- Fitridge R, Chuter V, Mills J, et al. The intersocietal IWGDF, ESVS, SVS guidelines on peripheral artery disease in people with diabetes and a foot ulcer. *Diab Metab Res Rev* 2024; :(3) 40 e3686.
- Armstrong DG, Tan TW, Boulton AJM, Bus SA. Diabetic foot ulcers: a review. *JAMA Online* 2023; 330 (1): 62-75.
- Lavery LA, Armstrong DG, Harkless LB. Classification of diabetic foot wounds. *J Foot Ankle Surg* 1996; 35 (6): 528-31.
- van Netten JJ, Bus SA, Apelqvist J, et al; International Working Group on the Diabetic Foot. Definitions and criteria for diabetes-related foot disease (IWGDF 2023 update). *Diabetes Metab Res Rev* 2024; 40 (3): e3654.
- Calvo-Wright MDM, Álvaro-Afonso FJ, López-Moral M, García-Álvarez Y, García-Morales E, Lázaro-Martínez JL. Is the combination of plain X-ray and probe-to-bone test useful for diagnosing diabetic foot osteomyelitis? A systematic review and meta-analysis. *J Clin Med* 2023; 12 (16): 5369.
- Armstrong DG, Lavery LA, Kimbriel HR, Nixon BP, Boulton AJ. Activity patterns of patients with diabetic foot ulceration: patients with active ulceration may not adhere to a standard pressure off-loading regimen. *Diab Care* 2003;2595-7 :(9) 26 .
- Armstrong D, Nguyen H, Lavery L, Schie C, Boulton A, Harkless L. Off-loading the diabetic foot wound: a randomized clinical trial. *Diab Care* 2001; 24: 1019-22.
- Ha Van G, Amouyal C, Bourron O, et al. Diabetic foot ulcer management in a multidisciplinary foot centre: one-year healing, amputation and mortality rate. *J Wound Care* 2020; 29 (8): 464-71.
- Rumanes A, van Netten JJ, Hutting KH, van Gemert-Pijnen LJEWC, van Baal JG. Offloading strategies used for plantar diabetic foot ulcers and their outcomes in real-life clinical practice. *J Clin Med* 2025; 14 (11): 3834.
- Gallagher KA, Mills JL, Armstrong DG, et al. Current status and principles for the treatment and prevention of diabetic foot ulcers in the cardiovascular patient population: a scientific statement from the American Heart Association. *Circulation* 2024; 149 (4): e232-53
- Coye TL, Bargas Ochoa M, Zulbaran-Rojas A, et al. Healing of diabetic neuropathic foot ulcers receiving standard treatment in randomized controlled trials: a random effects meta-analysis. *Wound Repair Regen* 2025; 33 (1): e13237.
- Margolis DJ, Kantor J, Berlin JA. Healing of diabetic neuropathic foot ulcers receiving standard treatment. A meta-analysis. *Diab Care* 1999; 22 (5): 692-5.
- Leibovitch M, Gellman YN, Haze A, et al. [Hospitalizations due to acute diabetic foot: annual trends and predictors of morbidity and mortality - 5-years experience of a multidisciplinary unit. *HaRefuah* 2021; 160 (10): 651-6. [Hebrew].
- Chen L, Sun S, Gao Y, Ran X. Global mortality of diabetic foot ulcer: a systematic review and meta-analysis of observational studies. *Diab Obes Metab* 2023;36-45 :(1) 25 .

Drama is life with the dull bits cut out.

Alfred Hitchcock (1899–1980), English filmmaker widely regarded as one of the greatest and most influential figures in the history of cinema

The beginnings and endings of all human undertakings are untidy.

John Galsworthy (1867–1933), English novelist and playwright, awarded the 1932 Nobel Prize in Literature