Original Article

Plastic surgical repair of ulcer wounds of diabetic foot patients through systemic treatment and local infection control

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Background: This study was to investigate the efficacy of plastic surgery in patients with diabetic foot (DF) ulcer who had systemic treatment and local infection control.

Methods: A total of 112 patients with DF were randomly divided into surgery group and drug treatment group according to treatment methods. Firstly, the pathogenic bacteria were isolated and cultured to explore the specific factors causing glycosuria foot ulcer. Secondly, the wound recovery and average hospitalization of the patients were analyzed, and the effects of different treatment methods on the clinical cure rate and recovery rate of the patients were compared.

Results: The results showed that 53 patients were diagnosed with type 2 DF, accounting for 47.32%; 22 patients were diagnosed with DF disease complicated by infections, accounting for 19.64%; 25 patients were diagnosed with DF complicated by ulcers, accounting for 22.32%; and 12 patients (10.71%) were diagnosed with DF complicated by ulcer infection. Of the pathogens cultured, *Enterococcus faecalis* accounted for the highest proportion (19.35%). Statistical analysis was conducted on Wagner grading. It was found that with the increase of the grade, the wound recovery time of patients gradually increased, with the longest recovery time for grade V and the shortest recovery time for grade I. Additionally, with the extension of hospital stay, the area of the ulcer wound gradually decreased. In the analysis of induced factors, there were 17 cases of nail cutting, accounting for 15.18%.

Conclusions: The operation of repairing DF ulcer wound under the guidance of plastic surgery principle had good efficacy, safety, and reliability, and was worthy of clinical promotion.

Keywords: Diabetic foot (DF); local infection; wound bed preparation; etiology analysis; wound healing

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Introduction

Diabetic foot (DF) is one of the most serious complications of diabetes (1). DF refers to diabetic neuropathy, including lower limb infection, ulcer, deep tissue injury caused by peripheral nerve sensory disturbance, vegetative nerve injury, lower limb neuropathy, and peripheral vascular lesions of varying degrees (2). The high incidence and disability rate of DF have become a serious social problem. Like deep burn wounds, post-traumatic wounds and chronic deep wounds need to be repaired by surgery. In recent years, clinical practice has shown that based on controlling blood glucose, improving local circulation, and preventing infection, wound preparation, skin grafting, or skin flap transplantation were performed on DF of different Wanger grades by plastic surgery method, which can quickly repair the wound and accelerate the healing of ulcer surface, reducing the rate of disabling sugar and shortening the course of disease (3,4). The main indications for DF microsurgery include recurrent non-healing of DF wounds, foot numbness, skin cooling, pain after activity, intermittent postural, accompanied by obvious resting pain, lower limb angiography showed arterial segmentation of nasal obstruction, and parts of the foot are gangrenous and accompanied by infection (5-7). In the process of surgical treatment, the role of medical therapy, especially neurotrophic drugs, should not be ignored.

Management of local wounds turns chronic wounds into acute wounds, turning infected or contaminated wounds into clean wounds and turning wounds into fresh granulation wounds that can be grafted (8). This also creates good conditions for surgical sales. For wound cleaning, hydrogen peroxide and normal saline are routinely rinsed repeatedly (9). All necrotic, inactivated, infected soft tissue, healthy tissue, and bone are removed by surgical method, so that the DF ulcer can form a fresh wound which is conducive to the growth of granulation tissue (10,11).

DF patients have smaller ulcer surface, deeper layers, and better blood supply around the wound, which can expand the ulcer wound surface, expose the well-grown base, and then directly suture (12). Some studies showed that surgical debridement can significantly shorten the healing time and improve the wound healing rate (13,14). Granulation tissue on ulcer surface grew well and had a large area. Continuous negative pressure suction was performed after continuous sealing negative pressure drainage. Sufficient human acid was applied to the wound surface to form micro-growth factors until the epidermis grew and the wound healed (15). This way is relatively simple, can reduce the number of patients changing dressing, shorten the length of hospital stay, and reduce medical costs. Wound surgery for chronic wound healing has been fully recognized in clinical nutrition and is significantly effective in the treatment of DF patients' wounds (16). The treatment of DF requires a process of surgical and nursing cooperation, including blood glucose control, infection prevention and treatment, improvement and recovery of local blood circulation, wound repair, and high-quality nursing to improve patients' self-management ability (17,18). Plastic surgery plays a key role in wound repair and cosmetic surgery (19). The main clinical treatment methods include lowering blood glucose and routine wound cleaning instead of dressing (20). With the development of the times, the treatment methods are gradually increasing. In this study, the therapeutic effect of plastic surgery in patients with DF ulcer who pay equal attention to systemic treatment and local infection control was studied, and the therapeutic effect and surgical safety were analyzed, to provide reference for the treatment of clinical DF infection. We present the following article in accordance with the STROBE reporting checklist (available at https://apm.amegroups.com/article/view/10.21037/apm-22-352/rc).

Methods

Research object

A total of 112 DF patients treated in the Affiliated Hospital of Guangdong Medical University from 2014 to 2020 were selected as the research subjects. There were 42 women, aged 64–91 years, with an average age of 71.54±2.18 years, and 70 males, aged 47–88 years, with an average age of 77.54±3.75 years. Of the 112 patients, 53 patients were diagnosed with type 2 DF, accounting for 47.32%; 22 patients were diagnosed with DF disease and infection, accounting for 19.64%; 25 patients were diagnosed with DF disease with ulcer, accounting for 22.32%; and 12 patients were diagnosed with DF disease with ulcer infection, accounting for 10.71%.

All included DF ulcer patients and their families gave informed consent and voluntarily participated in this study. There were no statistically significant differences in gender ratio, average age, type of diseases, and degree of diseases between the 2 groups ($P>0.05$), indicating comparability. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the Affiliated Hospital of Guangdong Medical University (No. 2021-139-01).

Inclusion and exclusion criteria

The inclusion criteria were as follows: (I) diagnosed with type 2 diabetes as per the World Health Organization (WHO) diagnostic criteria in 1999; (II) the diagnosis and grading of DF were in accordance with the clinical grading standards for DF formulated by the first national DF academic conference of the Chinese Medical Association in 1995; (III) patients voluntarily participated in this study; (IV) no immune system diseases or infectious diseases; (V) complying with the Wagner grading standard; and (VI) with complete clinical data.

The exclusion criteria were as follows: (I) patients with incomplete clinical data; (II) unwilling to participate in

Table 1 Diabetic foot ulcer grading

Grade	Characteristics
0	The skin is intact and there is potential for foot ulcers
I	Superficial ulceration is found on the skin surface without infection
II	There are ulcers deep into the Achilles tendon, bone, or joint, and no infection occurs
III	There is deep ulceration with osteomyelitis or abscess
IV	Gangrene occurs in part of the foot (toe, foot, heel, or front dorsum)
V	Gangrene appears all over the foot

the study; (III) patients with mental illness; (IV) patients with extensive local necrosis requiring immediate high amputation; (V) patients with lesions such as tuberculosis, tumors, and osteomyelitis; and (VI) patients who could not tolerate surgery or died in hospital.

General situation of the research object

The number of cases in the hospital during the study period determined the sample size. Of the 112 cases, 76 cases underwent surgery, including phalangectomy in 25 cases (22.32%), negative pressure vacuum sealing drainage (VSD) in 38 cases (33.93%), soft tissue debridement in 7 cases (6.25%), DF debridement and suture in 1 case (0.89%), ureteral stenting to correct the amputation stump in 1 case, ulcer debridement and skin grafting in 2 cases (1.79%), and open reduction and internal fixation for phalanx fracture and debridement and suture for skin laceration in 2 cases (1.79%), while 36 cases (32.14%) did not undergo surgery. A total of 76 patients undergoing surgery were in the operation group, and 36 patients treated with drugs were in the drug group.

Systemic therapy

All patients were assessed for systemic complications before surgery and were then treated with a combination of treatments, starting with glucose control at glucose <8.0 mm/L and 2-h postprandial glucose <11.1 mm/L. In terms of diet, all patients were given a reasonable diet and nutritional supplements. To control the infection in a timely manner, antibiotics were selected reasonably according to the wound secretion culture. The simultaneous use of similar antibiotics was avoided in order to prevent the occurrence of drug resistance. Related complications were also treated in a timely manner, such as hypertension, coronary heart disease, hyperlipidemia, and hypoproteinemia. In addition, microcirculation could be improved by prostate hormone drugs, enteric-soluble aspirin, and other vasoactive drugs. DF ulcer was divided into 6 grades according to the Wagner grading method as shown in *Table 1*, mainly using ulcer depth as a reference.

General treatment

All patients took conventional short-acting insulin to control blood sugar under 10 mmol/L during the preoperative period. Ligustrazine and alprostadil were used to improve microcirculation. Mecobalamin was used to treat peripheral neuropathy. Patients with high cholesterol and high blood pressure were treated with lipid-lowering and blood pressure drugs. For local wounds, sulphadiazine zinc was applied or iodine was used to disinfect the skin and soft tissue around the ulcer. To promote granulation tissue and skin growth on the ulcer wound, inorganic salt dressings were applied on the wounds. Patients in the control group received routine dressing change, and X-ray examination was performed to further master the lesion location. The wound surface was cleaned with 0.9% sodium chloride solution and iodophor, and dressing changes were reviewed 1–2 times per hour.

Surgical treatment

For observer patients requiring surgery, local debridement was performed first. After debridement, the necrotic surface skin and soft tissue as well as deep necrotic fascia should be completely removed, and the operation should be performed according to the ulcer area. If the ulcer area was large, free skin grafting or skin flap transplantation would be performed on fresh wound granulation tissue. If the ulcer area was small, it could be sutured directly if tension allowed. If the wound was in a weight-bearing area, and nerve, blood vessel, or bone tissue was exposed, an adjacent flap or in-situ flap was cut to cover the wound. If the periosteum was necrotic and the bone was not destroyed, necrotic bone was removed with a bone biter. An electric drill could be used until fresh bleeding or until it reached the fresh bone surface. Dressings should be changed reasonably according to the infection, depth,

Table 2 Pathogen distribution in diabetic foot patients

Types of pathogens	Number	Percentage (%)
Enterococcus faecalis	12	19.35
Pseudomonas aeruginosa	7	11.29
Klebsiella pneumoniae	5	8.06
Staphylococcus epidermidis	5	8.06
Proteus mirabilis	6	9.68
Escherichia coli	5	8.06
Enterobacter cloacae	7	11.29
Staphylococcus aureus	9	14.52
Other staphylococcus	6	9.68
Total	62	100.00

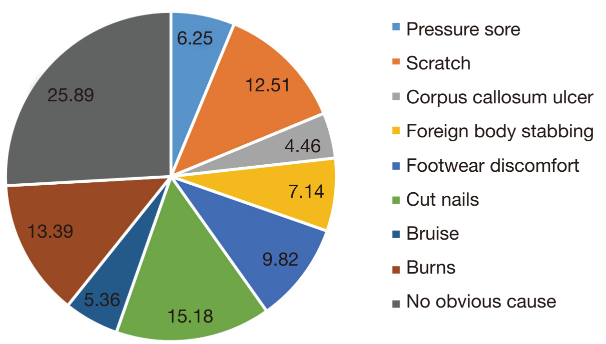

Figure 1 Analysis of the induced factors of diabetic foot (DF) ulcers.

and area. During surgery, adequate drainage was required. After the pus cavity was removed, blood-rich tissue filled the cavity. VSD was used for adequate drainage to reduce the inflammation in the surrounding tissue. Then, free skin grafting was performed.

Efficacy evaluation index

The wound reduction and local conditions (spontaneous pain, swelling, and fishy smell), curative effect, and healing time of the two groups were observed after treatment. Curative effect judgment criteria were as follows. Cure: wound healing, no secretion, redness, no pain; significant effect: the wound healed area was more than 3/4, and the effect of secretion, and redness and pain was improved; improvement: the wound healing area was 1/4 to 3/4 of secretion, redness, and pain relief; invalid: the wound did not heal obviously, accompanied by discharge, redness, and pain. Total effective rate = (cure + significant effect + improvement)/total number of cases *100%.

Statistical methods

All data were analyzed by SPSS 21.0 statistical software. T test was used for comparison between the two groups, χ^2 test was used for comparison of component rate (%) of counting data, and the measurement data was mean ± standard deviation. $P<0.05$ indicated that the difference was statistically significant.

Results

Distribution of pathogenic bacteria in patients

The pathogenic bacteria of all diabetic patients were classified, as shown in *Table 2*. A total of 62 strains of pathogenic bacteria were cultured, with *Enterococcus faecalis* accounting for 19.35%, followed by *Staphylococcus aureus*, accounting for 14.52%. *Klebsiella pneumoniae*, *Staphylococcus epidermidis*, and *Escherichia coli* all accounted for 8.06%.

Descriptive data

The induced factors of DF ulcer were analyzed and mainly included foreign body injury, burns and scalding, pressure ulcers, bruising, discomfort of shoes and socks, scissors (nail scissors), scratching to ulceration, and scratching to ulceration. The analysis results are shown in *Figure 1*. There were 7 cases of pressure ulcers, accounting for 6.25%; 14 cases of laceration, accounting for 12.5%; 5 cases of corpus callosum ulcer, accounting for 4.46%; 8 cases of foreign body injury, accounting for 7.14%; 11 cases of discomfort in shoes and socks, accounting for 9.82%; 17 cases of cuts with scissors, accounting for 15.18%; 6 cases of bruising, accounting for 5.36%; 15 cases of burns, accounting for 13.39%; and 29 cases without obvious cause, accounting for 25.89%.

Outcome data

DF patients were classified according to the Wagner grading method, as shown in *Figure 2*. There were 0 cases of grade 0 and 11 cases of grade I, accounting for 9.82%; 45 cases of grade II, accounting for 40.18%; 34 cases of

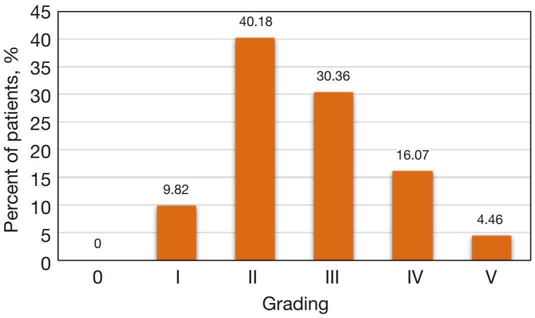

Figure 2 Hierarchical classification of diabetic foot (DF) patients based on Wanger's classification.

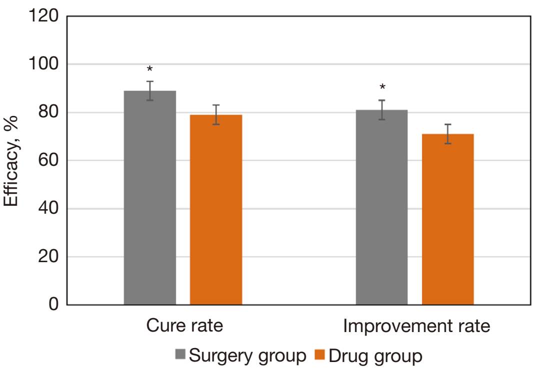

Figure 3 Efficacy comparison. *, the difference between the groups was statistically significant (P<0.05).

grade III, accounting for 30.36%; 18 cases of IV, accounting for 16.07%; and 5 cases of grade V, accounting for 4.46%. It was noted that there were more patients in grade II.

Comparison of efficacy

In this study, patients receiving surgical treatment were classified as the surgery group, while 36 patients receiving drug treatment were classified as the drug group. The treatment effects of the 2 groups were compared, and the results are shown in *Figure 3*. The cure rate and recovery rate in the surgery group were significantly higher than those of the drug group, with statistically significant differences (P<0.05).

Images of patients

Figure 4 shows images of a 58-year-old male patient with a right plantar ulcer for more than 2 years and diabetes mellitus for 8 years. He was admitted to hospital because of the formation and infection of the right plantar ulcer. From *Figure 4A*, the patient's sole wound was red, swollen, and fluctuating. In *Figure 4B*, the incision was incised and drained, and the foul-smelling pus flowed out, and there were many small abscess cavities in the wound surface when the wound was expanded. Then, thorough incision and drainage, dressing change, iodophor, and saline flushing were performed. After wound expansion and removal of necrotic tissue, a disposable negative pressure suction material was used to seal the wound. *Figure 4C* depicts the process of negative pressure dressing change, showing that the wound surface became lighter after the medication, and the granulation at the base was fresh. Necrotic tissue was found in the lower part and rinsed with iodophor saline, then negative pressure suction therapy was continued. *Figure 4D* shows the necrosis of the lateral tissue of the patient's left foot. After removal of necrotic tissue, routine dressing changes were performed, and the wound surface of the left foot was significantly reduced after continuous dressing changes. *Figure 4E* shows a dressing change. The granulation at the base of the wound was fresh and significantly reduced. *Figure 4F* is an image of the healing of the sole of the foot.

Figure 5 depicts an elderly male patient with DF. The feet were scalded during a foot bath, and no special treatment was given. There was an ulcer on the foot surface and exudation of light-yellow liquid. The surrounding skin was red and swollen, and the bones were exposed. After admission, an incision reduction operation was performed. *Figure 5A* shows the foot before treatment, *Figure 5B* shows the foot after treatment, and *Figure 5C* is an image of the patient's foot after 89 days of recovery and discharge.

Wound repair time

Statistical analysis was conducted on the wound recovery of DF patients and Wagner grading. As shown in *Figure 6*, with the increase of grade, the wound recovery time of patients was gradually prolonged, with the longest recovery time for grade V and the shortest recovery time for grade I. The area of the ulcer wound gradually decreased with the extension of hospitalization time (*Figure 7*).

Discussion

DF is a serious complication of diabetes, preceding diabetes-related amputations. It requires more than $9

Figure 4 Pictures of diabetic foot (DF) of a 58-year-old male patient before and after treatment.

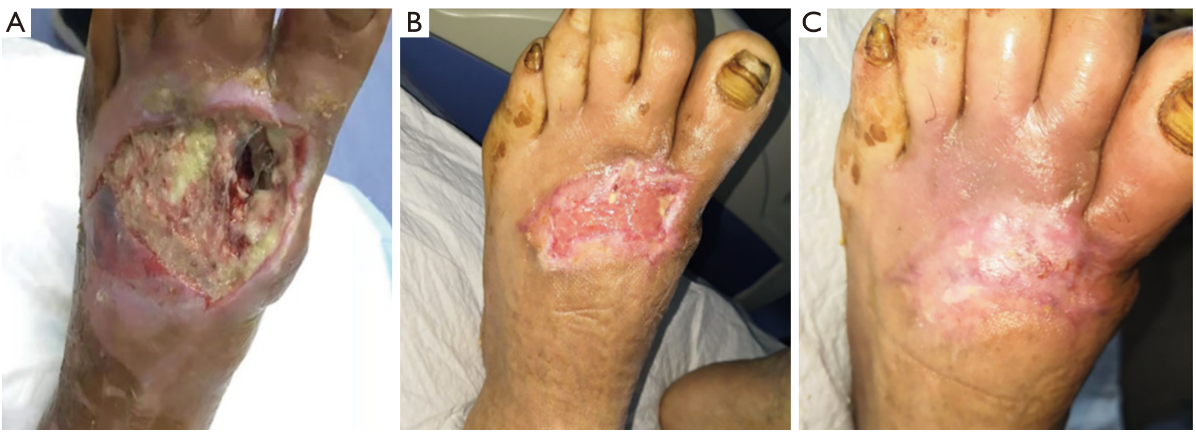

Figure 5 Pictures of diabetic foot (DF) of an elderly male patient before and after treatment.

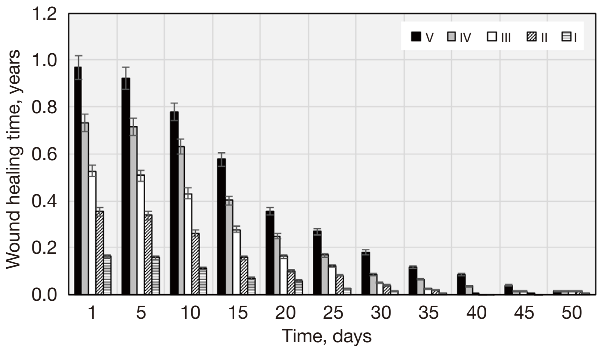

Figure 6 Wound healing time.

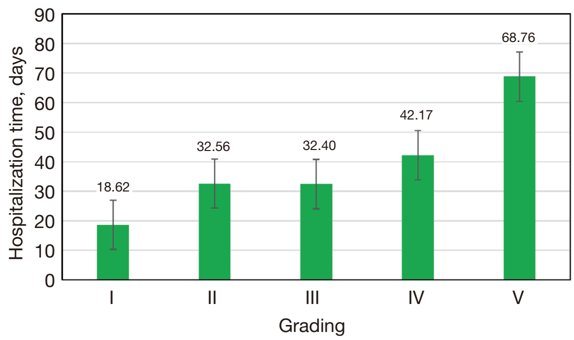

Figure 7 The average hospitalization time.

billion in treatment costs every year and has become a global public health problem (21). DF occurs in the context of ischemia, infection, neuropathy, and metabolic disorders, leading to poor wound healing and poor treatment options. DF ulcer patients are at risk of disability due to vascular neuropathy. If patients do not receive timely treatment, their condition will deteriorate and they may even die (22). DF ulcers are treated in a variety of ways. Stem cell therapy has become a new interventional strategy for DF ulcer treatment, and is safe and effective in preclinical and clinical trials (23). Lopes *et al.* [2018] (24) used stem cells to treat DF ulcer. They found that stem cell therapy was an effective treatment for DF ulcer. This method is currently used as an alternative to amputation in some patients who have no other revascularization options. Consistency between preclinical and clinical studies may help design future randomized clinical trials. Yang *et al.* [2021] (25) synthesized nano silver antibacterial dressings to control bacterial infection on the ulcer surface and promote wound healing. It was found that nano silver antibacterial dressings can significantly reduce the incidence of infection in DF patients, reduce the number of dressing changes, shorten the healing time of ulcers, and speed up dressing changes. They can also shorten the course of DF disease and should be popularized in clinical practice. VSD technology can protect exposed bone and tendon well, reduce the number of bacteria, and promote the growth of the wound surface through the drainage of pus. The newly-developed dressing promotes granulation growth through absorption of exudate, anti-inflammation, and removal of necrotic tissue, and also creates a favorable environment for wound growth.

In this study, a total of 62 strains of pathogenic bacteria were cultured, and *Enterococcus faecalis* accounted for the highest proportion (19.35%), followed by *Staphylococcus aureus* (14.52%). *Klebsiella pneumoniae*, *Staphylococcus epidermidis*, and *Escherichia coli* all accounted for 8.06%. This study did not conduct routine erythrocyte sedimentation rate detection. There are many complications of the systemic treatment of local infection in DF. The depth and breadth of infection and blood supply need to be comprehensively analyzed in practice and clinically.

This study focused on the wound repair of DF ulcers, aiming to identify the best surgical method and the best time for surgery. As for wound infection and skin lesions, dressing changes, VSD technology, and bone drilling were adopted according to the patient's own situation to promote wound healing. In this study, after examination of the left foot debridement, one patient was implanted with the negative pressure device for debridement of the left foot ulcer. The second, third, and fourth toe were amputated on the left foot and the subcutaneous tissue was treated with VSD technology. After treatment, the patient recovered well. There was also one patient who underwent left foot ulceration plus local flap transfer repair and VSD, which showed good results. Chen *et al.* [2017] (26) explored the relationship between the complications of osteomyelitis and the risk of DF ulcer drug-resistant infection, and the results showed that osteomyelitis can be treated with narrow-spectrum antibiotics based on bone culture to prevent DF ulcer drug-resistant infection.

Foot ulcers are a common complication in patients with diabetes, and infection of these wounds leads to increased morbidity and mortality. DF infection is caused by a variety of microorganisms, including *Staphylococcus aureus* as a major related pathogen. Shettigar *et al.* [2020] (27) stated that *Staphylococcus aureus* was also the main pathogen associated with DF osteomyelitis, which can lead to chronic and recurrent bone infection. The occurrence and development of *Staphylococcus aureus* infection relies on the virulence of pathogens and host immune factors. Pathogen-related factors include bacterial structural complexity and functional properties that provide metabolic and adhesion properties to overcome host immune responses. Although virulence markers and toxins of *Staphylococcus aureus* are broadly similar in different wound models, some striking features are observed in DF infection. Specific clonal lineages and virulence factors, such as toxic shock syndrome toxin-1 (TSST-1), interleukins, enterotoxins, and exfoliation protein, play important roles in determining wound outcome.

Conclusions

In this study, 112 patients with DF ulcer were selected as the research subjects. The results showed that of all the cultured pathogens, *Enterococcus faecalis* accounted for the highest proportion (19.35%). Statistical analysis was conducted on the wound recovery of DF patients and Wagner classification. It was found that with the increase of the grade, the wound recovery time of patients gradually increased, with the longest recovery time for grade V and the shortest recovery time for grade I. Furthermore, with the extension of hospital stay, the area of the ulcer wound gradually decreased. In the analysis of induced factors, there were 18 cases of nail cutting, accounting for 16.07%. In the study, some patients had intermittent movement in the early stage and no obvious skin lesions with resting pain, and were unwilling to accept hospitalization, which also limited the early treatment of DF. Therefore, DF patients may not have sufficient understanding of the disease, and doctors should give more guidance. The pathogenesis of DF ulcer is complex. In the treatment process, attention should be paid to its etiology and active prevention, and wound bed preparation should be strengthened to select the optimal treatment plan to promote the healing of the wound.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://apm.amegroups.com/article/view/10.21037/apm-22-352/rc

Data Sharing Statement: Available at https://apm.amegroups.com/article/view/10.21037/apm-22-352/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://apm.amegroups.com/article/view/10.21037/apm-22-352/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the Affiliated Hospital of Guangdong Medical University (No. 2021-139-01) and informed consent was taken from all the patients.

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