Application of a simple skin stretching system and negative pressure wound therapy in repair of complex diabetic foot wounds

Yaojun Wu
Ningbo No 2 Hospital: Ningbo Huamei Hospital University of Chinese Academy of Sciences

Liang Chen (✉ alanchenl@aliyun.com)
Ningbo No 2 Hospital: Ningbo Huamei Hospital University of Chinese Academy of Sciences
https://orcid.org/0000-0003-4946-0000

Shaokun Wu
Ningbo No 2 Hospital: Ningbo Huamei Hospital University of Chinese Academy of Sciences

Liying Yu
Ningbo No 2 Hospital: Ningbo Huamei Hospital University of Chinese Academy of Sciences

Mimi Chen
Ningbo No 2 Hospital: Ningbo Huamei Hospital University of Chinese Academy of Sciences

Jingnan Wang
Ningbo No 2 Hospital: Ningbo Huamei Hospital University of Chinese Academy of Sciences

Jiejie Chen
Ningbo No 2 Hospital: Ningbo Huamei Hospital University of Chinese Academy of Sciences

Qingjiang Pang
Ningbo No 2 Hospital: Ningbo Huamei Hospital University of Chinese Academy of Sciences

Study protocol

Keywords: simple skin stretching system, negative pressure wound therapy, diabetic foot wounds

Posted Date: February 11th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-206865/v1

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Version of Record: A version of this preprint was published at Journal of Orthopaedic Surgery and Research on April 14th, 2021. See the published version at https://doi.org/10.1186/s13018-021-02405-6.
Abstract

Management of complex diabetic foot wounds with large skin defects poses a challenge for surgeons. We presented a simple skin stretching system and negative pressure wound therapy for the repair of complex diabetic foot wounds to examine the effectiveness and safety.

A total of 16 patients with diabetic foot ulcers were retrospectively reviewed between January 2015 to October 2020. All patients underwent the treatment by 3 stages. In stage 2, these difficult-to-close wounds of diabetes foot were residual. This method was applied to the wounds with a median defect size of 20.42 cm² (range: 4.71-66.76 cm²).

The median time for closure of complex diabetic foot wounds was 14 days ranging from 8 days to 19 days. With respect to the absolute rates of reduction, it was observed with a median of 1.86 cm² per day, ranging from 0.29 cm² per day to 8.35 cm² per day. In accordance with the localization of the defect, the patients were divided into 3 groups: side of the foot (37.5%), dorsum of the foot (50.0%), and others (12.5%). There was no statistically difference between side of the foot and dorsum of the foot in terms of the median defect size with $P = 0.069$ (Kruskal–Wallis test). Otherwise, there were statistically significant differences regarding the median time and the median absolute rates ($P < 0.05$; Kruskal–Wallis test). No severe complications were encountered in this study.

In summary, our results show that application of the simple skin stretching system and NPWT is an effective and safe approach for complex diabetic foot wounds. Nevertheless, more attentions should be paid for the appropriate patient selection and intraoperative judgment to ensure wound closure and avoid undue complications.

Introduction

Diabetes mellitus (DM) is a severe and complex disease with significant socioeconomic and health care implications, both in developed as well as developing nations. There were more than 415 million adults with DM in 2017, and the prevalence of diabetes is estimated to get 642 million by 2040 all over the world [1]. Specifically, the published literatures showed that the estimated prevalence of adult diabetes was 11.6% and the prevalence of prediabetes was 50.1%, which meant there were 113.9 million with diabetes and 493.4 million with prediabetes in China[2].

Unfortunately, the prevalence of diabetic foot ulcers (DFUs) was up to be 15% among the patients with DM [3]. This is secondary to a variety of diabetes-related risk factors, such as: peripheral neuropathy and vascular disease[4]. Diabetic foot ulcers (DFUs) are associated with a high rate of hospitalization and a 20-fold increased risk of lower limb amputations[5]. Various DFU treatments have been reported in the literature, including off-loading, debridement, revascularization, negative pressure wound therapy (NPWT), growth factors, platelet-rich plasma, skin grafts [6-10]. NPWT was proved to be an effective method in accelerating the healing of DFUs. However, for complex diabetic foot wounds with large skin defects that cannot be stitched together by low tension, wound reduction is limited with application of NPWT alone. In
terms of large skin defects, many skin stretching devices were introduced. All of them were designed to reduce local mechanical loads in skin, and fully take advantages of the skin mechanical properties with creep and stress relaxation for the wound closure[11].

Thus, we present this retrospective observational study by application of a simple skin stretching system and NPWT in repair of complex diabetic foot wound. We hypothesized that the method would be effective and safe for wound healing.

**Patients And Methods**

**Patients**

In our single-center study, 16 patients with DFUs were retrospectively reviewed between January 2015 to October 2020 in the Department of Orthopedics, Hwa Mei Hospital, University of Chinese Academy of Sciences (Ningbo NO. 2 Hospital), Ningbo, Zhejiang, China. Patients were included to the study if complex diabetic foot wounds that cannot be primarily closed were residual after debridement. The exclusion criteria included that poor skin viscoelasticity, renal failure, poor compliance with medical treatments, and ischemic ulcer that needed revascularization. The study protocol was approved by the ethics committee of Hwa Mei hospital and performed in accordance with the ethical standards prescribed by the Helsinki Declaration. Informed consent was obtained from all the participants before the treatment in the study.

**Methods**

All patients underwent the treatment by 3 stages. In stage 1, the patient’s wound was sharply debrided and digitally photographed as soon as possible. During the surgery, infected and nonviable soft tissues were absolutely debrided. The decision to excise the infected bone was made combining with the preoperative radiographs and intraoperative finding. The debridement was finished until the skin, soft tissue and bone visually appeared normal. The NPWT system (VSD Medical Science and Technology Co. Ltd., Wuhan, China) was applied to the diabetic wound that cannot be primarily closed by the manufacturer’s guidelines which could provide controlled negative pressures between 50 mmHg and 100 mmHg. The NPWT dressing was changed 3–5 days after the initial operation until the diabetic foot wound had no clinical signs and symptoms of infection.

In stage 2, these difficult-to-close wounds of diabetic foot were residual. Determining which large defects of the wounds were suitable for the simple skin stretching system was all-important which included assessing the wound size as well as the mobility and quality of the neighboring cutaneous condition. If the viscoelastic properties of skin were good, staples were placed along the margins of the diabetic foot wound at 1.5-cm to 2-cm intervals. Subsequently, one elastic band derived from 7# surgical glove was inserted through the staples, and crossed over the whole wound. The elastic band was tied with knots at both ends to sustain gentle but constant uniform tension at each anchoring point along the margins of the wound. Finally, the wound was connected with the NPWT system as described before. This method
created a gradual wound closure by persist traction on the skin margins, which could be periodically applied until definitive wound closure was achieved.

In stage 3, the tension of the wound closure was assessed according to the intraoperative findings. During the procedure of the simple skin stretching system, the skin tension was reduced over time. If the tension was low, the wounds could be sutured finally.

**Statistical analysis**

Data collected for this study included basic demographics, duration and severity of DFU, wound length and width, area of the defect (length * width * pi/4), time to definite closure (from stage 2 to wound closure finally), complications by 2 independent wound care specialist nurses. A visual analogue scale (VAS) was used to assess the pain, which ranged from 0 – no pain to 10 – most intense pain

Statistical analysis of the data was performed using the Statistical Package for the Social Sciences (SPSS), version 20.0 (SPSS, Inc., Chicago, IL, USA). All quantitative variables were expressed as means and standard deviation (SD) and skewed data were written by median values and range. Kruskal–Wallis test was used to compare groups when appropriate. The results were considered statistically significant at the level of P<0.05 in all applied analyses.

**Results**

This retrospective observational clinical study analyzed the outcome of 16 patients with complex diabetic foot wounds residual. There were 12 male and 4 female patients. The mean age of all patients was 60.6±10.5 years with a mean follow-up of 10.8±3.1 months (Table 1). All of the patients were Type 2 DM, and the mean duration of diabetes was 9.6±4.8 years. The diabetic foot ulcers were divided by Wagner classification with 3 cases (18.8%) of Grade 3 and 13 cases (81.2%) of Grade 4. There were 6 patients who were hypertensive, 4 patients with ischemic heart disease, 14 patients with peripheral neuropathy, 7 patients with nephropathy and 8 patients with retinopathy.

After the treatment of stage 1, these complex diabetic foot wounds were residual. The defect size of complex diabetic foot wounds ranged from 4.71 to 66.76 cm² with a median defect size of 20.42 cm² (Table 2). In accordance with the localization of the defect, the patients were divided into 3 groups: side of the foot (37.5%), dorsum of the foot (50.0%), and (12.5%) (Table 2). The median time for complex diabetic foot wound closure was 14 days ranging from 8 days to 19 days (Table 2). With respect to the absolute rates of reduction, it was observed with a median of 1.86 cm² per day, ranging from 0.29 cm² per day to 8.35 cm² per day.

The median wound size observed on the side of the foot was 26.69 cm² (range: 16.49-66.76 cm²), which was 18.85 cm² (range:14.13-25.13 cm²) on the dorsum of the foot (Table 3). There was no statistically difference between 2 groups in terms of the median defect size with P = 0.069 (Kruskal–Wallis test). The median time for diabetic foot wound closure was 10.5 days ranging from 8 days to 14 days on the side
of the foot (Table 3). Defects on the dorsum of the foot were closed within a median time of 14.5 days (range:10-19 days). The median time between 2 groups was statistically significant different with P < 0.05 (Kruskal–Wallis test). The absolute rates of wound reduction were observed on the side of the foot with a median of 2.32 cm² per day (range:2.06-8.35 cm² per day) followed by the dorsum of the foot with 1.22 cm² per day (range:0.99-2.09 cm² per day). There was statistically significant difference between 2 groups regarding the absolute rates of wound reduction (P < 0.05; Kruskal–Wallis test), thus it became obvious that different anatomical areas on the foot had different viscoelastic properties (Table 3). Figure.1 and Figure.2 were examples of the progression of wound healing using the simple skin stretching system and NPWT.

All the defects were finally closed without skin graft or local flaps, and the scars were relatively acceptable. No severe complications were encountered in this study, such as amputation and death. Some staples were dislodged due to point loading from tightening or full range of motion in 2 cases. Three cases of skin edge necrosis were observed which were healed after several wound dressings. Retrospectively, patients felt that the procedure of the method was just a little pain. Pain relief was achieved through oral analgesics.

Discussion

We present the results of this retrospective observation of patients with diabetic foot ulcers (DFUs) and large skin defects residual after debridement. The main findings supported our hypothesis that application of the simple skin stretching system and negative pressure wound therapy in repair of complex diabetic foot wound was effective and safe.

Negative pressure wound therapy (NPWT) reported by Argenta and Morykwas[12] was generally used all over the world. NPWT reduces extracellular edema, improves local blood flow and stimulates local angiogenesis to increase the formation of granulation tissue[13-15]. In addition, wound bioburden and risk of infection are decreased, and wound healing is accelerated[16, 17]. Moreover, NPWT increases the expression of many cytokines to promote collagen deposition[18]. Furthermore, NPWT in patients with DFUs increases let-7f expression in plasma which may help to control the inflammation and induct the angiogenesis, both associated with wound healing[19]. However, there is a potential problem in the treatment of DFUs by using NPWT. Tissue pressure beneath the foam of NPWT system is increased by the external compression, which could decrease tissue oxygenation in wound beds, especially in diabetic foot. Jae-A. Jung et al. in their study found that NPWT would significantly reduce tissue oxygenation levels in diabetic feet, thus suggested that taking care of the compression of the foam dressing when NPWT was applied, but didn't suggest that NPWT should be discarded in treating DFUs in considering of its various positive effects[20].

On the other hand, Liu Z et al.[4] and Matthew Wynn[21] et al. both in their review concluded that comparing with other wound dressings, it remained unclear whether NPWT could increase the proportion
of diabetic foot wounds healed and reduce the time to heal the wounds of DFUs. Likewise, there is no obvious advantage in reduction of wound area by application of NPWT alone in our opinion.

In order to solve the problem, we applied a simple skin stretching system simultaneously in our clinical study. The skin stretching system is an effective method that can accelerate the wound healing by the biomechanical properties of the skin. Compared to traditional surgeries, the technique has the advantages of healing wounds without subsequent reconstruction surgeries, reducing the time for wound closure, and the properties of the stretched skin similar to the adjacent skin [22-25]. There have been various skin stretching devices for wound closure described in the literature[22, 24, 26-28]. However, the application is limited because of the availability and cost which is particularly important in a developing country with limited resources. In our cases, all materials used in the simple skin stretching system are inexpensive and easily available in most operating theatres. On account of that the skin viscoelasticity of diabetic foot is relatively poor, we take more attentions to the assessment of the mobility and quality of the neighboring cutaneous condition before applying the skin stretching system. Several studies in related fields clearly demonstrated that the skin stretching system was fairly a good adjunctive treatment for diabetic-foot wound closure, but better elucidation of the relative indications and contraindications was still needed[29-31].

There are currently few studies about application of a skin stretching system and NPWT simultaneously in diabetic foot wounds. Lee et al. proposed a similar concept in patients with necrotizing fasciitis and showed this method can be an alternative treatment for the necrotizing fasciitis patients with large wounds[32]. Zhang, F et al. in his study concluded that VSD associated with SSD in patients with stress-induced injuries could improve the therapeutic effect[33]. Wang L. C et al. [34]and Ji P et al. [29]reported that the application of skin stretching device and NPWT in diabetic foot ulceration can reduce wound healing time and increase wound healing rate. These literatures support our hypothesis that the combination of simple skin stretching system and NPWT is advantageous.

In our research, the time for closure of complex diabetic wound ranged from 8 to 19 days with a median of 14 days making it more effective than secondary intention healing and skin graft. Furthermore, the procedure is easy to operate, and less time is spent compared with flap transposition. In regards to the absolute rates of reduction, we found a fact that different anatomical sites of the foot had different viscoelastic properties. It was much easier for the side of the foot to reduce the area of diabetic foot wound than dorsum of the foot. The reason might be that the soft tissue was more on the side than on the dorsum, thus the wounds on the side could be treated with greater traction tension to promote wound healing compared with the dorsum.

It was ineluctable that some staples were occasionally dislodged due to constant tension occurred in 2 cases. In consideration of that the other staples could still maintain enough traction tension, so it had few influences for wound closure. Additionally, 3 cases of skin edge necrosis were occurred in our study. Ji Peng et al. concluded that the skin viscoelasticity and local micro-circulation of diabetic foot was relatively poor[29]. Therefore, we need to carefully assess before using the skin stretch system to avoid
the complication of skin necrosis as far as possible. Moreover, pain will occur in the skin stretching system when applying a persist force. In the study, all of the patients could tolerate anchorage pain just through oral analgesics. The reason might be that the tension of elastic bandage was relatively mild and diabetic peripheral neuropathy affected sensory nerve markedly in lower extremities.

**Limitation**

The first limitation was that our study was a retrospective single-center study. To the best of our knowledge, there are few studies to evaluate the value of the skin stretching system and NPWT in management of complex diabetic foot wounds. It is essential to make sure of its safety and validity before a randomized controlled trial conducted. Second, an important limitation of the simple skin stretching system is the absence of a monitoring system which can adjust the skin tension anytime. Third, the small number of wounds included could be a source of bias. Randomized controlled trials with larger sample size and longer follow-up period should be conducted to determine the advantages of the simple skin stretching system and NPWT in future.

**Conclusion**

In summary, our results show that application of the simple skin stretching system and NPWT is an effective and safe approach for complex diabetic foot wounds which can decrease the time of hospitalization stay and costs, allow earlier rehabilitation and increase patient satisfaction. We believe that this method can provide an alternative choice to surgeons for closure of large diabetic foot wounds. Nevertheless, more attentions should be paid for the appropriate patient selection and intraoperative judgment to ensure wound closure and avoid undue complications.

**Abbreviations**

negative pressure wound therapy = NPWT, Diabetes mellitus = DM, diabetic foot ulcers = DFUs

**Declarations**

**Acknowledgments**

Not applicable

**Authors’ contributions**

Yaojun Wu: responsible for concept design and paper writing; Liang Chen: responsible for operation and concept design; Qingjiang Pang: responsible for technical guidance; Mimi Chen: responsible for data analysis; Liying Yu and Shaokun Wu, responsible for data collection and manuscript writing; Jiejie Chen and Jingnan Wang: literature search and patient follow up. The author(s) read and approved the final manuscript.
Funding

This study was supported by a grant from the Natural Science Foundation of Ningbo City (2016A610146), the Medical and Health Science and Technology Program Foundation of Zhejiang Province (2020KY843, 2015KYB342), Hwa Mei foundation (2019HMKY10).

Availability of data and materials

Not applicable.

Ethics approval and consent to participate

This clinical study has been reviewed by the Hwa Mei Hospital Ethics Committee. All patients signed written consent forms.

Consent for publication

Consent for publication using the opt-out form on the website.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

1. International Diabetes Federation. IDF Diabetes Atlas. 8th ed. Brussels, Belgium, International Diabetes Federation, 2017.

2. Pang B, Lian FM, Zhao XY, Zhao XM, Jin D, Lin YQ, Zheng YJ, Ni Q, Tong XL: Prevention of type 2 diabetes with the traditional Chinese patent medicine: A systematic review and meta-analysis. Diabetes Res Clin Pract 2017, 131:242-259.

3. Tzeng YS, Deng SC, Wang CH, Tsai JC, Chen TM, Burnouf T: Treatment of nonhealing diabetic lower extremity ulcers with skin graft and autologous platelet gel: a case series. Biomed Res Int 2013, 2013:837620.

4. Liu Z, Dumville JC, Hinchliffe RJ, Cullum N, Game F, Stubbs N, Sweeting M, Peinemann F: Negative pressure wound therapy for treating foot wounds in people with diabetes mellitus. Cochrane Database Syst Rev 2018, 10(10):Cd010318.

5. Skrepnek GH, Mills JL, Sr., Lavery LA, Armstrong DG: Health Care Service and Outcomes Among an Estimated 6.7 Million Ambulatory Care Diabetic Foot Cases in the U.S. Diabetes Care 2017, 40(7):936-942.

6. Hingorani A, LaMuraglia GM, Henke P, Meissner MH, Loretz L, Zinszer KM, Driver VR, Frykberg R, Carman TL, Marston W et al: The management of diabetic foot: A clinical practice guideline by the
Society for Vascular Surgery in collaboration with the American Podiatric Medical Association and the Society for Vascular Medicine. *J Vasc Surg* 2016, **63**(2 Suppl):3s-21s.

7. Game FL, Apelqvist J, Attinger C, Hartemann A, Hinchliffe RJ, Löndahl M, Price PE, Jeffcoate WJ: Effectiveness of interventions to enhance healing of chronic ulcers of the foot in diabetes: a systematic review. *Diabetes Metab Res Rev* 2016, **32** Suppl 1:154-168.

8. Elraiayah T, Tsapas A, Prutsky G, Domecq JP, Hasan R, Firwana B, Nabhan M, Prokop L, Hingorani A, Claus PL et al.: A systematic review and meta-analysis of adjunctive therapies in diabetic foot ulcers. *J Vasc Surg* 2016, **63**(2 Suppl):46S-58S.e41-42.

9. Snyder RJ, Frykberg RG, Rogers LC, Applewhite AJ, Bell D, Bohn G, Fife CE, Jensen J, Wilcox J: The management of diabetic foot ulcers through optimal off-loading: building consensus guidelines and practical recommendations to improve outcomes. *J Am Podiatr Med Assoc* 2014, **104**(6):555-567.

10. Ahmed M, Reffat SA, Hassan A, Eskander F: Platelet-Rich Plasma for the Treatment of Clean Diabetic Foot Ulcers. *Ann Vasc Surg* 2017, **38**:206-211.

11. Wilhelmi BJ, Blackwell SJ, Mancoll JS, Phillips LG: Creep vs. stretch: a review of the viscoelastic properties of skin. *Ann Plast Surg* 1998, **41**(2):215-219.

12. Morykwas MJ, Argenta LC, Shelton-Brown El, McGuirt W: Vacuum-assisted closure: a new method for wound control and treatment: animal studies and basic foundation. *Ann Plast Surg* 1997, **38**(6):553-562.

13. Robert N: Negative pressure wound therapy in orthopaedic surgery. *Orthop Traumatol Surg Res* 2017, **103**(1S):S99-S103.

14. Morbi AH, Shearman CP: Topical Negative Pressure Therapy for Diabetic Foot Ulcers: Where is the Evidence? *Int J Low Extrem Wounds* 2016, **15**(1):96.

15. Kim PJ, Attinger CE, Crist BD, Gabriel A, Galiano RD, Gupta S, Lantis li JC, Lavery L, Lipsky BA, Teot L: Negative Pressure Wound Therapy With Instillation: Review of Evidence and Recommendations. *Wounds* 2015, **27**(12):S2-S19.

16. Li Z, Wu W, Liu S, Hao Y: Effect of vacuum sealing drainage in dermatoplasty of large area of cutaneous defects. *Int J Surg* 2017, **42**:143-146.

17. Li W, Ji L, Tao W: Effect of vacuum sealing drainage in osteofascial compartment syndrome. *Int J Clin Exp Med* 2015, **8**(9):16112-16116.

18. Wang W, Pan Z, Hu X, Li Z, Zhao Y, Yu AX: Vacuum-assisted closure increases ICAM-1, MIF, VEGF and collagen I expression in wound therapy. *Exp Ther Med* 2014, **7**(5):1221-1226.

19. Kapusta P, Konieczny PS, Hohendorff J, Borys S, Totoń-Żurańska J, Kieć-Wilk BM, Wołkow PP, Malecki MT: Negative pressure wound therapy affects circulating plasma microRNAs in patients with diabetic foot ulceration. *Diabetes Res Clin Pract* 2020, **165**:108251.

20. Jung JA, Yoo KH, Han SK, LeeYN, Jeong SH, Dhong ES, Kim WK: Influence of Negative-Pressure Wound Therapy on Tissue Oxygenation in Diabetic Feet. *Adv Skin Wound Care* 2016, **29**(8):364-370.
21. Wynn M, Freeman S: The efficacy of negative pressure wound therapy for diabetic foot ulcers: A systematised review. *J Tissue Viability* 2019, **28**(3):152-160.

22. Zhu Z, Tong Y, Wu T, Zhao Y, Yu M, Topaz M: TopClosure® tension-relief system for immediate primary abdominal defect repair in an adult patient with bladder extrophy. *J Int Med Res* 2020, **48**(1):300060519891266.

23. Wang G, Zhang X, Zhang Z, Wei Z: Clinical study on a skin stretching technique with adjustable external fixators to treat skin defects. *Medicine (Baltimore)* 2020, **99**(37):e22144.

24. Huahui Z, Dan X, Hongfei J, Hang H, Chunmao H, Haitao R, Jianxin Y, Zhiping T: Evaluation of a new tension relief system for securing wound closure: A single-centre, Chinese cohort study. *Plast Surg (Oakv)* 2016, **24**(3):177-182.

25. Melis P, Bos KE, Horenblas S: Primary skin closure of a large groin defect after inguinal lymphadenectomy for penile cancer using a skin stretching device. *J Urol* 1998, **159**(1):185-187.

26. Song M, Zhang Z, Liu T, Liu S, Li G, Liu Z, Huang J, Chen S, Li L, Guo L et al: EASApprox((R)) skin-stretching system: A secure and effective method to achieve wound closure. *Exp Ther Med* 2017, **14**(1):531-538.

27. Topaz M, Carmel NN, Silberman A, Li MS, Li YZ: The TopClosure® 3S System, for skin stretching and a secure wound closure. *Eur J Plast Surg* 2012, **35**(7):533-543.

28. Barnea Y, Gur E, Amir A, Leshem D, Zaretski A, Shafir R, Weiss J: Our experience with Wisebands: a new skin and soft-tissue stretch device. *Plast Reconstr Surg* 2004, **113**(3):862-869; discussion 870-861.

29. Ji P, Zhang Y, Hu DH, Zhang Z, Li XQ, Tong L, Han JT, Tao K: [Clinical effects of combined application of skin-stretching device and vacuum sealing drainage in repairing the diabetic foot wounds]. *Zhonghua Shao Shang Za Zhi* 2020, **36**(11):1035-1039.

30. Gao L, Wang S, Wang L, Wang J: [Application of skin stretching device in repair of diabetic foot wound]. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi* 2018, **32**(5):591-595.

31. Armstrong DG, Wunderlich RP, Lavery LA: Reaching closure with skin stretching. Applications in the diabetic foot. *Clin Podiatr Med Surg* 1998, **15**(1):109-116.

32. Lee JY, Jung H, Kwon H, Jung SN: Extended negative pressure wound therapy-assisted dermatotraction for the closure of large open fasciotomy wounds in necrotizing fasciitis patients. *World J Emerg Surg* 2014, **9**:29.

33. Zhang F, Gu Y, Wu L: Skin-stretching device promotes the treatment effect of vacuum sealing drainage technique on phases III and IV stress-induced injuries in aged patients with chronic critical illness: A retrospective study of 70 patients. *Medicine (Baltimore)* 2019, **98**(47):e18027.

34. Wang LC, Wang CR, Chen HM: Application of noninvasive skin&stretcing device in wound healing of diabetic foot. *Chinese Journal of Diabetes* 2018, **10**(11):729-734.

**Tables**
Table 1: Baseline demographics and clinical characteristics of the study population.

| Variable                              | total n=16 |
|---------------------------------------|------------|
| Age (mean ± SD, years)                | 60.6 ± 10.5|
| Gender                                |            |
| Male                                  | 12(75%)    |
| Female                                | 4(25%)     |
| Type 2 DM                             | 16(100%)   |
| Duration of diabetes (mean ± SD, years)| 9.6 ± 4.8 |
| Wagner classification                  |            |
| Grade 3                               | 3(18.8%)   |
| Grade 4                               | 13(81.2%)  |
| Follow-up (mean ± SD, months)         | 10.8±3.1   |
| Comorbidities                         |            |
| Hypertension                          | 6(37.5%)   |
| Ischemic heart disease                | 4(25.0%)   |
| Peripheral neuropathy                 | 14(37.5%)  |
| Nephropathy                           | 7(43.8%)   |
| Retinopathy                           | 8(50.0%)   |

Table 2 Wound-related study characteristics and outcomes. For quantitative variables, median and range are calculated.

| Variable                              | total n=16 |
|---------------------------------------|------------|
| Wound location                        |            |
| Bilateral side of the foot            | 6(37.5%)   |
| Dorsum of the foot                    | 8(50.0%)   |
| Others                                | 2(12.5%)   |
| Wound size (cm²)                      | 20.42[4.71-66.76] |
| Time for wound closure (days)         | 14(8-19)   |
| Absolute reduction (cm²/day)          | 1.86(0.29-8.35) |
Table 3 Surgical data separated by localization (n = 14). For quantitative variables, median and range as well as the P-value arising from Kruskal–Wallis test are calculated.

| Parameter                      | Bilateral side of the foot | Dorsum of the foot | P-value |
|--------------------------------|----------------------------|--------------------|---------|
| Wound size (cm²)               | 26.69(16.49-66.76)         | 18.85(14.13-25.13) | P=0.069 |
| Time for wound closure (days)  | 10.5(8-14)                 | 14.5(10-19)        | P<0.05  |
| Absolute reduction (cm²/day)   | 2.32(2.06-8.35)            | 1.22(0.99-2.09)    | P<0.05  |

Figures

Figure 1
54-year-old man, diabetic foot, Wagner classification: Grade 4. (A) Diabetic foot condition with second toe necrosis after admission. (B) Diabetic foot condition after absolute debridement. (C) Application of the simple skin stretching system and condition of the margin of the wound. (D) Use NPWT system simultaneously. (E) Diabetic wound condition after removing the NPWT system. (F) The condition of the wound after removing the staples and elastic band. (G) The wound was sutured without high tension. (H) 3 months after last operation.
75-year-old man, diabetic foot ulcer, Wagner classification: Grade 3. (A) Diabetic foot condition on the tibial side of the foot after admission. (B) Diabetic foot condition after debridement. (C) Application of the simple skin stretching system. (D) Diabetic wound condition after removing the NPWT system. (E) The staples and elastic band were removed, and the wound was sutured. (F) 3 months after last operation.