











RESEARCH ARTICLE

Guidelines on interventions to enhance healing of foot ulcers in people with diabetes (IWGDF 2023 update)

Pam Chen^{1,2}  | Nalini Campillo Vilorio³ | Ketan Dhatariya^{4,5}  |
 William Jeffcoate⁶  | Ralf Lobmann⁷  | Caroline McIntosh⁸  |
 Alberto Piaggese⁹  | John Steinberg¹⁰  | Prash Vas¹¹  | Vijay Viswanathan¹²  |
 Stephanie Wu¹³ | Fran Game¹⁴ 

¹Joondalup Health Campus, Ramsay Healthcare Australia, Joondalup, Western Australia, Australia

²Faculty of Health, University of Tasmania, Hobart, Tasmania, Australia

³Department of Diabetology, Diabetic Foot Unit, Plaza de la Salud General Hospital, Santo Domingo, Dominican Republic

⁴Elsie Bertram Diabetes Centre, Norfolk and Norwich University Hospitals NHS Foundation Trust, Norwich, UK

⁵Norwich Medical School, University of East Anglia, Norwich, UK

⁶Retired Physician, Nottingham, UK

⁷Clinic for Endocrinology, Diabetology and Geriatrics, Klinikum Stuttgart, Stuttgart, Germany

⁸Podiatric Medicine, School of Health Sciences, University of Galway, Galway, Ireland

⁹Diabetic Foot Section, Department of Medicine, University of Pisa, Pisa, Italy

¹⁰Georgetown University School of Medicine, Georgetown, Washington DC, USA

¹¹King's College Hospital NHS Foundation Trust, London, UK

¹²MV Hospital for Diabetes and Prof M Viswanathan Diabetes Research Center, Chennai, India

¹³Dr. William M. Scholl College of Podiatric Medicine at Rosalind Franklin University of Medicine and Science, North Chicago, Illinois, USA

¹⁴University Hospitals of Derby and Burton NHS Foundation Trust, Derby, UK

Abstract

Aims: Principles of wound management, including debridement, wound bed preparation, and newer technologies involving alternation of wound physiology to facilitate healing, are of utmost importance when attempting to heal a chronic diabetes-related foot ulcer. However, the rising incidence and costs of diabetes-related foot ulcer management necessitate that interventions to enhance wound healing of chronic diabetes-related foot ulcers are supported by high-quality evidence of efficacy and cost effectiveness when used in conjunction with established aspects of gold-standard multidisciplinary care. This is the 2023 International Working Group on the Diabetic Foot (IWGDF) evidence-based guideline on wound healing interventions to promote healing of foot ulcers in persons with diabetes. It serves as an update of the 2019 IWGDF guideline.

Materials and Methods: We followed the GRADE approach by devising clinical questions and important outcomes in the Patient-Intervention-Control-Outcome (PICO) format, undertaking a systematic review, developing summary of judgements tables, and writing recommendations and rationale for each question. Each recommendation is based on the evidence found in the systematic review and, using the GRADE summary of judgement items, including desirable and undesirable effects, certainty of evidence, patient values, resources required, cost effectiveness, equity, feasibility, and acceptability, we formulated recommendations that were agreed by the authors and reviewed by independent experts and stakeholders.

Results: From the results of the systematic review and evidence-to-decision making process, we were able to make 29 separate recommendations. We made a number of conditional supportive recommendations for the use of interventions to improve healing of foot ulcers in people with diabetes. These include the use of sucrose octasulfate dressings, the use of negative pressure wound therapies for post-operative wounds, the use of placental-derived products, the use of the

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Correspondence

Pam Chen.

Email: chenp@ramsayhealth.com.au

autologous leucocyte/platelet/fibrin patch, the use of topical oxygen therapy, and the use of hyperbaric oxygen. Although in all cases it was stressed that these should be used where best standard of care was not able to heal the wound alone and where resources were available for the interventions.

Conclusions: These wound healing recommendations should support improved outcomes for people with diabetes and ulcers of the foot, and we hope that wide-scale implementation will follow. However, although the certainty of much of the evidence on which to base the recommendations is improving, it remains poor overall. We encourage not more, but better quality trials including those with a health economic analysis, into this area.

KEYWORDS

amputation, diabetes-related foot ulcers, guideline, wound healing

1 | LIST OF RECOMMENDATIONS

All recommendations should be considered to be adjunctive to best standard of care when best standard of care alone has failed to heal the ulcers. This should include sharp debridement and basic wound dressings, which according to the IWGDF Practical Guidelines, should be dressings to absorb exudate and maintain a moist wound healing environment¹

1. Do not use autolytic, biosurgical, hydrosurgical, chemical, or laser debridement over standard of care (GRADE Strength of recommendation: Strong; Certainty of evidence: Low).
2. Do not routinely use enzymatic debridement as opposed to standard of care (i.e. sharp debridement) to improve wound healing outcomes in people with diabetes and a foot ulcer (Strong; Low).
- 2a. In specific situations where the availability of sharp debridement may be limited by access to resources and/or availability of skilled personnel, consider using enzymatic debridement (Conditional; Low).
3. Do not use any form of ultrasonic debridement over standard of care (i.e. sharp debridement) (Strong; Low).
4. Do not use surgical debridement in those for whom sharp debridement can be performed outside a sterile environment (Strong; Low).
5. We recommend that the frequency of sharp debridement should be determined by the clinician based on clinical need (Strong; Low).
6. Do not use topical antiseptic or antimicrobial dressings for wound healing of diabetes-related foot ulcers (Strong; Moderate).
7. Do not use honey (or bee-related products) for the purpose of wound healing in diabetes-related foot ulcers (Strong; Low).
8. Do not use collagen or alginate dressings for the purpose of wound healing of diabetes-related foot ulcers (Strong; Low).
9. Consider the use of the sucrose–octasulfate impregnated dressing as an adjunctive treatment, in addition to the best standard of care, in non-infected, neuro-ischaemic diabetes-related foot ulcers that have had insufficient change in ulcer area with best standard of care including appropriate off-loading for at least 2 weeks (Conditional; Moderate).
10. Do not use topical phenytoin for the purpose of wound healing in diabetes-related foot ulcers (Strong; Low).
11. Do not use any dressing based or topical applications impregnated with herbal remedies for the purpose of wound healing in diabetes-related foot ulcers (Strong; Low).
12. Consider the use of hyperbaric oxygen as an adjunct therapy in neuro-ischaemic or ischaemic diabetes-related foot ulcers where standard of care alone has failed and where resources already exist to support this intervention (Conditional; Low).
13. Consider the use of topical oxygen as an adjunct therapy to standard of care for wound healing in people with diabetes-related foot ulcers where standard of care alone has failed and resources exist to support this intervention (Conditional; Low).
14. Do not use other gases (e.g. cold atmospheric plasma, ozone, nitric oxide, and CO₂) in comparison to standard of care for wound healing in people with diabetes-related foot ulcers (Strong; Low).
15. Do not use any interventions reported in the field of physical therapies for wound healing in the management of diabetes-related foot ulcers (Strong; Low).
16. We suggest not using cellular skin substitute products as a routine adjunct therapy to standard of care for wound healing in patients with diabetes-related foot ulcers (Conditional; Low).
17. We suggest not using acellular skin substitute products as a routine adjunct therapy to standard of care for wound healing in patients with diabetes-related foot ulcers (Conditional; Low).
18. Do not use autologous skin graft skin substitute products as an adjunct therapy for wound healing in patients with diabetes-related foot ulcers (Strong; Low).
19. With the exception of autologous leucocyte, platelet, and fibrin patch, we suggest not using autologous platelets therapy (including blood bank-derived platelets) as an adjunct therapy to standard of care (Conditional; Low).

20. Consider the use of autologous leucocyte, platelet, and fibrin patch for diabetes-related foot ulcers as an adjunctive therapy to standard of care where best standard of care alone has been ineffective and where the resources and expertise exist for the regular venepuncture required (Conditional; Moderate).
21. We suggest not using other cell therapy as an adjunct therapy to standard of care for wound healing in people with diabetes-related foot ulcers (Conditional; Low).
22. We suggest not using growth factor therapy as an adjunct therapy to standard of care for wound healing in people with diabetes-related foot ulcers (Conditional; Low).
23. Consider the use of placental-derived products as an adjunct therapy to standard of care for wound healing in people with diabetes-related foot ulcers where standard of care alone has failed (Conditional; Low).
24. Do not use pharmacological agents promoting perfusion and angiogenesis to improve wound healing outcomes over standard of care (Strong; Low).
25. Do not use pharmacological agents that supplement vitamins and trace elements to improve wound healing outcomes over standard of care (Strong; Low).
26. Do not use pharmacological agents that stimulate red cell production or protein supplementation to improve wound healing outcomes over standard of care (Strong; Low).
27. Do not use other pharmacological agents to improve wound healing outcomes over standard of care (Strong; Low).
28. Consider the use of Negative Pressure Wound Therapy as an adjunct therapy to standard of care for the healing of post-surgical diabetes-related foot wounds (Conditional; Low).
- 28a. Do not use Negative Pressure Wound Therapy as an adjunct therapy to standard of care for the healing of non-surgically related diabetes foot ulcers (Strong; Low).
29. We do not recommend any specific educational and lifestyle support programmes over standard of care to improve healing of diabetes-related foot ulcers (Strong; Low).

2 | INTRODUCTION

Diabetes-related foot ulcer management remains challenging and costly, posing high financial burdens on healthcare economies and having impacts on morbidity, mortality, and quality of life. Principles of wound management, including debridement, wound bed preparation, and newer technologies involving alternation of wound physiology to facilitate healing, are thus of utmost importance when attempting to heal a chronic diabetes-related foot ulcer. However, the rising incidence and costs of diabetes-related foot ulcer management necessitate that interventions promoted to enhance wound healing of chronic diabetes-related foot ulcers are adequately supported by high-quality evidence promoting efficacy and cost-effectiveness when used in conjunction with established aspects of gold-standard multidisciplinary care.²⁻⁴

Since 2008, the International Working Group of the Diabetic Foot (IWGDF) have commissioned evidence-based guidelines, updated every four years, with a chapter focusing on interventions to enhance wound healing. Up until 2019, each systematic review and guideline represented an update of previous search results. However, updated standards⁵ for assessment of diabetes-related foot ulcer healing therapies have resulted in better quality studies in recent years. To enable consistent benchmarking across newer and older studies alike, the aim of developing this edition of the guidelines and systematic review was thus to undertake a complete search and re-evaluation of the literature, describing trials of interventions intended to improve wound healing of foot ulcers in people with diabetes.^{6,7}

2.1 | What's new

We have made several changes to the recommendations included in this updated 2023 wound healing interventions guideline compared to the previous 2019 wound healing interventions guideline. The main changes are as follows:

- Instead of a 4-yearly update, we performed a new systematic review of wound healing interventions and re-evaluated previous interventions in line with newest benchmarking and risk of bias assessments according to GRADE methodology⁷
- We only evaluated randomised controlled trials (RCTs) to ensure that only evidence at the highest level was included
- We increased the number of outcomes critical to decision-making in wound healing, including sustained healing, resource utilisation, quality of life, maintenance of function and ability to perform activities of daily living, new infection, and mortality
- We added new clinical questions on behavioural, educational, and pharmacological interventions
- We changed categorisation of dressings, autologous products, and skin substitutes
- We have 29 new recommendations with six interventions receiving conditional positive recommendations

3 | METHODS

In this guideline, we have followed the key steps of the GRADE evidence-to-decision framework, including (i) establishing a diverse expert panel to develop the guideline, (ii) defining key clinical questions and important outcomes in the PICO-format (Patient-Intervention-Comparison-Outcome), (iii) performing systematic reviews and rigorous appraisals of all available evidence that address the questions, (iv) assessing key summary of judgement items for each question, (v) developing recommendations and their rationale based on these summary of judgements, and (vi) consulting external stakeholders on each step.^{8,9} The methodology for this guideline is summarised below; we refer those seeking a more detailed description on

the methods for developing and writing these guidelines to the 'IWGDF Guidelines development and methodology' document.¹⁰

First, a multidisciplinary working group of independent international experts in wound healing for diabetes-related foot ulcers (the authors of this guideline) was invited by the IWGDF Editorial Board to develop and author this guideline. International experts were defined as those having significant experience in practising or studying the healing of diabetes-related foot ulcers. The working group comprised members from podiatric surgery, podiatry, and endocrinology disciplines from the USA, Caribbean, Europe, Asia, and Australia.

Second, the working group devised important clinical questions and associated outcomes, building on the last version of the guideline, to be answered using the GRADE approach. The questions and outcomes were reviewed and prioritised with the help of 15 external clinical experts and two persons with lived diabetes-related foot ulcer experiences from various geographical regions, and the IWGDF Editorial Board. The aim was to ensure the questions and outcomes were of relevance to a wide range of healthcare professionals and people with the disease so as to provide the most useful clinical information on wound interventions to treat foot ulcers in people with diabetes. The working group classified the outcomes as critically important or important, aligning with international diabetes-related foot ulcer standards^{5,11} or the expert opinion of the working group if standards did not exist.

Interventions (topical and systemic therapeutic agents) included were those previously addressed in the previous guidelines⁶ where it was known that trials had been performed to address our clinical questions. In addition, the working group agreed interventions not previously looked at, including educational and behavioural interventions designed to aid wound healing were important additions. We did not include offloading interventions or systemic interventions designed to treat infection or interventions that were designed to improve limb perfusion unless they were pharmacological in nature and reported wound healing, as these interventions were included in other working group guidelines.¹²⁻¹⁴

Third, we systematically reviewed the literature and appraised all studies addressing the above agreed upon clinical questions. Unlike previous versions of the guidelines, in view of the huge increase in the volume of literature and the need to assess only the evidence of the highest quality in formulating guidelines, we included only randomised controlled trials (RCTs) in our systematic review. We considered as a comparator best standard of care, defined as those described in the practical guidelines¹, that is, local debridement, offloading, revascularisation, and treatment of infection where appropriate.

For each assessable outcome, we graded the quality of evidence based on the risk of bias of included studies, effect sizes, presence of inconsistency, and any evidence of publication bias (where appropriate).¹⁵ We then rated the quality of evidence as 'high', 'moderate', or 'low' according to GRADE methodology.⁸ Finally, we developed summary of findings tables, including evidence statements, for each assessable outcome for each question which we presented in full in the systematic review. The systematic review supporting this guideline is published separately.⁷

Fourth, based on the systematic review, summary of findings tables and expert opinion, teams of two members of the working group developed a summary of judgement tables for each question following GRADE (see Supporting Information S1). The summary of judgement items assessed included desirable and undesirable effects, balance of effects, certainty of evidence, values, resource use, cost-effectiveness, equity, acceptability, and feasibility. Definitions for these items can be found in the Summary of Judgements table in the Supporting Information S1. For the resources required, the group considered potential financial and/or human resources directly linked to the implementation of the intervention in clinical practice and any specific expertise required. Where such information was missing, the group made a pragmatic decision based on their clinical expertise. The group defined equity in this context as the ability of all people with a diabetes-related foot ulcer (i.e. on a societal level) to have equitable access to the procedures required for the intervention application.

Acceptability to stakeholders was based on expert opinion and consideration of the balance of effects and any resources required by the users themselves. Feasibility was determined based on the groups' experience and the ease of use of the interventions.

After careful weighing of the summary of judgements, the team proposed to the working group a direction, strength, certainty of evidence, and wording of recommendation(s) and rationale to address the question concerned. Certainty of evidence was rated as 'high', 'moderate', 'low', or 'very low' based on the critical outcome(s) reviewed for the question in accord with GRADE. Recommendations aimed to be clear, specific, and unambiguous on what was recommended, for which persons, and under what circumstances. Rationale for each recommendation was also provided and based on the summary of judgement tables (see Supporting Information S1).^{8,9}

Fifth, summary of judgement tables and recommendations for each question were extensively discussed in online meetings with the working group. After discussion, a voting procedure was used for each recommendation to grade the direction of the recommendation as 'for' or 'against' the particular intervention, and the strength of each recommendation as 'strong' or 'conditional'. A quorum of 60% of members were needed to be present for a discussion and vote to go ahead and a majority vote of those present was needed for final decisions on each recommendation. The outcomes of the voting are provided in the supplementary material.

Finally, all recommendations, with the rationales, were collated into a consultation (draft) guideline manuscript that was reviewed by the same clinical experts and persons with lived experience who reviewed the clinical questions as well as by members of the IWGDF Editorial Board. The working group then collated, reviewed, and discussed all feedback on the consultation manuscript and revised accordingly to produce the final guideline manuscript.

To aid consideration of the literature, the interventions were grouped into nine broad categories of (i) debridement (ii) dressings and topical applications (iii) oxygen and other gases (iv) therapies involving physical alteration of wound bed properties (v) skin substitutes (vi) autologous and other cellular products including growth factors and placental-derived products (vii) pharmacological interventions (viii) negative pressure, and (ix) educational and

psychological interventions. Ten outcomes were identified as critical to decision-making in wound healing, which were (a) Complete wound healing; (b) Time to healing; (c) Sustained healing, (d) Reduction in ulcer area, (e) Amputation (major or minor), (f) Quality of life, (g) Maintenance of function and ability to perform activities of daily living, (h) New infection, (i) Resource utilisation, and (j) death/mortality.

4 | RECOMMENDATIONS

Overall, nine clinical questions, each with up to 10 outcomes critical to decision-making were addressed by this guideline. This has led to the formulation of 29 separate recommendations. The accompanying systematic review⁷ has been published, and we developed 27 summary of judgement tables (available as online-only Supporting Information S1).

We considered the interventions to be adjunctive to best standard of care when best standard of care alone has failed to heal the ulcers. This should include basic wound dressings, which according to the IWGDF Practical Guidelines should be dressings to absorb exudate and maintain a moist wound healing environment.¹ Additionally, these should be of the lowest acquisition cost for the local healthcare economy.

4.1 | Clinical question 1: In people with diabetes-related foot ulcers, is enzymatic debridement, autolytic debridement, biosurgical debridement, ultrasonic debridement, hydrosurgical abrasion, or chemical debridement more effective for achieving wound healing compared to best standard of care (including sharp debridement)?

4.1.1 | Intervention: Debridement

Debridement involves the removal of dead and devitalised tissue (necrosis and slough) from wounds in order to create a clean wound bed and is designed to promote wound healing. There are several different types of debridement, including physical (e.g. surgical, sharp, hydrodebridement, or gaseous debridement), biological (larvae), autolytic (hydrogels), or biochemical (enzymes). Although there is unequivocal consensus amongst experts in support of the need for regular wound debridement to facilitate healing, high-quality evidence to justify debridement in general, and to identify the best form of debridement is limited. For types of debridement, we found 10 RCTs that met our prespecified inclusion criteria as described in our systematic review.^{16–25} There were five RCTs^{16–20} of enzymatic debridement, 3 RCTs^{21–23} of low-frequency ultrasonic debridement, 1 RCT²⁴ of surgical debridement, and 1 RCT²⁶ on frequency of sharp debridement. However, we found no RCTs of other types of debridement.

Recommendation 1: Do not use autolytic, biosurgical, hydrosurgical, chemical, or laser debridement over standard of care (GRADE Strength of recommendation: Strong; Certainty of evidence: Low).

Rationale: No publications of RCTs were found on the use of autolytic, biosurgical, hydrosurgical, chemical, or laser debridement that met our prespecified inclusion criteria, or had sufficient cost effectiveness data to warrant their use. Thus, we were unable to make a recommendation supporting their use.

4.1.2 | Enzymatic debridement

Recommendation 2: Do not routinely use enzymatic debridement as opposed to standard of care (i.e. sharp debridement) to improve wound healing outcomes in people with diabetes and a foot ulcer (Strong; Low).

Recommendation 2a: In specific situations where the availability of sharp debridement may be limited by access to resources and/or availability of skilled personnel, consider using enzymatic debridement (Conditional; Low).

Rationale: We found five RCTs on clostridial collagenase ointment^{16–20} all of which were compared to standard of care (i.e. sharp debridement). All were exploratory RCTs that were designed to generate hypotheses and were not designed to provide a statistically significant outcome. All had significant methodological limitations, were mainly unblinded and at high risk of bias. Outcomes were assessed at different time points, between 4 and 6 weeks, with limited long-term follow up and different definitions of healing making comparisons between studies difficult.

Overall, the evidence behind the use of enzymatic debridement is limited, and the certainty of evidence is low. This reflects the methodological limitations of the studies and the resultant high risk of bias. Overall, the balance of effects did not favour either enzymatic debridement or sharp debridement in terms of complete wound healing or wound area reduction. One specific type of enzymatic debridement, topical clostridium collagenase, would probably have higher resource implications but there was low certainty of evidence of the required resources, and no formal cost effectiveness data were found. Due to the additional resources required to provide topical clostridium collagenase, we considered that equity may be reduced, particularly in low and middle income regions. However, we also recognise that in some lower income regions access to standard of care (i.e. sharp debridement) may be limited as this requires skilled personnel, training programmes, and sterile instruments. Hence, in healthcare systems where such skills are not available, alternative methods with enzymatic debriding agents could be considered.

4.1.3 | Ultrasonic debridement

Recommendation 3: Do not use any form of ultrasonic debridement over standard of care (i.e. sharp debridement) (Strong; Low).

Rationale: We found three RCTs^{21–23} of low frequency ultrasonic debridement compared to standard of care (i.e. sharp debridement). All three studies were at high risk of bias with none being blinded. Only one²¹ suggested any differences between groups in time to healing, but this result should be treated with caution given the high risk of bias of the study. None showed any differences in absolute healing in the timescales of the follow-up of the studies. The other two studies^{22,23} presented either no difference between the two groups or did not present any between group analyses.

One of the three identified RCTs showed small desirable effects in regard to wound healing outcomes. Thus, ultrasonic debridement may be associated with decreased time to wound healing versus standard of care, albeit with low certainty evidence, thus these findings should be interpreted with caution. No differences in complete wound healing or sustained healing were reported between groups. Thus, overall, the balance of effects does not favour either the intervention or control. The intervention, ultrasonic debridement, has a higher resource implication although with low certainty of evidence of the required resources and no formal cost effectiveness data found. From the limited data available, it is uncertain as to whether the higher costs incurred could be offset by the small desirable effects in terms of decreased time to healing in the intervention group; although it seems unlikely, given the low certainty of the evidence of the beneficial effect. Due to the additional resources required to provide ultrasonic debridement, equity is probably reduced, particularly in lower income regions; however, the intervention is probably acceptable to patients and its use in a healthcare system was thought to be feasible. Due to all the above reasons, but mostly the low certainty of evidence of benefit and an absence of cost effectiveness data, we do not recommend the use of ultrasonic debridement over standard of care, that is, sharp debridement.

4.1.4 | Surgical debridement

Recommendation 4: Do not use surgical debridement in those for whom sharp debridement can be performed outside a sterile environment (Strong; Low).

Rationale: We found one RCT²⁴ of surgical debridement compared to standard of care (i.e. sharp debridement), which reported two of our critical outcomes, time to healing and sustained healing, but was assessed as being at high risk of bias; and any positive benefits reported should be treated with caution.

Overall, we considered that the balance of effects did not favour either the intervention or control. The intervention, surgical debridement, has a higher resource implication with large costs albeit with low certainty of the evidence of the required resources, and no

formal cost effectiveness data were found. From the limited data available, it is uncertain as to whether the higher costs incurred could be offset by the small desirable effects in terms of greater sustained healing in the intervention group although this seems unlikely. Due to the additional resources required to provide surgical debridement equity was felt to be reduced, particularly in low income regions; however, the intervention is probably acceptable to patients and feasible. For all the above reasons but particularly the low certainty of evidence of benefit, we do not recommend the routine use of surgical debridement in those for whom sharp debridement can be performed outside of a sterile environment. However, in the absence of high-quality evidence, the opinion of the expert group was that (a) people with diabetes-related foot ulcers that can be managed appropriately with sharp debridement in an outpatient setting should not be taken to theatre for unnecessary surgical debridement as this approach is more expensive, resource intensive, and might actually delay debridement if it could be undertaken at the chairside. (b) People with diabetes-related foot ulcers with limb or life-threatening features (e.g. extensive necrosis, collections, or gas forming infections) must always be referred urgently for a surgical opinion to assess the need for surgical intervention to avoid the risk of further deterioration and worse outcomes (see Recommendation 18 of the 2023 Infection Guidelines).¹⁴ The type of debridement modality, that is, sharp versus surgical should be made by an experienced clinician based upon clinical severity and the presence or absence of any limb-threatening features.

4.1.5 | Frequency of sharp debridement

Recommendation 5: We recommend the frequency of sharp debridement should be determined by the clinician based on clinical need (Strong; Low).

Rationale: We found one RCT²⁵ at high risk of bias that investigated frequency of sharp debridement, weekly versus fortnightly. This one study, involving 61 participants per group, reported no statistically significant difference in wound healing outcomes, wound closure, or healing times at 12 weeks between groups. The certainty of the evidence is low, as this is based on one unblinded study at high risk of bias. Overall, we felt that the balance of effects does not favour either the weekly or fortnightly sharp debridement. No formal cost effectiveness data were found. From the limited data, it is uncertain as to whether there would be a difference in costs based on frequency of sharp debridement, given that all participants were attending clinics weekly. Sharp debridement, regardless of frequency is acceptable to patients and feasible. Due to limited evidence, we do not recommend a specific frequency of debridement. The frequency should thus be determined by the clinician based on clinical need.

4.2 | Clinical question 2: In people with diabetes-related foot ulcers, are dressings or applications with surface antimicrobial properties, honey, or those that influence chronic wound biology more effective for achieving wound healing compared to basic contact dressings and best standard of care?

4.2.1 | Intervention: Dressings

We identified 50 published RCTs related to our interventions and reporting our outcomes of choice which informed these guidelines. All but four studies reviewed were considered at high or moderate risk of bias. The duration of treatment and follow-up period varied widely between the studies reviewed (24 h to 34 weeks) and many studies provided limited description of the ulcer and patient characteristics, but typically recruited superficial ulcers or non-infected ulcers. Additionally, most studies recruited individuals without peripheral artery disease (PAD) or with mild PAD (in most studies, but not all, defined as Ankle Brachial Index [ABI] 0.7 to 0.9, Transcutaneous Oxygen pressure (TcPO₂) 30–50 mmHg). Therefore, the certainty of evidence and assessment of balance of effect in favour of the intervention in addition to generalisability to the typical diabetes-related foot ulcers seen in clinical practice was hard to determine. Furthermore, we also noted a significant lack of clear descriptions of standard of care provision, including the type and quality of off-loading provided, type and impact of any additional supportive interventions undertaken, such as revascularisation.

Given this is a large group of interventions, we have broken down the key recommendations into smaller sections based on the groups of types of products and applications currently available.

4.2.2 | Topical antimicrobial or antiseptic dressings

Recommendation 6: Do not use topical antiseptic or antimicrobial dressings for wound healing of diabetes-related foot ulcers (Strong; Moderate).

Rationale: We found 12 studies^{27–38} evaluating anti-septic or antimicrobial dressings or topical antiseptic applications. Five evaluated the use of silver impregnated dressings in comparison with usual care^{27–30,37} but all were considered at high or moderate risk of bias. Four of these showed no significant improvement in terms of complete healing^{27–30} or percentage area wound reduction.

We found three studies investigating the use of iodine-impregnated dressings.^{31–33} Apart from one,³² all were at high risk of bias. This, the only study with blinding regarding the evaluation of outcomes showed no difference in the incidence of outcomes of importance when compared with usual care. Thus, any positive benefits reported by the other studies should be treated with caution.

One study on diperoxochloric acid³⁴ was found which evaluated the effect of this intervention in hospitalised patients. Although with

double blinding, usual care was not well defined and the clinical significance of the apparent positive results are not clear.

We identified two studies of topical gentamicin^{35,36} which fulfilled our inclusion criteria; although both were considered at high risk of bias and only one reported apparent superiority of the intervention on wound healing after minor amputations. Thus, any apparent benefit on wound healing is of low certainty.

We identified only one non-blind study on a superoxidised solution.³⁸ Although no differences were reported in complete wound healing, a shorter time to heal and lower rates of reinfection were reported at 6 months in the intervention arm. The study was however at high risk of bias and thus we have low confidence in this result.

The evidence to support positive impact on wound healing of surface antiseptics or antimicrobials is thus inconsistent, and where present, the effect size was small with low certainty of evidence. There was significant heterogeneity in the type and size of diabetes-related foot ulcers recruited and the standard of care provided, making comparison between studies using the same type of dressing/application difficult. Thus, the balance of effects was felt not to be in favour of the intervention. Although costs were thought to be moderate/low and equity, feasibility and acceptability were not thought to be affected. Given the low certainty of evidence of benefit, we do not recommend the use of any of these products for the sole purpose of promoting wound healing of diabetes foot ulcers.

4.2.3 | Honey or bee products

Recommendation 7: Do not use honey (or bee related products) for the purpose of wound healing in diabetes-related foot ulcers (Strong; Low).

Rationale: We found six RCTs^{28,39–43} of interventions containing topical bee or honey products, which reported some of our outcomes of importance. All were deemed at high risk of bias and any positive results on wound healing should be treated with caution. The only blinded study of a royal jelly found no difference in healing over 12 weeks.⁴⁰ No studies reporting data on amputation, cost effectiveness, or quality of life were found.

Overall, therefore, the certainty of any positive benefit of the topical use of honey or bee related products is very low. Although adverse effects were rarely reported, the groups' experience was that any undesirable effects are likely to be trivial. However, the balance of effects could not be ascertained as either favouring the intervention or the comparison. Resource use was thought to be similar to standard of care but no formal cost-effectiveness data was found. Although thought to be feasible, acceptable to patients and with equity unaffected, it was felt that in the absence of certainty of benefit, we cannot recommend the use of any of these products for promoting wound healing in diabetes-related foot ulcers.

4.2.4 | Collagen or alginate

Recommendation 8: Do not use collagen or alginate dressings for the purpose of wound healing of diabetes-related foot ulcers (Strong; Low).

Rationale: We found 12 RCTs^{29,44-54} of collagen or alginate (or both) as an intervention to enhance wound healing and which fulfilled our inclusion criteria. All were at moderate or high risk of bias and most were non-blinded. Four studies compared collagen only with moist wound therapy,^{45,47,48,52} one study⁴⁶ used collagen-alginate, one used a calcium alginate,⁵¹ one compared a collagen/oxidised regenerated cellulose/silver treatment with foam,²⁹ one the same collagen/oxidised regenerated cellulose but without silver,⁵⁴ one compared collagen with negative pressure wound therapy,⁵⁰ one compared collagen with gauze or hydrocolloid dressings⁴⁹, and another two^{51,53} alginate alone as the intervention. Of the 12 studies, nine of them^{29,45-47,49,51-54} did not report a difference in wound healing or reduction in ulcer area at the end of study duration. Thus, any reported positive outcomes should be treated with caution.

The group agreed that in view of the known low incidence of undesirable effects, it is possible that the balance of effects favours the intervention, although the certainty of this was very low. The cost of these interventions was thought to be moderate, although no formal cost effectiveness studies were found and so the certainty of this was low. Equity, acceptability, and feasibility were agreed to be unlikely to be affected. Nevertheless, given the uncertainty of benefit and possible cost implications, we do not recommend the use of any of these products for promoting wound healing in diabetes-related foot ulcers.

4.2.5 | Sucrose octasulfate

Recommendation 9: Consider the use of the sucrose-octasulfate impregnated dressing as an adjunctive treatment, in addition to the best standard of care, in non-infected, neuro-ischaemic diabetes-related foot ulcers that have had insufficient change in ulcer area with best standard of care including appropriate off-loading for at least 2 weeks (Conditional; Moderate).

Rationale: We found one large double blind multinational RCT⁵⁵ assessed to be at low risk of bias investigating the use of sucrose-octasulfate impregnated dressings in non-infected neuro-ischaemic foot ulcers that were deemed hard to heal at the end of a 2-week run-in period. There was a significant improvement in complete wound healing at week 20, a significantly faster estimated time to heal, and increased percentage area reduction compared to the placebo dressing; and we considered this evidence to be of high certainty. We therefore concluded that, in neuro-ischaemic foot ulcers where there has been insufficient change in ulcer area with best standard of care, including appropriate offloading, there is sufficient evidence to consider the use of sucrose-octasulfate impregnated dressing. We found few data on harms and concluded that the balance of risks and benefits were in favour of the intervention.

Resource use was considered to be low/moderate, and we are aware that there is cost-effectiveness data from modelling studies now available for various Western health-care systems, which are supportive.⁵⁶⁻⁵⁹ Equity was not thought to be reduced with this intervention and it was felt to be feasible and acceptable to patients in all healthcare settings. However, the optimal timing of initiating treatment remains to be established. Furthermore, it is recognised that this is the only study of this intervention, and so despite the quality of the data in this one study, the evidence was considered to be moderate and the strength of the recommendation limited to conditional.

4.2.6 | Topical phenytoin

Recommendation 10: Do not use topical phenytoin for the purpose of wound healing in diabetes-related foot ulcers (Strong; Low).

Rationale: Despite there being 12 RCTs⁶⁰⁻⁷¹ investigating the use of topical phenytoin for wound healing of diabetes-related foot ulcers, with some benefit of its use on time to healing and reduction in ulcer area, the evidence to support any benefit was of low certainty, as all trials were at moderate to high risk of bias and most were unblinded. Although the intervention is not likely to be expensive, and equity and feasibility is unlikely to be unaffected, the certainty of the evidence is such that we cannot recommend this intervention.

4.2.7 | Topical herbal or traditional medicinal preparations

Recommendation 11: Do not use any dressing based or topical applications impregnated with herbal remedies for the purpose of wound healing in diabetes-related foot ulcers (Strong; Low).

Rationale: We found nine RCTs which reported on the use of topical herbal or traditional medicinal preparations, which fulfilled our inclusion criteria.⁷²⁻⁸⁰ Of seven studies reporting on complete wound healing,^{72-77,79} all were at moderate or high risk of bias, and any positive effects on wound healing should be interpreted cautiously. Further, reduction in ulcer area was reported in six studies^{72,74,75,77,79,80} of which only two^{72,77} found an apparent improvement in comparison to the control. Again, these were at high risk of bias. No differences in amputation rates⁷⁴ or mortality⁷⁸ were reported. No studies reported on quality of life, new infection, resource utilisation, or maintenance of function.

Overall, we found nine studies assessing the effect of traditional or herbal-based remedies, although all were rated at high risk of bias. Despite some of the studies reporting positive effects on wound healing, including reduction in ulcer area, the low confidence in the results and the fact that no two studies evaluated the same product, meant the balance of effects could not be ascertained as either favouring the intervention or the comparison. Furthermore, there was significant heterogeneity in the ulcer type and patients recruited, adherence to standard of care was unclear in many studies, and no

cost-effectiveness data was found. Therefore, on balance, given the poor quality of evidence, presently we do not recommend the use of any of these products for the purpose of promoting wound healing in difficult to heal diabetes-related foot ulcers.

4.3 | Clinical question 3: In people with diabetes-related foot ulcers, is hyperbaric oxygen, topical oxygen, or the use of other gases compared to standard of care more effective for achieving wound healing?

4.3.1 | Intervention: Oxygen and other gases

Oxygen is a critical element in key processes of wound healing, including angiogenesis, collagen deposition, and epithelialisation. Hyperbaric oxygen therapy involves breathing 100% oxygen at a pressurised atmosphere of 2ATA or above (i.e. twice the atmospheric pressure exerted at sea level), which increases the partial pressure of oxygen in hypoxic or ischaemic tissues. This has been proposed as a key mechanism for improving wound healing in diabetes-related foot ulcers with ischaemia or hypoxia. Previous guidelines⁶ have conditionally recommended the use of hyperbaric oxygen therapy as an adjunctive treatment on the basis of several RCTs. For this guideline, we included 18 RCTs on hyperbaric oxygen⁸¹⁻⁹⁸ with no new studies published in the last 4 years.

Topical oxygen is a relatively new(er) therapy, and this involves the administration of oxygen topically over the tissue by continuous diffusion or pressurised systems using mechanical devices.⁹⁹ Whilst there was insufficient evidence to recommend its use for healing diabetes-related foot ulcers in 2019,⁶ the evidence on topical oxygen has substantially expanded in the last four years with several new RCTs¹⁰⁰⁻¹⁰³; a total of 10 are included in the systematic review for these guidelines.¹⁰⁰⁻¹⁰⁹

In addition, we found one study on nitric oxide,¹¹⁰ three on ozone therapy,¹¹¹⁻¹¹³ two on cold atmospheric plasma^{114,115}, and one on carbon dioxide.¹¹⁶ With all of these studies being either at high risk of bias and/or with lack of demonstrable effect, these were grouped together as 'other gases'.

Recommendation 12: Consider the use of hyperbaric oxygen as an adjunct therapy in neuro-ischaemic or ischaemic diabetes-related foot ulcers where standard of care alone has failed and where resources already exist to support this intervention (Conditional; Low).

Rationale: Of the 18 studies on the evaluation of the use of hyperbaric oxygen as an adjunct therapy to improve diabetes-related foot ulcer healing, only three were double-blinded RCTs.^{87,89,91} One of these showed no difference in the critical outcome of wound healing⁸⁷ with both the others showing improved wound healing.^{89,91} Overall, the evidence is conflicting, but the studies with lowest risk of bias suggest that there may be some benefit for its use in improving

absolute wound healing and reduction in ulcer area. Good evidence of benefit in preventing amputation is, however, lacking. Different time points (ranging between 30 days and 12 months), degree of ischaemia, and definitions of healing make comparisons between studies difficult.

Overall, the evidence at low risk of bias behind the use of hyperbaric oxygen therapy was limited. The majority of studies were at high risk of bias although there was one good quality study showing evidence of benefit on the critical outcomes of healing and time to healing. Overall, the certainty of evidence was low and although there were moderate desirable effects with benefit in improving absolute wound healing and reduction in ulcer area, evidence of amputation reduction was not found. People with diabetes require assessment for suitability for hyperbaric oxygen therapy; and those with general frailty and comorbid conditions may have to be excluded from this treatment modality due to increased risks of adverse events. Amongst those assessed as suitable, however, reported undesirable effects were small. Overall, the group felt the balance of effects will likely favour the use of hyperbaric oxygen over standard of care alone. However, hyperbaric oxygen therapy requires large costs and although several poor quality in-trial studies have demonstrated cost savings with its use, these fail to account for costs of construction of hyperbaric oxygen units. Nonetheless, where there are already established hyperbaric oxygen units used for treating other medical conditions, there may be cost effectiveness justifying the use of this intervention if desirable effects of improved wound healing are achieved. Although time consuming, hyperbaric oxygen was thought to be acceptable to most patients and clinicians. Overall, because hyperbaric oxygen is only limited to individuals assessed as being suitable, who live in close proximity to established hyperbaric units, and are able to commit to weeks of intense treatment, we acknowledge that this conditional recommendation is likely to reduce equity.

Our ratings are consistent with findings from previous guidelines; and with no new good quality evidence published in the last 4 years, we continue to conditionally recommend the use of hyperbaric oxygen as an adjunct therapy where standard of care alone has failed although we recognise that the groups most likely to benefit still requires evaluation.

4.3.2 | Topical oxygen

Recommendation 13: Consider the use of topical oxygen as an adjunct therapy to standard of care for wound healing in people with diabetes-related foot ulcers where standard of care alone has failed and resources exist to support this intervention (Conditional; Low).

Rationale: We found three double-blinded RCTs^{100,102,103} and seven non-blinded studies^{101,104-109} for the use of topical oxygen. Of the double-blinded studies, one was terminated early and had uneven baseline characteristics between control and intervention groups.¹⁰⁰

Two double-blinded trials were at low risk of bias, but only one had statistically significant results for complete wound healing in favour of topical oxygen at 12 weeks¹⁰² with the other showing no difference between topical oxygen and standard of care.¹⁰³ There was no benefit of topical oxygen on amputation, probably due to short duration of follow-up in most trials. We found no data on resource use, and few data on adverse events.

The evidence behind the use of topical oxygen in diabetes-related foot ulcers was of low certainty, with overall desirable effects rated as moderate with benefit on achieving absolute wound healing and reduction in ulcer area, but no evidence for reduction in amputation up to 12 weeks. Undesirable effects were poorly reported in the studies available to us, but assumed to be trivial based on expert opinion. Overall, the group felt that the balance of effects would favour the use of topical oxygen, but the certainty of evidence is rated as low across the different devices delivering topical oxygen; and at present, it is difficult to say which devices, if any, are superior. There was also a lack of cost effectiveness or published data on resource use, but expert opinion agreed upon moderate costs, with therapy requiring multiple units of single-use topical oxygen delivery devices. Unlike hyperbaric oxygen, topical oxygen therapy can be administered in patients' homes and is likely to be feasible and acceptable to patients and clinicians alike; but due to the moderate costs for mainly single-use devices, it was felt that equity may be reduced. Overall, despite the balance of effects being in favour of the intervention, a conditional recommendation only for topical oxygen was made because of the costs involved and their effect on equity.

4.3.3 | Other gases

Recommendation 14: Do not use other gases (e.g. cold atmospheric plasma, ozone, nitric oxide, and CO₂) in comparison to standard of care for wound healing in people with diabetes-related foot ulcers (Strong; Low).

Rationale: The evidence to support the use of other gases such as nitric oxide, ozone, carbon dioxide, and cold atmospheric plasma is poor, with no studies assessed to be at low risk of bias.¹¹⁰⁻¹¹⁶ Overall, the desirable and undesirable effects were both rated to be trivial, although the latter was an assumption with lack of data on adverse events reported in trials. Due to high risk of bias, the certainty of evidence is rated as very low, and the balance of effects was felt unlikely to favour the use of other gases over standard of care. Expert opinion rated the costs of therapy as moderate, again with lack of cost effectiveness data from trials. Thus, the use of other gases is probably not as cost-effective when compared to standard of care. Due to limited availability and information about use, storage and administration of these gases, these therapies are unlikely to be acceptable or feasible for wide use. Thus, we cannot recommend the use of these interventions to support wound healing of diabetes-related foot ulcers.

4.4 | Clinical question 4: In people with diabetes-related foot ulceration, is the use of interventions which physically alter the wound bed compared to standard of care more effective for wound healing?

4.4.1 | Intervention: Physical alteration of wound bed

We found a number of studies relating to the use of 'physical wound bed alteration therapies', including heat application, therapeutic ultrasound, compression, electrical or electromagnetic stimulation (ES/EM), light and laser treatment, Extracorporeal Shock Wave Therapy (ESWT), ischaemic preconditioning, therapeutic magnetic resonance, and connective tissue manipulation.

As there were few studies on each of these interventions individually, and those that we did identify were either at high risk or moderate risk of bias and/or showed no benefit, we have taken this group all together in making a recommendation.

Recommendation 15: Do not use any interventions reported in the field of physical therapies for wound healing in the management of diabetes-related foot ulcers. (Strong; Low)

Rationale: The evidence to support the use of heat application for diabetes-related foot ulcer management is weak, depending on only three small, non-blinded RCTs¹¹⁷⁻¹¹⁹ all at high risk of bias and in one of which¹¹⁷ the incidence of healing in the comparator group seemed to be much lower than expected for the type of ulcers included. We found just two studies of therapeutic ultrasound,^{120,121} only one of which was methodologically sound,¹²⁰ although healing rates were again lower than expected in the control arm.

Three studies¹²²⁻¹²⁴ evaluated compression on some of our outcomes of importance. All three were at moderate or high risk of bias.

We identified six studies investigating the use electrical or electromagnetic stimulation on some of our outcomes of importance.¹²⁵⁻¹³⁰

Eight studies were found on the use of light and laser therapy.¹³¹⁻¹³⁸ Only three of these¹³¹⁻¹³³ reported complete healing or time to healing, the remainder reporting only area reduction. Results were conflicting, possibly contributed by the heterogeneity of treatment protocols.

We identified four studies of extra corporeal shock wave therapy.¹³⁹⁻¹⁴² Of our outcomes of importance, only complete healing,¹³⁹⁻¹⁴¹ time to healing,^{139,141} and percentage area reduction of the ulcer¹⁴² were reported.

The evidence available from the single study¹⁴³ of ischaemic preconditioning identified does not support its use due to its high risk of bias.

We identified only one study of therapeutic magnetic resonance,¹⁴⁴ which was at moderate risk of bias and did not show any differences in outcome between the two groups.

We found only one study of connective tissue manipulation,¹⁴⁵ reporting only percentage area reduction and no benefit was shown in the use of the intervention.

The analysis of the studies dealing with different physical therapies proposed for diabetes-related foot ulcer management provided limited evidence to suggest that these therapies might be beneficial in improving outcomes in diabetes-related foot ulcers. While a small number of studies were at low risk of bias, none of these indicated any effect. Overall, the desirable effects of physical therapies on wound healing were considered small, and in most cases, no significant differences emerged when compared to standard of care. As the studies focused on a number of interventions and as the results were not strong, it was decided to consider them as part of the whole group of 'physical therapies' rather than analysing them separately. It was also noted that undesirable effects were rarely reported, and no severe adverse events were described. It was considered, therefore, that the balance of effects would not favour either the intervention or usual care, but that this was based on low certainty evidence. In addition, it was considered that most, if not all, of the treatments might be associated with appreciable extra costs and resources. Although formal cost-effectiveness studies were not found, it was felt that cost-effectiveness would be unlikely given the small size of effects noted. It was also noted that some treatments might have reduced acceptability and equity for patients, and hence feasibility. For these reasons, we do not currently recommend the use of any of the physical therapies described either as first-line or as adjuvant therapies for diabetes-related foot ulcer management.

4.5 | Clinical question 5: In people with diabetes-related foot ulcers, are skin substitutes more effective for wound healing compared to best standard of care?

4.5.1 | Intervention: Skin substitutes

Skin substitutes are a grouping of wound care products that include cellular, acellular, and autologous skin graft subgroups. These products are applied to non-healing wounds to supply structural and/or biological support to the site via this externally derived product. They are generally secured with suture, adhesive strips, and/or a secondary dressing. This heterogeneous group of products are generally used to artificially deliver wound healing stimulation and seek to mimic the composition and function of human skin.

We found 28 RCTs across the wider category of skin substitutes. This body of research has greatly expanded over the last decade and now contains a significant number of enrolled people with diabetes-related foot ulcers, but presents a very complex review challenge given the non-uniformity of products, significant drop out rates, inconsistent blinding, and analysis that was often per protocol and not intention to treat. A helpful way to categorise and compare skin substitutes is to divide them into groups based on cellular (those products that contain cells) and acellular (those products that do not contain cells). An example of a cellular skin substitute would be a

product containing human cells such as fibroblasts or keratinocytes. Some examples of acellular skin substitutes would be products such as human acellular dermal matrix and bovine collagen dermal matrix where the cells have been removed and the support structure or matrix is left in place. For the systematic review,⁷ we found 10 RCTs¹⁴⁶⁻¹⁵⁵ on cellular products, 13 RCTs^{150,156-167} on acellular products, and 5 RCTs¹⁶⁸⁻¹⁷² on autologous skin graft products.

4.5.2 | Cellular skin substitutes

Recommendation 16: We suggest not using cellular skin substitute products as a routine adjunct therapy to standard of care for wound healing in patients with diabetes-related foot ulcers (Conditional; Low).

Rationale: Although evidence from 10 RCTs¹⁴⁶⁻¹⁵⁵ suggest that cellular skin substitutes may improve healing and reduce the time to healing in patients with diabetes-related foot ulcers when provided in addition to standard of care, all studies were at high risk of bias due to non-blinding, had high dropout rates and per-protocol analyses. Moreover, there is insufficient evidence to establish which particular cellular skin substitutes may be more effective. There is, additionally, limited evidence to indicate that cellular skin substitutes are associated with a reduction in amputation rates. Minimal undesirable effects were reported with its use, and whilst the overall balance of effects are likely to favour the intervention, cellular skin substitutes are likely to require moderate costs/resources. Despite the certainty of evidence of resources being low with lack of formal cost effectiveness data, the moderate resources required meant that the group decided that cost effectiveness would not favour cellular skin substitutes over standard of care. This raises concerns for equity, and whilst likely acceptable for general use, feasibility is low due to the expertise and costs required in using these products.

4.5.3 | Acellular skin substitutes

Recommendation 17: We suggest not using acellular skin substitute products as a routine adjunct therapy to standard of care for wound healing in patients with diabetes-related foot ulcers (Conditional; Low).

Rationale: Based on the review of the 13 RCTs^{150,156-167} found on acellular skin substitutes, we concluded that these interventions may improve the incidence of healing and reduce the time to healing in patients with diabetes-related foot ulcers, when provided in addition to standard of care. However, all of the studies were considered at high risk of bias with the majority having no blinding as part of the protocol and only three^{158,160,166} being blinded for outcome assessment. Thus, any positive effects should be considered with caution. In addition, evidence to establish which, if any, particular acellular skin substitutes are superior is lacking, and there was insufficient

evidence on cost effectiveness of this modality. There is limited evidence to indicate that acellular skin substitutes are associated with a reduction in amputation rates, with only two studies, and conflicting results reporting on this outcome.^{156,159} Moreover, the lack of negative studies may suggest a degree of publication bias, and most studies were industry-sponsored. Thus, while there is some evidence that the balance of effects probably favours the intervention, the certainty of the evidence is low. Limited resource utilisation data were found, indicating moderate costs in a single health care setting, but it was agreed that these products do come with a significant cost and that this raises a concern for equity and availability, although limited data is available on cost effectiveness. The groups agreed that the products would be acceptable for general use, but feasibility is probably low due to expertise and costs required.

4.5.4 | Autologous skin graft skin substitutes

Recommendation 18: Do not use autologous skin graft skin substitute products as an adjunct therapy for wound healing in patients with diabetes-related foot ulcers (Strong; Low).

Rationale: We identified just 5 RCTs¹⁶⁸⁻¹⁷² with publication dates ranging from 2003 to 2021. All were at high risk of bias and thus the positive outcomes of two of them should be treated with caution. There is insufficient evidence to establish their effectiveness or cost utility. Overall, we considered that the balance of effects is not likely to favour autologous skin substitutes over standard of care. Although backed by limited evidence, the resources required come at moderate costs and thus cost effectiveness does not favour autologous skin substitutes over standard of care. Concerns are raised for equity and availability along with the additional challenge of autologous harvest from the patient. Whilst acceptable for general use, feasibility is probably low due to expertise and costs required.

4.6 | Clinical question 6: In people with diabetes-related foot ulcers, is the use of autologous and other cellular products including growth factors and placental-derived products more effective for wound healing compared to standard of care?

4.6.1 | Intervention: Autologous products

One possible treatment option for non-healing ulcers is the use of interventions, which either promotes the release of cytokines and growth factors involved in tissue repair, angiogenesis, and inflammation or directly donates these factors to the ulcer bed.

Thus, the use of autologous cells, including autologous platelets, which are fundamental to the co-ordination of normal wound healing has been investigated in a few trials. Most cells, including adipocytes derived stem cells and fibroblasts, require relatively invasive methods to extract the relevant cells from donor sites. Although only

requiring venepuncture, the difficulty of the volume of blood required to produce sufficient platelets has hampered their wider use, although the use of the leucocyte fibrin and platelet patch has largely overcome this.

Individual growth factors applied directly to the wound including platelet-derived growth factors (PDGF) (although this is only one of the many types of cytokines released by platelets) have also been trialed, although researchers have noted that individual growth factors alone may not be sufficient to ensure that the whole wound healing cascade of cytokines is enhanced.

Human placental membranes contain a combination of growth factors, collagen-rich extracellular matrix, and cells, including mesenchymal stem cells, neonatal fibroblasts, and epithelial cells, that provide mechanisms for coordinated wound healing. Several products derived from different components of the placenta and umbilical cord have been developed. Cryopreserved preparations contain living cells and growth factors, whereas dehydrated products, which are easier to store and handle, contain growth factors but no living cells.

We divided this group of interventions into autologous cells, human/recombinant growth factors, and human placental-derived products.

Of the autologous cells, there were a number of studies utilising platelets in various formulations, but with the exception of the autologous leucocyte, fibrin, and platelet patch, the evidence to support the use of any other formulation of platelets or other autologous cells as detailed in our systematic review⁷ was limited. For this reason, we have considered this intervention separately but grouped platelets together as the evidence to support any particular formulation of this intervention was less certain.

Similarly, we have considered other autologous cells, growth factors, and placental-derived products as separate groups of interventions.

4.6.2 | Autologous platelets—With exception of the autologous leucocyte and platelet patch

Recommendation 19: With the exception of the autologous leucocyte, platelet, and fibrin patch, we suggest not using autologous platelets therapy (including blood bank derived platelets) as an adjunct therapy to standard of care (Conditional; Low).

Rationale: We included 15 RCTs¹⁷³⁻¹⁸⁷ on the use of platelet products for the management of diabetes-related foot ulcers. The majority of studies investigated the use of platelet gel, with the inherent problem of requiring moderate amounts of autologous venous blood to generate the product.

Of the studies looking at complete wound healing, all were at risk of bias with only one of a platelet gel being outcome blinded,¹⁷⁴ however, the positive outcome in this study was of low certainty with per protocol analysis only. The problem of autologous blood volumes was overcome in one study using a blood bank of platelets,¹⁷⁹ but the

apparent superior outcome of healing was marred by non-blinded outcomes' assessment and was considered at high risk of bias. A number of these studies also assessed percentage wound area reduction as well as absolute wound healing, but all were at high risk of bias or did not report a difference between groups. Only one study reported an apparent benefit in terms of amputation, but the evidence was of low certainty.¹⁷⁶ The only study reporting resource use¹⁸² was limited by including hospitalised patients only.

The different timescales to the outcomes chosen made comparison of different interventions difficult to establish.

Although there were 15 included RCTs, the studies were at high risk of bias overall, with only one being outcome blinded and one with patient- but not outcome-blinded. Those at the lowest risk of bias demonstrated the lowest improvement in healing outcomes casting doubt on the size of the effect seen in the majority of the studies. On this basis, we evaluated the size of the potential positive effect as small although the certainty of this was very low. Few studies published adverse effects but expert opinion suggested that undesirable effects would be small. Overall, it was felt that it would be difficult to be certain that in clinical practice a positive effect on healing would be seen consistently above what would be expected with good standard of care. The costs of these interventions was thought to be moderately high, although no formal cost effectiveness analyses were found. Thus, it was felt that the use of these interventions would decrease equity, given the costs involved and the need for venous samples to be taken for the autologous platelet gel products; and hence feasibility would be reduced in some lower income countries. Where resources existed in healthcare systems, their use might, however, be feasible and acceptable to patients.

Overall weighing up the lack of certainty around the effectiveness of these interventions, the resource use, and the possible lack of feasibility in most healthcare systems, we felt we could not recommend these interventions as an adjunctive therapy to good standard of care.

4.6.3 | Leucocyte, fibrin, and platelet patch

Recommendation 20: Consider the use of autologous leucocyte, platelet, and fibrin patch for diabetes-related foot ulcers as an adjunctive therapy to standard of care, where best standard of care alone has been ineffective and where the resources and expertise exist for the regular venepuncture required (Conditional; Moderate).

Rationale: One high-quality multicentre outcome blinded RCT¹⁸⁸ at low risk of bias was identified which showed significant improvements in healing, time to healing, and wound area reduction at 20 and 26 weeks after weekly treatment with the intervention in patients with hard to heal ulcers when used in addition to best standard of care. Participants in the intervention arm had weekly visits for venesection to produce the patch. No differences were seen in the outcomes of new infection, major or minor amputations, or mortality. Although 18–36 mL of venous blood was required weekly to create

the patch at the bedside, no increase in the incidence of new anaemia was found and there were no other additional reported undesirable effects. For these reasons, it was felt that there was a favourable balance of effects in favour of the intervention but the findings of a single study suggested that the certainty of this was moderate at best. We found no formal published cost effectiveness data even though it was recognised that the weekly venepuncture would incur costs and that in some healthcare systems, the expertise for this may not be readily available. If confirmed, these could have a negative effect on equity and feasibility in some healthcare systems. However, where such a resource exists, it was felt that the use of this intervention would be acceptable to patients. Hence, we concluded that the use of autologous leucocytes, platelets, and fibrin patches could be conditionally recommended for hard to heal ulcers in addition to best standard of care where the best standard of care including offloading (where appropriate) had not healed the ulcer. Nevertheless, we recognise that this may not be feasible where expertise and resources for regular venepuncture are not available.

4.6.4 | Other cell therapies

This group of interventions included other cell therapies for the promotion of healing of diabetes-related foot ulcers, including adipocytes,^{189–193} fibroblasts,¹⁹⁴ keratinocytes,^{195,196} bone marrow-derived stem cells,¹⁹⁷ allogeneic bone marrow mesenchymal stromal cells (allohBM MSC), and cultured allogeneic bone marrow mesenchymal stromal cells derivatives (cultured allohBM MSCs).¹⁹⁸

Recommendation 21: We suggest not using other cell therapy as an adjunct therapy to standard of care for wound healing in people with diabetes-related foot ulcers (Conditional; Low).

Rationale: In total, 10 studies were identified. These included studies investigating autologous adipocytes,^{189–193} fibroblasts,¹⁹⁴ keratinocytes,^{195,196} bone marrow-derived stem cells,¹⁹⁷ allogeneic bone marrow mesenchymal stromal cells (allohBM MSC), and allogeneic bone marrow mesenchymal stromal cells derivatives (cultured allohBM MSCs).¹⁹⁸

Of the adipocyte or adipocyte stem cell studies which reported complete healing, only two were outcome-blinded. There was heterogeneity of outcomes with some studies showing no improvement in healing, and those reporting positive benefit being at high risk of bias. Similarly, the single studies of autologous fibroblast or keratinocytes were assessed at being high risk of bias, neither being blinded. The single study of the use of periwound autologous bone marrow stem cells in patients with critical limb ischaemia was outcome blind but there was a high loss to follow-up with a per-protocol analysis only presented. A second study of allogeneic bone marrow mesenchymal stromal cells (allohBM MSC) and allogeneic bone marrow mesenchymal stromal cell derivatives (cultured allohBM MSCs) was at high risk of bias and consequently no clear conclusions could be drawn.

Only one study at moderate risk of bias¹⁹⁷ reported major amputation at 12 weeks noting no difference between the groups. Only one described resource utilisation¹⁹² but this was, however, not a full health economic analysis and the trial was considered at high risk of bias.

Overall, the evidence to support improved wound healing, wound area reduction, or time to healing for the use of cultured keratinocytes, fibroblasts, adipocytes, either as fat grafting or following liposyrates and bone marrow derived cells is currently poor, with most studies being at moderate to high risk of bias.

The available evidence as described suggested moderate beneficial effects on healing, although the confidence in this was low. Few studies published adverse effects or serious adverse effects but expert opinion suggested that undesirable effects could be present. The one study which published quality of life suggested that there was little improvement. Overall, it was felt that the balance of effects may favour the intervention but this was based on limited studies with high risk of bias. The resource use involved in these interventions was thought to be high as they required access to cell culture and the ability to harvest the cells from patients. Thus, this would decrease equity and feasibility, particularly in healthcare systems in low-income countries.

Overall, weighing up the lack of certainty around the effectiveness of these interventions and the costs and possible lack of feasibility in some healthcare systems, we felt we could not recommend these interventions as an adjunctive therapy to good standard of care.

4.6.5 | Growth factors

Within this category we included PDGF, granulocyte stimulating factor (GCSF), epidermal growth factor (EGF), fibroblast growth factor (FGF), and studies of combined growth factors.

Recommendation 22: We suggest not using growth factor therapy as an adjunct therapy to standard of care for wound healing in people with diabetes-related foot ulcers (Conditional; Low).

Rationale: We identified seven studies^{199–205} investigating the use of PDGF. Only two of the studies were double blind^{200,202} and only one of which was considered to be at low risk of bias and this, like one of the other large studies,²⁰² showed no difference in healing between the two groups. An earlier large trial did show a difference in healing and time to healing²⁰⁴ but was at moderate risk of bias, thus reducing confidence in the result. The other studies reporting a positive outcome for those treated with the intervention were considered at high risk of bias, thus any positive results should be treated with caution.

None of the studies reported on the outcomes of sustained healing, amputation, resource utilisation, maintenance of function, or mortality and, therefore, the evidence to support the use of PDGF was poor with the majority of studies being assessed as being at high risk of bias.

Three studies were identified investigating the use of GCSF.^{206–208} None of the studies showed benefit in terms of wound healing, amputation, or any other of our outcomes of importance; however, the studies identified were mainly aimed at the treatment of infection.

We identified four studies investigating the use of EGF^{209–212} which reported wound healing of diabetes-related foot ulcers at 6 and 12 weeks. With the exception of one study,²¹¹ which investigated topical EGFR spray, all were at high risk of bias. The single low risk of bias study reported improved healing at 12 weeks, although the effect size was only moderate.

Two studies investigating FGF^{213,214} also reported healing in double-blinded RCTs. The small size of one study and the high risk of bias in the other mean that the positive results reported should be treated with caution.

A single study²¹⁵ investigated a combination of growth factors (EGF, & FGF) but was judged to be at high risk of bias. It also showed no difference in time to healing between the four groups.

No studies of any GFs were reported on the outcomes of sustained healing, amputation, quality of life, new infection, resource utilisation, or mortality.

Few studies of any of the growth factors published adverse effects but expert opinion suggested that these would be small. Overall, it was felt that the balance of effects was therefore not in favour of the intervention for PDGF or GCSF and possibly in favour of EGF although this was based on very low certainty evidence. Resource use was thought to be moderate for all growth factors although formal cost effectiveness data was not found. Thus, although feasible, equity would likely be reduced especially in lower income countries where resource use may be limited.

On balance, it was felt that the lack of certainty of effectiveness of these interventions and the costs and possible lack of feasibility in some healthcare systems, we felt we could not recommend these interventions as an adjunctive therapy to good standard of care.

4.6.6 | Placental-derived products

Recommendation 23: Consider the use of placental-derived products as an adjunct therapy to standard of care for wound healing in people with diabetes-related foot ulcers where standard of care alone has failed (Conditional; Low).

Rationale: We identified 10 studies of placental-derived products.^{153,203,216–223} Of these, one described the use of dehydrated amnion/chorion graft,²²¹ seven used dehydrated human amniotic membrane (dHAM),^{153,203,216,218,219,222,223} one the use of cryopreserved placental membrane,²¹⁷ and one the use of dehydrated human umbilical cord.²²⁰

All of the studies described absolute wound healing at time points between 4 and 20 weeks; however, only three studies were assessed as being at low risk of bias,^{219,220,223} and only one,²²³ a small pilot/feasibility study was double blinded. All suggested

improved healing and time to healing. Reports of percentage area reduction in five studies^{203,216,217,221,223} suggested improvements in favour of the intervention, although two of these studies were at high risk of bias and so the positive results should be treated with caution. New infection was reported to be similar in one study,²¹⁹ although no studies reported any effect on amputation.

Two papers reported the cost of the intervention per healed ulcer.^{219,220} In neither case was there any assessment of the cost of the control interventions; however, the mean cost per healed ulcer was over \$2000 for the dHAM and over \$3000 for the dehydrated umbilical cord product. Cost effectiveness data was only published in one post hoc analysis of a study otherwise judged at high risk of bias.²²⁴

There were no studies reporting quality of life or maintenance of function.

Although most of the studies were considered at high risk of bias, and none of the definitive studies were patient or care giver blind, those at low risk of bias suggest that the use of placental-derived products (and particularly of amniotic membrane) are associated with improved absolute healing at times up to 20 weeks and reduced time to healing. We found no evidence to suggest that there was an influence on new infections, and the short-term nature of the majority of studies and the lack of inclusion of patients with significant PAD means that we have no evidence of improvement in incidence of amputation. No formal cost effectiveness data were found but the resource use data suggest the interventions may be less expensive for some providers compared to other skin substitutes.

Overall, the group felt that the balance of effects was in favour of the intervention although the certainty of the evidence was low. Although formal cost effectiveness data was not available and resource use was noted to be lower than skin substitutes in one study, it was recognised that there would be moderate costs involved in their use. Thus it was felt that equity may be reduced in some healthcare systems particularly those of lower countries. However, where resources existed, it was felt that apart from cryopreserved products which would need storage and defrosting time, acceptability and feasibility would not be reduced in most settings.

4.7 | Clinical question 7: In people with diabetes-related foot ulcers, is the use of pharmacological interventions more effective for wound healing compared to best standard of care?

4.7.1 | Intervention: Pharmacological interventions

This intervention is the systemic administration of naturally occurring or pharmacological agents prescribed to the person with diabetes-related foot ulcers in an attempt to improve wound healing outcomes. These agents may consist of 'over-the-counter' (e.g. vitamins and minerals) or physician only prescribed agents, including traditional Chinese herbal medicines. We included 18 full papers

describing randomised trials of pharmacological interventions promoting wound healing.

4.7.2 | Agents promoting perfusion and angiogenesis

Recommendation 24: Do not use pharmacological agents promoting perfusion and angiogenesis to improve wound healing outcomes over standard of care (Strong; Low).

Rationale: We found nine studies²²⁵⁻²³³ of agents promoting perfusion and angiogenesis. The studies comparing the use of pentoxifylline,²²⁵ resveratrol,²²⁶ low-dose erythropoietin (EPO),²²⁷ subcutaneous injection dalteparin,²²⁸ insulin plus sulodexide to insulin plus placebo,²²⁹ a two-herb traditional Chinese medicine formula,²³² and an intravenous native herbal extract, angipars,²³⁰ contained too few patients to be certain of the results, and only the latter performed an intention-to-treat analysis. Therefore, any apparent improvement in healing should be treated with caution. One study²³¹ investigating injections of a DNA derivative, polydeoxyribonucleotide, although double-blinded was considered to be at moderate risk of bias.²³³ A second study of polydeoxyribonucleotide was too small to show any difference between the two groups. Overall, the evidence suggests that certain pharmacological interventions that promote perfusion and angiogenesis may improve wound healing but the quality of evidence is low and findings should be interpreted with caution.

Of the studies identified, none provided cost effectiveness data.

Overall, the studies showed only small beneficial effects on wound healing, with trivial undesirable effects even though the level of certainty was very low. Overall, therefore, it was felt that the balance of effects suggested little difference between intervention or control. It is also likely that the intervention has a resource implication of moderate costs but with a lack of published data there was low certainty of the required resources. Due to the additional resources required to provide agents promoting perfusion and angiogenesis, equity is probably reduced, particularly in lower income regions, even though the intervention is probably acceptable to patients and would be feasible. Due to limited evidence, we cannot recommend agents promoting perfusion and angiogenesis over standard of care.

4.7.3 | Agents that supplement vitamins and trace elements

Recommendation 25: Do not use pharmacological agents that supplement vitamins and trace elements to improve wound healing outcomes over standard of care (Strong; Low).

Rationale: We identified four studies using systemic supplementation of vitamins and trace elements,²³⁴⁻²³⁷ all at moderate or high risk of bias. The interventions investigated were daily doses of Vitamins E and C (with platelet-rich plasma-fibrin glue),²³⁷ oral weekly doses

Vitamin D,²³⁴ a daily probiotic,²³⁵ and oral omega-3 fatty acids.²³⁶ Although the latter two studies were double blinded the outcome measure of absolute reductions in ulcer length and width, and the lack of detail of baseline ulcer characteristics and offloading means that the positive results reported should be treated with caution. We found no studies of these interventions reporting on outcomes of complete wound healing, time to healing, sustained healing, amputation, quality of life, maintenance of function and ability to perform activities of daily living, new infection, resource utilisation and mortality. The available evidence suggests that certain pharmacological interventions, that is, probiotic or omega-3 fatty acids supplementation, may promote reduction in ulcer area with no overall difference in complete healing; however, the quality of evidence is low and findings should be interpreted with caution.

The studies were at moderate or high risk of bias with no cost effectiveness data. The studies showed small desirable effects in regard to wound healing outcomes with trivial undesirable effects, but this was considered to be of low certainty of evidence. Overall, therefore the balance of effects was thought to favour neither the intervention nor control. It is likely that the intervention has a resource implication of moderate costs; however, the certainty of this was as no formal evaluation was found. From the limited data, it is uncertain as to whether the costs incurred would be offset by the small desirable effects. Due to the additional resources required to provide the vitamin and trace element supplementation, equity is probably reduced; particularly in lower income regions, however, the intervention is probably acceptable to patients and feasible. Due to limited evidence, we cannot recommend agents that supplement vitamins and trace elements over standard of care.

4.7.4 | Agents that stimulate red cell production or protein supplementation

Recommendation 26: Do not use pharmacological agents that stimulate red cell production or protein supplementation to improve wound healing outcomes over standard of care (Strong; Low).

Rationale: We identified one study of an agent that stimulates red cell production or protein supplementation that matched our pre-specified inclusion criteria.²³⁸ This study was considered at moderate risk of bias. There were no differences in wound healing outcomes when the whole group was considered, although there were small desirable effects on wound healing limited to those with a low albumin, with trivial undesirable effects. Overall, the balance of effects was felt to favour neither the intervention nor the control. It is likely that the intervention has a resource implication of moderate costs with low certainty of evidence of the required resources. From the limited data, it is uncertain as to whether the costs incurred would be offset by the small desirable effects in those with low albumin. Due to additional resources required to provide protein supplementation, equity is probably reduced; however, the intervention is probably acceptable to patients and feasible. Due to limited evidence, we

cannot recommend agents that stimulate red cell production or protein supplementation over standard of care.

4.7.5 | Other pharmacological agents

Recommendation 27: Do not use other pharmacological agents to improve wound healing outcomes over standard of care (Strong; Low).

Rationale: We identified four studies of other pharmacological agents,²³⁹⁻²⁴² all at moderate or high risk of bias. One study²⁴⁰ suggested that time to healing was lower with the use of fluconazole in wounds with invasive fungal infections. However, the certainty of these results was considered to be very low. The other study of a Chinese Herb preparation²³⁹ showed no difference in wound healing outcomes when compared to standard of care. One study designed to stimulate the release of bone marrow stem cells, which although at low risk of bias, was not powered to show a difference in healing.²⁴² The final study showed no difference in ulcer area reduction with use of nanocurcumin supplements compared to placebo.²⁴¹

Overall, the balance of effects was not thought to favour either the interventions or control. It is likely that the interventions have a resource implication of moderate costs with low certainty of evidence of the required resources. From the limited data, it is uncertain as to whether the costs incurred are offset by the small desirable effects. Due to the additional resources required to provide other pharmacological agents, equity is probably reduced; however, the interventions are probably acceptable to patients and feasible. Due to limited evidence, we cannot recommend other pharmacological agents over standard of care.

4.8 | Clinical question 8: In people with diabetes-related foot ulcers, is the use of negative pressure wound therapy more effective for wound healing when compared to standard of care?

4.8.1 | Intervention: Negative pressure wound therapy (NPWT)

Negative Pressure Wound Therapy (NPWT) involves the controlled application of sub-atmospheric pressure to a wound using a sealed wound dressing connected to a vacuum pump. The sub-atmospheric pressure may be applied continuously or intermittently. The mechanism of action for NPWT has been described to include macro- and micro-deformation of wound tissue, drainage of extracellular inflammatory fluids, and stabilisation of the wound environment.²⁴³

Recommendation 28: Consider the use of NPWT as an adjunct therapy to standard of care for the healing of postsurgical diabetes-related foot wounds (Conditional; Low).

Recommendation 28a: Do not use NPWT as an adjunct therapy to standard of care for the healing of non-surgically related diabetes foot ulcers (Strong; Low).

Rationale: We identified 19 studies which fulfilled our inclusion criteria.^{50,152,244–260} All studies were thought to be at moderate to high risk of bias.

Of all the studies, only three^{244,250,256} were undertaken in non-surgical wounds, two of which were in a mixed population comprising post-surgical and non-surgical wounds.^{244,256} The one study in entirely non-surgical wounds was at high risk of bias and reported per protocol analyses only; hence, the positive benefits reported should be treated with caution.²⁵⁰ The first study in a mixed population²⁵⁶ although at risk of bias, had blinded outcomes, but reported no difference in healing or time to healing between the two groups. The latter was a non-blinded study at high risk of bias.²⁴⁴ Hence, any evidence to support the use of NPWT in non-surgical wounds is of low certainty.

The remaining studies investigated the use of NPWT in post-operative wounds alone. Two studies thought to be of moderate risk of bias, reported positive benefit after partial foot amputation²⁵⁷ and beneficial effects in terms of healing,²⁵⁵ although these outcomes were not assessed blind. Another study at moderate risk of bias reported no difference in healing after soft tissue incision and drainage.²⁵⁸

Amputation was reported as an outcome in nine studies.^{244,246,247,249,254–258} Those at the lowest risk of bias noted no difference in amputation; however, the studies were of relatively short duration. Only one study at high risk of bias²⁴⁴ noted any improvement in quality of life; although this should be treated with caution. New infection was reported in five studies with no difference between the groups, although all were at moderate or high risk of bias.^{244,245,255,257,258}

Three studies documented resource utilisation as an outcome.^{259,261,262} The first two were post hoc analyses of previously reported studies^{255,257} and one only reported resource use.²⁵⁹ All three reported either lower resource use or better cost effectiveness than the comparator, although the certainty was thought to be low because of the use of post hoc analyses. We identified no studies that documented death/mortality as an outcome. NPWT may thus reduce the time to healing in postsurgical wounds when provided in addition to standard of care. For chronic ulcers, there is insufficient evidence to establish whether NPWT reduces time to healing when provided in addition to standard of care.

Thus, overall, the evidence behind the use of NPWT was of low certainty. There were moderate desirable effects that NPWT may reduce the time to healing in postsurgical wounds, but not in chronic wounds when provided in addition to standard of care. Our conclusions are consistent with the findings from previous guidelines, as no new good quality evidence has been published in the last 4 years. In regions where NPWT is a widely available and affordable modality, undesirable effects are considered small, and it is therefore likely that the use of NPWT will be favoured as an addition to high

standard of care. NPWT may require moderate to high costs, and in areas where NPWT is widely available, there may be cost effectiveness justifying its use. This is of low certainty though. NPWT was generally considered acceptable to most patients and clinicians. We acknowledge that this recommendation may reduce equity when considering the limited access to and financial burden of starting NPWT in regions where this modality is not already widely available.

4.9 | Clinical question 9: In people with diabetes-related foot ulcers, are education and lifestyle programmes compared to standard of care more effective for wound healing?

4.9.1 | Education and lifestyle programmes

Recommendation 29: We do not recommend any specific educational and lifestyle support programmes over standard of care to improve healing of diabetes-related foot ulcers (Strong; Low).

Rationale: We found one RCT of educational and lifestyle support programmes that met our predefined inclusion criteria but was judged to be at high risk of bias.²⁶³ The evidence from this one study showed small desirable effects in regard to reduction in wound area. The certainty of the evidence is therefore low. The educational and lifestyle support programme would have incurred moderate costs but there was very low evidence of the resources required. From the limited data, it is uncertain as to whether the costs incurred are offset by the small desirable effects. Due to the additional resources required to deliver the educational and lifestyle programme, equity is probably reduced even though the programme is likely acceptable to patients and feasible to deliver. Due to an absence of evidence, we cannot recommend any specific educational and lifestyle support programmes over current standards of care, which should include ongoing advice on foot health. Further high-quality evidence for the impact of educational and lifestyle programmes are needed.

5 | FURTHER CONSIDERATIONS

This document represents the update of our 2019 recommendations on interventions designed to support healing of foot ulcers in people with diabetes.⁶ However, we have not simply updated the systematic review done in 2019 but completely re-reviewed the published literature, as our clinical questions and outcomes have changed after consultation with external experts and patients. We have, additionally, considered only RCTs for inclusion in our current systematic review.⁷ Thus some interventions previously supported have not been recommended in these guidelines, particularly where more recent studies have not shown the positive results seen in earlier controlled but non-randomised studies. Furthermore, we have used the full GRADE approach⁸ for the evidence analysis and development

of the recommendations, and this has led to a change in the certainty of evidence for several interventions.

The group decided to not undertake any meta-analyses, because for most groups of interventions, it was considered that heterogeneity of patients characteristics, follow-up, and clinical settings would be high. However, where high-quality meta-analyses were found, we took them into consideration in our discussions.

With this process, we have developed 29 recommendations based on our systematic review.⁷ The systematic review described a number of different interventions, which the expert clinical group divided into nine different overarching groups of interventions as described above. Given the change in the number of articles retrieved for some interventions and the lack of any new data from others, we have regrouped some of the intervention categories compared to our last guideline. In particular, surgical debridement of the wound has been regrouped with other debridement interventions, skin substitutes, and placenta-derived products were grouped together, albeit with separate recommendations, and we looked for the first time at educational and behavioural interventions which reported any of our outcomes of importance.

It is of note that since the last review, there has been a significant increase in research activity in this field with over 400 articles retrieved describing RCTs of our chosen interventions compared with just 284 controlled (but not necessarily randomised) studies from our previous systematic review.²⁶⁴ However, despite the number of RCTs being published, many are at high risk of bias and for many commonly used wound healing interventions there is a complete lack of RCTs at low risk of bias to guide healthcare practitioners as to the relevance of their use. In addition, it is still the case that many of the studies included types of ulcers that should heal with good standard of care alone¹ and that good standard of care was either not well described or not well implemented in many cases. It is also the case that in many healthcare systems, people with diabetes and ulcers of the feet are increasingly frail and may have multiple comorbidities,²⁶⁵ a patient cohort which is frequently excluded from clinical trials, and hence, for whom, even more uncertainty about treatment choices remains.

Due to the limitations in the available evidence, we were only able to conditionally recommend the use of six interventions or types of intervention. In some cases, we were unable to make a decision on a particular intervention within a group of interventions, either because comparative data were not available or because the patient cohorts differed or because we had little information on resource use for the majority of the interventions. Indeed, we were disappointed to see so few studies which looked within the trial at the resource use of interventions and so much of the information was based on post hoc modelling. It was also disappointing that it is still the case that the majority of trials are done outside countries or regions where healthcare resource is lacking, and therefore, it was difficult for the group to draw conclusions as to the feasibility and equity for many interventions. Thus, their applicability outside these settings, in particular, where there are limitations of human and financial resource, and where

climate, humidity, and the effect of other environmental issues on ulcer healing remains unknown.

6 | FUTURE RESEARCH AGENDA

Whilst writing this guideline based on our systematic review, we were encouraged to see that the number of RCTs had increased since we last reviewed this group of interventions. Nevertheless the quality of the trials remains poor, the majority being at moderate or high risk of bias, with outcomes poorly described, lack of blinding, or even any attempt to blind outcome assessors and frequently with sample sizes which were either not pre-defined or which were too small to lead to confidence in any positive results. We have repeatedly called for researchers and journal editors to be aware of the IWGDF/EWMA standards of reporting of trials of this type⁵ and make no apology for repeating this advice here.

Equally many of the studies reported included ulcers, which according to international and national audits should have healed anyway should best standard of care have been instituted early as described in the IWGDF practical guidelines.¹ That few studies adequately described best standard of care, including relevant off-loading, means that we can have little confidence of the ability of some interventions to provide not just effective, but cost effective improvements in outcome.

Information on undesirable effects (such as adverse events, quality of life, and costs), equity, acceptability, and feasibility is critical in clinical decision for any intervention. Using the GRADE methodology in these 2023 guidelines,⁸ we have paid more attention to these outcomes than previous versions of these guidelines. Few studies, however, reported these outcomes. As above, we urge future researchers to ensure all outcomes whether positive or negative are reported.

Costs and particularly cost-effectiveness have also received little attention in many studies. Whilst accepting that cost effectiveness in particular varies between healthcare systems and providers, the fact that costs are rarely reported is disappointing, given the cost pressures on healthcare systems throughout the world.

Inconsistency in timeframes for measuring critical outcomes also limited ability to perform meaningful comparisons between studies. A significant number of studies reported very short follow-up periods, whereas, yet others reported outcomes over timeframes as long as 12 months. Consensus on a minimum or recommended timeframe for outcome collection across wound healing or indeed other diabetes-related foot ulcer intervention studies will reduce heterogeneity between studies and may lead to better quality meta-analyses in the future.

Finally, we are aware that wound healing is a cascade of physiological processes and that wound healing interventions may not be appropriate in all phases of the wound healing cycle. Thus, more innovative approaches to trial design may be needed to ensure that a wound healing protocol is relevant to all stages of the process and that outcomes relevant to this are developed, agreed, and objectively measured.

AUTHOR CONTRIBUTIONS

The working group was chaired by FG (on behalf of the IWGDF). PC acted as scientific secretary. All members of the guideline were involved in summarising available evidence in the supporting systematic reviews that are published separately⁷ and in writing this guideline. All members were assigned to individual sections of the guideline, and all authors reviewed and discussed during group meetings the evidence obtained, the evidence to decision-making items according to GRADE and each recommendation (further details are available in the Methods section). All authors reviewed and agreed with the final document before external review and subsequent submission for endorsement. The list of authors and their contributions to the guideline is listed at the end of this document. All members of the working group undertook Level 1 GRADE training and both FG and PC additionally undertook Level 2 Guideline Methodology training (McMaster University).

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CONFLICT OF INTEREST STATEMENT

The IWGDF is committed to developing trustworthy clinical practice guidelines through transparency and full disclosure by those participating in the process of guideline development. In order to prevent a major conflict of interest (COI), members of the guideline were not allowed to serve as an officer, board member, trustee, owner, or employee of a company directly or indirectly involved in the topic of this guideline. At each working group, meeting members were asked to report on any new conflicts of interest in writing, and any conflicts were declared on a written COI form. These COIs included income received from biomedical companies, device manufacturers, pharmaceutical companies, or other companies producing products related to the field. In addition, industry relationships had to be disclosed each time and these included: ownership of stocks/options or bonds of a company; any consultancy, scientific advisory committee membership, or lecturer for a company, research grants, income from patents etc. These incomes could either be personal or

obtained by an institution with which the member had a relationship. Working group members were additionally requested to declare COI and refrain from the risk of bias scoring process or voting process for particular interventions if they had a professional working relationship with any of the co-authors on a particular paper. Production of the 2023 IWGDF Guidelines was supported by unrestricted grants from Advanced Oxygen Therapy Inc., Essity, Mölnlycke, Reaplix, and Urgo Medical. These sponsors did not have any communication related to the systematic reviews of the literature or related to the guidelines with working group members during the writing of the guidelines and have not seen any guideline or guideline-related document before publication. Full conflict of interest statements of all authors can be found online at www.iwgdguidelines.org.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

ETHICS STATEMENT

Not applicable.

ORCID

Pam Chen  <https://orcid.org/0000-0001-8082-5050>

Ketan Dhatariya  <https://orcid.org/0000-0003-3619-9579>

William Jeffcoate  <https://orcid.org/0000-0002-1744-7576>

Ralf Lobmann  <https://orcid.org/0000-0002-0537-0233>

Caroline McIntosh  <https://orcid.org/0000-0003-1801-9554>

Alberto Piaggini  <https://orcid.org/0000-0002-8704-561X>

John Steinberg  <https://orcid.org/0000-0003-3665-1481>

Prash Vas  <https://orcid.org/0000-0001-7448-2995>

Vijay Viswanathan  <https://orcid.org/0000-0001-9116-3937>

Fran Game  <https://orcid.org/0000-0002-5294-4789>

REFERENCES

- Schaper NC, Van Netten JJ, Apelqvist J, et al. Practical guidelines on the prevention and management of diabetes-related foot disease. *Diab Metab Res Rev*. 2023. <https://doi.org/10.1002/dmrr.3657>
- Rice JB, Desai U, Cummings AK, Birnbaum HG, Skornicki M, Parsons NB. Burden of diabetic foot ulcers for medicare and private insurers. *Diabetes Care*. 2014;37(3):651-658. <https://doi.org/10.2337/dc13-2176>
- Greenidge AR, Quimby KR, Rose AMC, et al. Direct healthcare services cost of non-healing diabetic foot wounds in an African origin population in Barbados. *Diabet Med*. 2022;39(6):e14773. <https://doi.org/10.1111/dme.14773>
- Jeffcoate W, Kerr M. The costs of foot disease in diabetes in resource poor countries. *Diabet Med*. 2022;39(9):e14900. <https://doi.org/10.1111/dme.14900>
- Jeffcoate WJ, Bus SA, Game FL, Hinchliffe RJ, Price PE, Schaper NC. Reporting standards of studies and papers on the prevention and management of foot ulcers in diabetes: required details and markers of good quality. *Lancet Diabetes Endocrinol*. 2016;4(9):781-788. [https://doi.org/10.1016/s2213-8587\(16\)30012-2](https://doi.org/10.1016/s2213-8587(16)30012-2)
- Rayman G, Vas P, Dhatariya K, et al. Guidelines on use of interventions to enhance healing of chronic foot ulcers in diabetes (IWGDF 2019 update). *Diabetes/Metabol Res Rev*. 2020;36(Suppl 1):e3283. <https://doi.org/10.1002/dmrr.3283>

7. Chen P, Vilorio NC, Dhataria K, et al. Effectiveness of interventions to enhance healing of chronic foot ulcers in diabetes: a systematic review. *Diabetes Metab Res Rev*. Forthcoming 2023.
8. Alonso-Coello P, Oxman AD, Moberg J, et al. GRADE Evidence to Decision (ETD) frameworks: a systematic and transparent approach to making well informed healthcare choices. 2: clinical practice guidelines. *BMJ*. 2016;353:i2089. <https://doi.org/10.1136/bmj.i2089>
9. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336(7650):924-926. <https://doi.org/10.1136/bmj.39489.470347.ad>
10. Bus SA, Van Netten JJ, Hinchliffe RJ, Apelqvist J, Lipsky BA, Schaper NC. Standards for the development and methodology of the 2019 international working group on the diabetic foot guidelines. *Diabetes Metab Res Rev*. 2020;36(Suppl 1):e3267. <https://doi.org/10.1002/dmrr.3267>
11. van Netten JJ, Bus SA, Apelqvist J, et al. Definitions and criteria for diabetic foot disease. *Diabetes Metab Res Rev*. 2020;36(Suppl 1):e3268.
12. Bus SA, Armstrong DG, Crews RT, et al. Guidelines on off-loading foot ulcers in persons with diabetes – IWGDF 2023 update. *Diabetes Metab Res Rev*. 2023. <https://doi.org/10.1002/dmrr.3647>
13. Fitridge R, Chuter VH, Mills JL, et al. The intersocietal IWGDF, ESVS, SVS guidelines on the diagnosis, prognosis and management of peripheral artery disease in patients with diabetes mellitus. *Diabetes Metab Res Rev*. 2023.
14. Senneville É, Albalawi Z, Van Asten SA, et al. Guidelines on the diagnosis and treatment of foot infection in persons with diabetes (IWGDF/IDSA 2023). *Diabetes Metab Res Rev*. Forthcoming 2023.
15. Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ ClinRes*. 2019;366:l4898. <https://doi.org/10.1136/bmj.l4898>
16. Jimenez JC, Agnew PS, Mayer P, et al. Enzymatic debridement of chronic nonischemic diabetic foot ulcers: results of a randomized, controlled trial. *Wounds*. 2017;29(5):133-139.
17. Motley TA, Caporusso JM, Lange DL, Eichelkraut RA, Cargill DI, Dickerson JE. Clinical outcomes for diabetic foot ulcers treated with clostridial collagenase ointment or with a product containing silver. *Adv Wound Care*. 2018;7(10):339-348. <https://doi.org/10.1089/wound.2018.0784>
18. Tallis A, Motley TA, Wunderlich RP, et al. Clinical and economic assessment of diabetic foot ulcer debridement with collagenase: results of a randomized controlled study. *Clin Therapeut*. 2013;35(11):1805-1820. <https://doi.org/10.1016/j.clinthera.2013.09.013>
19. Galperin RC, Lange DL, Ramsay SJ, et al. Anti-inflammatory effects of clostridial collagenase results from in vitro and clinical studies. *J Am Podiatric Med Assoc*. 2015;105(6):509-519. <https://doi.org/10.7547/14-066.1>
20. Lantis Li JC, Gordon I. Clostridial collagenase for the management of diabetic foot ulcers: results of four randomized controlled trials. *Wounds*. 2017;29(10):297-305. <https://doi.org/10.25270/wnds/2017.10.297305>
21. Lazaro-Martinez JL, Alvaro-Afonso FJ, Sevillano-Fernandez D, Garcia-alvarez Y, Sanz-Corbalan I, Garcia-Morales E. Cellular proliferation, dermal repair, and microbiological effectiveness of ultrasound-assisted wound debridement (UAW) versus standard wound treatment in complicated diabetic foot ulcers (DFU): an open-label randomized controlled trial. *J Clin Med*. 2020;9(12):1-13. <https://doi.org/10.3390/jcm9124032>
22. Amini S, ShojaeeFard A, Annabestani Z, et al. Low-frequency ultrasound debridement in patients with diabetic foot ulcers and osteomyelitis. *Wounds*. 2013;25(7):193-198.
23. Michailidis L, Bergin SM, Haines TP, Williams CM. Healing rates in diabetes-related foot ulcers using low frequency ultrasonic debridement versus non-surgical sharps debridement: a randomised controlled trial. *BMC Res Notes*. 2018;11(1):732. <https://doi.org/10.1186/s13104-018-3841-4>
24. Piaggese A, Schipani E, Campi F, et al. Conservative surgical approach versus non-surgical management for diabetic neuropathic foot ulcers: a randomized trial. *Diabet Med*. 1998;15(5):412-417. [https://doi.org/10.1002/\(sici\)1096-9136\(199805\)15:5<412::aid-dia584>3.0.co;2-1](https://doi.org/10.1002/(sici)1096-9136(199805)15:5<412::aid-dia584>3.0.co;2-1)
25. Nube VL, White JM, Brewer K, et al. A randomized trial comparing weekly with every second week sharp debridement in people with diabetes-related foot ulcers shows similar healing outcomes: potential benefit to resource utilization. *Diabetes Care*. 2021;44(12):e203-e205. <https://doi.org/10.2337/dc21-1454>
26. Nube VL, Alison JA, Twigg SM. Frequency of sharp wound debridement in the management of diabetes-related foot ulcers: exploring current practice. *J Foot Ankle Res*. 2021;14(1):52. <https://doi.org/10.1186/s13047-021-00489-1>
27. Jude EB, Apelqvist J, Spraul M, Martini J. Prospective randomized controlled study of hydrofiber dressing containing ionic silver or calcium alginate dressings in non-ischaemic diabetic foot ulcers. *Diabet Med*. 2007;24(3):280-288. <https://doi.org/10.1111/j.1464-5491.2007.02079.x>
28. Tsang KK, Kwong E-Y, To T-S, Chung J-Y, Wong T-S. A pilot randomized, controlled study of nanocrystalline silver, manuka honey, and conventional dressing in healing diabetic foot ulcer. *Evid Base Compl Altern Med*. 2017;2017:1-15. <https://doi.org/10.1155/2017/5294890>
29. Gotttrup F, Cullen BM, Karlsmark T, Bischoff-Mikkelsen M, Nisbet L, Gibson MC. Randomized controlled trial on collagen/oxidized regenerated cellulose/silver treatment. *Wound Repair Regen*. 2013;21(2):216-225. <https://doi.org/10.1111/wrr.12020>
30. Belcaro G, Cesarone MR, Errichi BM, et al. Venous and diabetic ulcerations: management with topical multivalent silver oxide ointment. *Panminerva Med*. 2010;52(2 Suppl 1):37-42.
31. Gwak HC, Han SH, Lee J, et al. Efficacy of a povidone-iodine foam dressing (betafoam) on diabetic foot ulcer. *Int Wound J*. 2020;17(1):91-99. <https://doi.org/10.1111/iwj.13236>
32. Jeffcoate WJ, Price PE, Phillips CJ, et al. Randomised controlled trial of the use of three dressing preparations in the management of chronic ulceration of the foot in diabetes. *Health Technol Assess*. 2009;13(54):1-86; iii-iv. <https://doi.org/10.3310/hta13540>
33. Apelqvist J, Ragnarson Tennvall G. Cavity foot ulcers in diabetic patients: a comparative study of cadexomer iodine ointment and standard treatment. An economic analysis alongside a clinical trial. *Acta Derm Venereol*. 1996;76(3):231-235.
34. Bal A, Jain SK, Jagannath, et al. Efficacy and safety of topical solution of diperoxochloric acid for neuropathic diabetic foot ulcer: results from a phase 3, multicentre, randomized, active-controlled, parallel-group study. *Int J Low Extrem Wounds*. 2022;15347346221076625. <https://doi.org/10.1177/15347346221076625>
35. Varga M, Sixta B, Bem R, Matia I, Jirkovska A, Adamec M. Application of gentamicin-collagen sponge shortened wound healing time after minor amputations in diabetic patients - a prospective, randomised trial. *Arch Med Sci*. 2014;10(2):283-287. <https://doi.org/10.5114/aoms.2014.42580>
36. Uckay I, Kressmann B, Di Tommaso S, et al. A randomized controlled trial of the safety and efficacy of a topical gentamicin-collagen sponge in diabetic patients with a mild foot ulcer infection. *SAGE Open Med*. 2018;6:205031211877395. <https://doi.org/10.1177/2050312118773950>
37. Yahia EA, El-Sharkawey AE, Bayoumi MM. Quantitative evaluation of diabetic foot wound healing using hydrogel composite nanosilver (agnps) - based dressing vs. traditional dressing: a prospective

- randomized control study. *Pak J Med Health Sci*. 2021;15(6):2043-2047. <https://doi.org/10.53350/pjmhs211562043>
38. Iacopi E, Abbruzzese L, Goretti C, Riitano N, Piaggese A. The use of a novel super-oxidized solution on top of standard treatment in the home care management of postsurgical lesions of the diabetic foot reduces reinfections and shortens healing time. *Int J Low Extrem Wounds*. 2018;17(4):268-274. <https://doi.org/10.1177/1534734618795593>
 39. Imran M, Hussain MB, Baig M. A randomized, controlled clinical trial of honey-impregnated dressing for treating diabetic foot ulcer. *J Coll Phys Surg Pakistan*. 2015;25(10):721-725.
 40. Siavash M, Shokri S, Haghighi S, Shahtalebi MA, Farajzadehgan Z. The efficacy of topical royal jelly on healing of diabetic foot ulcers: a double-blind placebo-controlled clinical trial. *Int Wound J*. 2015;12(2):137-142. <https://doi.org/10.1111/iwj.12063>
 41. Yakoot M, Abdelatif M, Helmy S. Efficacy of a new local limb salvage treatment for limb-threatening diabetic foot wounds - a randomized controlled study. *Diabetes Metab Syndrome Obes Targets Ther*. 2019;12:1659-1665. <https://doi.org/10.2147/dmsos.210680>
 42. Afkhamizadeh M, Aboutorabi R, Ravari H, et al. Topical propolis improves wound healing in patients with diabetic foot ulcer: a randomized controlled trial. *Nat Prod Res*. 2018;32(17):2096-2099. <https://doi.org/10.1080/14786419.2017.1363755>
 43. Mujica V, Orrego R, Fuentealba R, Leiva E, Zúñiga-Hernández J. Propolis as an adjuvant in the healing of human diabetic foot wounds receiving care in the diagnostic and treatment centre from the regional hospital of Talca. *J Diabetes Res*. 2019;2019:2507578. <https://doi.org/10.1155/2019/2507578>
 44. Djavid GE, Tabaie SM, Tajali SB, et al. Application of a collagen matrix dressing on a neuropathic diabetic foot ulcer: a randomised control trial. *J Wound Care*. 2020;29(Suppl 3):S13-S18. <https://doi.org/10.12968/jowc.2020.29.sup3.s13>
 45. Blume P, Driver VR, Tallis AJ, et al. Formulated collagen gel accelerates healing rate immediately after application in patients with diabetic neuropathic foot ulcers. *Wound Repair Regen*. 2011;19(3):302-308. <https://doi.org/10.1111/j.1524-475x.2011.00669.x>
 46. Donaghue VM, Chrzan JS, Rosenblum BI, Giurini JM, Habershaw GM, Veves A. Evaluation of a collagen-alginate wound dressing in the management of diabetic foot ulcers. *Adv Wound Care*. 1998;11(3):114-119.
 47. Veves A, Sheehan P, Pham HT. A randomized, controlled trial of Promogran (a collagen/oxidized regenerated cellulose dressing) vs standard treatment in the management of diabetic foot ulcers. *Arch Surg*. 2002;137(7):822-827. <https://doi.org/10.1001/archsurg.137.7.822>
 48. Park KH, Kwon JB, Park JH, Shin JC, Han SH, Lee JW. Collagen dressing in the treatment of diabetic foot ulcer: a prospective, randomized, placebo-controlled, single-center study. *Diabetes Res Clin Pract*. 2019;156:107861. <https://doi.org/10.1016/j.diabres.2019.107861>
 49. Stupin VA, Silina EV, Gorskiy VA, et al. Efficacy and safety of collagen biomaterial local application in complex treatment of the diabetic foot syndrome (final results of the multicenter randomised study). *Khirurgiia*. 2018(6):91-100. <https://doi.org/10.17116/hirurgia2018691-100>
 50. Zaitseva EL, Tokmakova AY, Shestakova MV, Galstyan GR, Doronina LP. The study of influence of different methods of local treatment on wound healing in patients with diabetic foot ulcers. *Vestn Ross Akad Med Nauk*. 2016;71(6):466-471.
 51. Lalau JD, Bresson R, Charpentier P, et al. Efficacy and tolerance of calcium alginate versus vaseline gauze dressings in the treatment of diabetic foot lesions. *Diabetes Metabol*. 2002;28(3):223-229.
 52. Tiwari S. Study to assess the efficacy of collagen dressing in diabetic foot ulcer patients. *Eur J Mol Clin Med*. 2022;9(3):10929-10935.
 53. Chitrabalam TG, Christopher PJ, Sundaraj J, Paladugu R, Selvamuthukumaran S. Comparison of efficacy of alginate filler dressings with conventional saline dressings for cavity wounds in diabetic foot ulcer - a prospective cohort study. *J Clin Diagn Res*. 2020;14(11):PC1-PC4. <https://doi.org/10.7860/jcdr/2020/46448.14221>
 54. Motzkau M, Tautenhahn J, Lehnert H, Lobmann R. Expression of matrix-metalloproteases in the fluid of chronic diabetic foot wounds treated with a protease absorbent dressing. *Exp Clin Endocrinol Diabetes*. 2011;119(5):286-290. <https://doi.org/10.1055/s-0030-1267235>
 55. Edmonds M, Lázaro-Martínez JL, Alfayate-García JM, et al. Sucrose octasulfate dressing versus control dressing in patients with neuroischaemic diabetic foot ulcers (explorer): an international, multicentre, double-blind, randomised, controlled trial. *Lancet Diabetes Endocrinol*. 2018;6(3):186-196. [https://doi.org/10.1016/s2213-8587\(17\)30438-2](https://doi.org/10.1016/s2213-8587(17)30438-2)
 56. Maunoury F, Oury A, Fortin S, Thomassin L, Bohbot S, Explorer S. Cost-effectiveness of TLC-NOSF dressings versus neutral dressings for the treatment of diabetic foot ulcers in France. *PLoS One*. 2021;16(1):e0245652. <https://doi.org/10.1371/journal.pone.0245652>
 57. National Institute for Health and Care Excellence. UrgoStart for Treating Diabetic Foot Ulcers and Leg Ulcers; 2019. Medical technologies guidance [MTG42]. Accessed February 28, 2023. <https://www.nice.org.uk/guidance/mtg42>
 58. Wen J, Jin X, Al Sayah F, Johnson JA, Paulden M, Ohinmaa A. Economic evaluation of sucrose octasulfate dressing for treatment of diabetic foot ulcers in patients with type 2 diabetes. *Can J Diabetes*. 2022;46(2):126-133. <https://doi.org/10.1016/j.cjcd.2021.07.001>
 59. Lobmann R, Augustin M, Lawall H, et al. Cost-effectiveness of TLC-sucrose octasulfate versus control dressings in the treatment of diabetic foot ulcers. *J Wound Care*. 2019;28(12):808-816. <https://doi.org/10.12968/jowc.2019.28.12.808>
 60. Ahmed A, Ahmed MI. A comparison of efficacy of topical use of phenytoin and vaseline gauze dressing with vaseline gauze dressing alone in healing of diabetic foot ulcers. *J Postgrad Med Inst*. 2014;28(3):297-302.
 61. Hajong R, Naku N, Hajong D, Anand M, Singh KL, Majumdar N. Effect of topical phenytoin on wound healing. *IOSR J Dent Med Sci*. 2016;15(9):161-164. <https://doi.org/10.9790/0853-150902161164>
 62. Jayalal JA, Kumar SJ, Thambithurai DD, Kadar JMA. Efficacy of topical phenytoin on healing in diabetic foot ulcer: a randomized control trial. *Int J Sci Study*. 2015;3(3):84-89.
 63. Kalyani R, Rajachidambaram K. Effect of local insulin vs topical phenytoin in diabetic foot ulcer. *Neuroquantology*. 2022;20(17):1870-1872.
 64. Motawea A, El-Gawad H, El-Gawad AH, Borg T, Motawea M, Tharshoby M. The impact of topical phenytoin loaded nanostructured lipid carriers in diabetic foot ulceration. *Foot*. 2019;40:14-21. <https://doi.org/10.1016/j.foot.2019.03.007>
 65. Nagaraj J, Subbiah V. The efficacy of local insulin vs topical phenytoin or normal saline in diabetic foot ulcer management: a prospective comparative study. *Cureus*. 2022;14(10):e30461. <https://doi.org/10.7759/cureus.30461>
 66. Prasad S, Prakash A, Patel S, Lunawat A, Mahore D. A comparative analysis of the efficacy of topical phenytoin with conventional wound dressing in healing of diabetic foot ulcers. *Int Surg J*. 2017;4(4):1389-1393. <https://doi.org/10.18203/2349-2902.isj20171148>
 67. Soundarapandian R, Srikanth R, Udhayasankar V. Role of topical phenytoin in diabetic foot ulcer care - a randomized control trial. *J Evol Med Dent Sci*. 2017;6(4):264-268.

68. Sudhir S, Ganashree MH, Naik D, Dilip DK. To compare the efficacy of topical phenytoin over conventional wound care (5% povidone-iodine) in diabetic ulcer. *Int J Surg Sci*. 2020;4(1):122-128. <https://doi.org/10.33545/surgery.2020.v4.i1b.320>
69. Pai MR, Sitaraman N, Kotian MS. Topical phenytoin in diabetic ulcers: a double blind controlled trial. *Indian J Med Sci*. 2001;55(11):593-599.
70. Patil V, Patil R, Kariholu PL, Patil LS, Shahapur P. Topical phenytoin application in grade i and ii diabetic foot ulcers: a prospective study. *J Clin Diagn Res*. 2013;7(10):2238-2240.
71. Shaw J, Hughes CM, Lagan KM, Stevenson MR, Irwin CR, Bell PM. The effect of topical phenytoin on healing in diabetic foot ulcers: a randomized controlled trial. *Diabet Med*. 2011;28(10):1154-1157. <https://doi.org/10.1111/j.1464-5491.2011.03309.x>
72. Fallah Huseini H, Yaghoobi M, Fallahi F, et al. Topical administration of technetium polium on diabetic foot ulcers accelerates healing: a placebo-controlled randomized clinical study. *Int J Low Extrem Wounds*. 2021;153473462110483. <https://doi.org/10.1177/15347346211048371>
73. Li FL, Deng H, Wang HW, et al. Effects of external application of Chinese medicine on diabetic ulcers and the expressions of beta-catenin, c-myc and K6. *Chin J Integr Med*. 2011;17(4):261-266. <https://doi.org/10.1007/s11655-011-0703-5>
74. Li S, Zhao J, Liu J, et al. Prospective randomized controlled study of a Chinese herbal medicine compound Tangzu Yuyang Ointment for chronic diabetic foot ulcers: a preliminary report. *J Ethnopharmacol*. 2011;133(2):543-550. <https://doi.org/10.1016/j.jep.2010.10.040>
75. Tonaco LAB, Gomes FL, Velasquez-Melendez G, Lopes MTP, Salas CE. The Proteolytic fraction from latex of *vasconcellea cundinamaricensis* (P1G10) enhances wound healing of diabetic foot ulcers: a double-blind randomized pilot study. *Adv Ther*. 2018;35(4):494-502. <https://doi.org/10.1007/s12325-018-0684-2>
76. Jacobs AM, Tomczak R. Evaluation of bensal HP for the treatment of diabetic foot ulcers. *Adv Skin Wound Care*. 2008;21(10):461-465. <https://doi.org/10.1097/01.asw.0000323573.57206.7b>
77. Aybar JNA, Mayor SO, Olea L, et al. Topical administration of lactiplantibacillus plantarum accelerates the healing of chronic diabetic foot ulcers through modifications of infection, angiogenesis, macrophage phenotype and neutrophil response. *Microorganisms*. 2022;10(3):14.
78. Viswanathan V, Kesavan R, Kavitha KV, Kumpatla S. A pilot study on the effects of a polyherbal formulation cream on diabetic foot ulcers. *Indian J Med Res*. 2011;134(2):168-173.
79. Chokpaisarn J, Chusri S, Voravuthikunchai SP. Clinical randomized trial of topical *Quercus infectoria* ethanolic extract for the treatment of chronic diabetic ulcers. *J Herb Med*. 2019;21:100301. <https://doi.org/10.1016/j.hermed.2019.100301>
80. Verdu-Soriano J, de Cristino-Espinar M, Luna-Morales S, et al. Superiority of a novel multifunctional amorphous hydrogel containing olea europaea leaf extract (EHO-85) for the treatment of skin ulcers: a randomized, active-controlled clinical trial. *J Clin Med*. 2022;11(5):19.
81. Chen CY, Wu RW, Hsu MC, Hsieh CJ, Chou MC. Adjunctive hyperbaric oxygen therapy for healing of chronic diabetic foot ulcers: a randomized controlled trial. *J Wound, Ostomy, Cont Nurs*. 2017;44(6):536-545. <https://doi.org/10.1097/won.0000000000000374>
82. Duzgun AP, Satir HZ, Ozozan O, Saylam B, Kulah B, Coskun F. Effect of hyperbaric oxygen therapy on healing of diabetic foot ulcers. *J Foot Ankle Surg*. 2008;47(6):515-519. <https://doi.org/10.1053/j.jfas.2008.08.002>
83. Nik Hisamuddin NAR, Wan Mohd Zahiruddin WN, Mohd Yazid B, Rahmah S. Use of hyperbaric oxygen therapy (HBOT) in chronic diabetic wound - a randomised trial. *Med J Malaysia*. 2019;74(5):418-424.
84. Semadi NI. The role of VEGF and TNF-alpha on epithelialization of diabetic foot ulcers after hyperbaric oxygen therapy. *Open Access Macedonian J Med Sci*. 2019;7(19):3177-3183. <https://doi.org/10.3889/oamjms.2019.297>
85. Salama SE, Eldeeb AE, Elbarbary AH, Abdelghany SE. Adjuvant hyperbaric oxygen therapy enhances healing of nonischemic diabetic foot ulcers compared with standard wound care alone. *Int J Low Extrem Wounds*. 2019;18(1):75-80. <https://doi.org/10.1177/1534734619829939>
86. Kessler L, Bilbault P, Ortéga F, et al. Hyperbaric oxygenation accelerates the healing rate of nonischemic chronic diabetic foot ulcers: a prospective randomized study. *Diabetes Care*. 2003;26(8):2378-2382. <https://doi.org/10.2337/diacare.26.8.2378>
87. Fedorko L, Bowen JM, Jones W, et al. Hyperbaric oxygen therapy does not reduce indications for amputation in patients with diabetes with nonhealing ulcers of the lower limb: a prospective, double-blind, randomized controlled clinical trial. *Diabetes Care*. 2016;39(3):392-399. <https://doi.org/10.2337/dc15-2001>
88. Santema KTB, Stoekenbroek RM, Koelemay MJW, et al. Hyperbaric oxygen therapy in the treatment of ischemic lower-extremity ulcers in patients with diabetes: results of the DAMO2CLES multicenter randomized clinical trial. *Diabetes Care*. 2018;41(1):112-119. <https://doi.org/10.2337/dc17-0654>
89. Löndahl M, Katzman P, Nilsson A, Hammarlund C. Hyperbaric oxygen therapy facilitates healing of chronic foot ulcers in patients with diabetes. *Diabetes Care*. 2010;33(5):998-1003. <https://doi.org/10.2337/dc09-1754>
90. Löndahl M, Landin-Olsson M, Katzman P. Hyperbaric oxygen therapy improves health-related quality of life in patients with diabetes and chronic foot ulcer. *Diabet Med*. 2011;28(2):186-190. <https://doi.org/10.1111/j.1464-5491.2010.03185.x>
91. Abidia A, Laden G, Kuhan G, et al. The role of hyperbaric oxygen therapy in ischaemic diabetic lower extremity ulcers: a double-blind randomised-controlled trial. *Eur J Vasc Endovasc Surg*. 2003;25(6):513-518. <https://doi.org/10.1053/ejvs.2002.1911>
92. Li G, Hopkins RB, Levine MAH, et al. Relationship between hyperbaric oxygen therapy and quality of life in participants with chronic diabetic foot ulcers: data from a randomized controlled trial. *Acta Diabetol* 2017;54(9):823-831. <https://doi.org/10.1007/s00592-017-1012-z>
93. Li N, Meng XE, Guo DZ, Fan DF, Pan SY. Wound healing process and related laboratory indexes in patients with type 2 diabetes mellitus after hyperbaric oxygen intervention. *Biomed Res*. 2017;28(20):8838-8843.
94. Ma L, Li P, Shi Z, Hou T, Chen X, Du J. A prospective, randomized, controlled study of hyperbaric oxygen therapy: effects on healing and oxidative stress of ulcer tissue in patients with a diabetic foot ulcer. *Ostomy/Wound Manag*. 2013;59(3):18-24.
95. Dhamodharan U, Karan A, Sireesh D, et al. Tissue-specific role of Nrf2 in the treatment of diabetic foot ulcers during hyperbaric oxygen therapy. *Free Radic Biol Med*. 2019;138:53-62. <https://doi.org/10.1016/j.freeradbiomed.2019.04.031>
96. Perren S, Gatt A, Papanas N, Formosa C. Hyperbaric oxygen therapy in ischaemic foot ulcers in type 2 diabetes: a clinical trial. *Open Cardiovasc Med J*. 2018;12(1):80-85. <https://doi.org/10.2174/1874192401812010080>
97. Doctor N, Pandya S, Supe A. Hyperbaric oxygen therapy in diabetic foot. *J Postgrad Med*. 1992;38(3):112-114.
98. Faglia E, Favales F, Aldeghi A, et al. Adjunctive systemic hyperbaric oxygen therapy in treatment of severe prevalently ischemic diabetic foot ulcer. A randomized study. *Diabetes Care*. 1996;19(12):1338-1343. <https://doi.org/10.2337/diacare.19.12.1338>

99. Frykberg RG. Topical wound oxygen therapy in the treatment of chronic diabetic foot ulcers. *Medicina*. 2021;57(9):917. <https://doi.org/10.3390/medicina57090917>
100. Frykberg RG, Franks PJ, Edmonds M, et al. A multinational, multicenter, randomized, double-blinded, placebo-controlled trial to evaluate the efficacy of cyclical topical wound oxygen (TWO2) therapy in the treatment of chronic diabetic foot ulcers: the TWO2 study. *Diabetes Care*. 2020;43(3):616-624. <https://doi.org/10.2337/dc19-0476>
101. Serena TE, Bullock NM, Cole W, et al. Topical oxygen therapy in the treatment of diabetic foot ulcers: a multicentre, open, randomised controlled clinical trial. *J Wound Care*. 2021;30(Suppl 5):S7-S14. <https://doi.org/10.12968/jowc.2021.30.sup5.s7>
104. Niederauer MQ, Michalek JE, Liu Q, Papas KK, Lavery LA, Armstrong DG. Continuous diffusion of oxygen improves diabetic foot ulcer healing when compared with a placebo control: a randomised, double-blind, multicentre study. *J Wound Care*. 2018;27(Suppl 9):S30-s45. <https://doi.org/10.12968/jowc.2018.27.sup9.s30>
105. Driver VR, Reyzelman A, Kawalec J, French M. A prospective, randomized, blinded, controlled trial comparing transdermal continuous oxygen delivery to moist wound therapy for the treatment of diabetic foot ulcers. *Ostomy/Wound Manag*. 2017;63(4):12-28.
106. Yu J, Lu S, McLaren AM, Perry JA, Cross KM. Topical oxygen therapy results in complete wound healing in diabetic foot ulcers. *Wound Repair Regen*. 2016;24(6):1066-1072. <https://doi.org/10.1016/j.jvs.2016.08.017>
107. Anirudh V, Kamath DY, Ghosh S, et al. Topical controlled warm oxygen therapy delivered through a novel device (KADAM (TM)) to treat diabetic foot ulcers: a randomized controlled, open, pilot trial. *Indian J Surg*. 2021;83(S4):907-914. <https://doi.org/10.1007/s12262-021-03057-w>
108. Leslie CA, Sapico FL, Ginunas VJ, Adkins RH. Randomized controlled trial of topical hyperbaric oxygen for treatment of diabetic foot ulcers. *Diabetes Care*. 1988;11(2):111-115. <https://doi.org/10.2337/diacare.11.2.111>
102. Wang S, Pan LF, Gao L, Qin XY, Wang JN. Randomized research on the mechanism of local oxygen therapy promoting wound healing of diabetic foot based on RNA-seq technology. *Ann Palliat Med*. 2021;10(2):973-983. <https://doi.org/10.21037/apm-20-295>
109. Zhang J, Guan M, Xie C, Luo X, Zhang Q, Xue Y. Increased growth factors play a role in wound healing promoted by noninvasive oxygen-ozone therapy in diabetic patients with foot ulcers. *Oxid Med Cell Longev*. 2014;2014:273475. <https://doi.org/10.1155/2014/273475>
103. He S, Liang C, Yi C, Wu M. Therapeutic effect of continuous diffusion of oxygen therapy combined with traditional moist wound dressing therapy in the treatment of diabetic foot ulcers. *Diabetes Res Clin Pract*. 2021;174:108743. <https://doi.org/10.1016/j.diabres.2021.108743>
110. Edmonds ME, Bodansky HJ, Boulton AJM, et al. Multicenter, randomized controlled, observer-blinded study of a nitric oxide generating treatment in foot ulcers of patients with diabetes-ProNOx1 study. *Wound Repair Regen*. 2018;26(2):228-237. <https://doi.org/10.1111/wrr.12630>
111. Wainstein J, Feldbrin Z, Boaz M, Harman-Boehm I. Efficacy of ozone-oxygen therapy for the treatment of diabetic foot ulcers. *Diabetes Technol Ther*. 2011;13(12):1255-1260. <https://doi.org/10.1089/dia.2011.0018>
112. Izadi M, Kheirjou R, Mohammadpour R, et al. Efficacy of comprehensive ozone therapy in diabetic foot ulcer healing. *Diabetes Metabol Syndr*. 2019;13(1):822-825. <https://doi.org/10.1016/j.dsx.2018.11.060>
113. Martinez-Sanchez G, Al-Dalain SM, Menendez S, et al. Therapeutic efficacy of ozone in patients with diabetic foot. *Eur J Pharmacol*. 2005;523(1-3):151-161. <https://doi.org/10.1016/j.ejphar.2005.08.020>
114. Mirpour S, Fathollah S, Mansouri P, et al. Cold atmospheric plasma as an effective method to treat diabetic foot ulcers: a randomized clinical trial. *Sci Rep*. 2020;10(1):10440. <https://doi.org/10.1038/s41598-020-67232-x>
115. Stratmann B, Costea TC, Nolte C, et al. Effect of cold atmospheric plasma therapy vs standard therapy placebo on wound healing in patients with diabetic foot ulcers: a randomized clinical trial. *JAMA Netw Open*. 2020;3(7):e2010411.
116. Macura M, Ban Frangez H, Cankar K, Finžgar M, Frangez I. The effect of transcutaneous application of gaseous CO(2) on diabetic chronic wound healing-a double-blind randomized clinical trial. *Int Wound J*. 2020;17(6):1607-1614. <https://doi.org/10.1111/iwj.13436>
117. Alvarez O, Patel M, Rogers R, Booker J. Effect of non-contact normothermic wound therapy on the healing of diabetic neuropathic foot ulcers. *J Tissue Viability*. 2006;16(1):8-11. [https://doi.org/10.1016/s0965-206x\(06\)61002-4](https://doi.org/10.1016/s0965-206x(06)61002-4)
118. Petrofsky JS, Lawson D, Berk L, Suh H. Enhanced healing of diabetic foot ulcers using local heat and electrical stimulation for 30 min three times per week. *J Diabetes*. 2010;2(1):41-46. <https://doi.org/10.1111/j.1753-0407.2009.00058.x>
119. McCulloch J, Knight CA. Noncontact normothermic wound therapy and offloading in the treatment of neuropathic foot ulcers in patients with diabetes. *Ostomy/Wound Manag*. 2002;48(3):38-44.
120. Rastogi A, Bhansali A, Ramachandran S. Efficacy and safety of low-frequency, noncontact airborne ultrasound therapy (glybetac) for neuropathic diabetic foot ulcers: a randomized, double-blind, sham-control study. *Int J Low Extrem Wounds*. 2019;18(1):81-88. <https://doi.org/10.1177/1534734619832738>
121. Ennis WJ, Foremann P, Mozen N, Massey J, Conner-Kerr T, Meneses P. Ultrasound therapy for recalcitrant diabetic foot ulcers: results of a randomized, double-blind, controlled, multicenter study. *Ostomy/Wound Manag*. 2005;51(8):24-39.
122. Armstrong DG, Nguyen HC. Oedema reduction by mechanical compression improved the healing of foot infection in patients with diabetes mellitus. *Evid Base Med*. 2001;6(4):122. <https://doi.org/10.1136/ebm.6.4.122>
123. Mars M, Desai Y, Gregory MA. Compressed air massage hastens healing of the diabetic foot. *Diabetes Technol Ther*. 2008;10(1):39-45. <https://doi.org/10.1089/dia.2007.0240>
124. Akbari A, Moodi H, Ghiasi F, Sagheb HM, Rashidi H. Effects of vacuum-compression therapy on healing of diabetic foot ulcers: randomized-controlled trial. *J Rehabil Res Dev*. 2007;44(5):631-636. <https://doi.org/10.1682/jrrd.2007.01.0002>
125. Peters EJ, Lavery LA, Armstrong DG, Fleischli JG. Electric stimulation as an adjunct to heal diabetic foot ulcers: a randomized clinical trial. *Arch Phys Med Rehabil*. 2001;82(6):721-725. <https://doi.org/10.1053/apmr.2001.23780>
126. Baker LL, Chambers R, DeMuth SK, Villar F. Effects of electrical stimulation on wound healing in patients with diabetic ulcers. *Diabetes Care*. 1997;20(3):405-412. <https://doi.org/10.2337/diacare.20.3.405>
127. Asadi MR, Torkaman G, Hedayati M, Mohajeri-Tehrani MR, Ahmadi M, Gohardani RF. Angiogenic effects of low-intensity cathodal direct current on ischemic diabetic foot ulcers: a randomized controlled trial. *Diabetes Res Clin Pract*. 2017;127:147-155. <https://doi.org/10.1016/j.diabres.2017.03.012>
128. Mohajeri-Tehrani MR, Nasiripoor F, Torkaman G, Hedayati M, Annabestani Z, Asadi MR. Effect of low-intensity direct current on expression of vascular endothelial growth factor and nitric oxide in diabetic foot ulcers. *J Rehabil Res Dev*. 2014;51(5):815-824. <https://doi.org/10.1682/jrrd.2013.08.0174>
129. Zulbaran-Rojas A, Park C, El-Refaei N, Lepow B, Najafi B. Home-based electrical stimulation to accelerate wound healing - a

- double-blinded randomized control trial. *J Diabetes Sci Technol*. 2021;17(1):15-24. <https://doi.org/10.1177/19322968211035128>
130. Kwan R-C, Wong WC, Yip SL, Chan KL, Zheng YP, Cheing G-Y. Pulsed electromagnetic field therapy promotes healing and microcirculation of chronic diabetic foot ulcers: a pilot study. *Adv Skin Wound Care*. 2015;28(5):212-219. <https://doi.org/10.1097/01.asw.0000462012.58911.53>
 131. Haze A, Gavish L, Elishoov O, et al. Treatment of diabetic foot ulcers in a frail population with severe co-morbidities using at-home photobiomodulation laser therapy: a double-blind, randomized, sham-controlled pilot clinical study. *Lasers Med Sci*. 2021;37(2):919-928. <https://doi.org/10.1007/s10103-021-03335-9>
 132. Kaviani A, Djavid GE, Ataie-Fashtami L, et al. A randomized clinical trial on the effect of low-level laser therapy on chronic diabetic foot wound healing: a preliminary report. *Photomed Laser Surg*. 2011;29(2):109-114. <https://doi.org/10.1089/pho.2009.2680>
 133. Landau Z, Migdal M, Lipovsky A, Lubart R. Visible light-induced healing of diabetic or venous foot ulcers: a placebo-controlled double-blind study. *Photomed Laser Surg*. 2011;29(6):399-404. <https://doi.org/10.1089/pho.2010.2858>
 134. Wade AN, Aref MHF, Nassar AA, Aboughaleb IH, Fahmy SM. The influence of low-intensity laser irradiation versus hyperbaric oxygen therapy on transcutaneous oxygen tension in chronic diabetic foot ulcers: a controlled randomized trial. *J Diabetes Metabolic Disord*. 2021;20(2):1489-1497. <https://doi.org/10.1007/s40200-021-00891-3>
 135. Srilestari A, Nareswari I, Simadibrata C, Tarigan TJE. Effectiveness of combined laser-puncture and conventional wound care to accelerate diabetic foot ulcer healing. *Med J Indones*. 2017;26(1):26-34. <https://doi.org/10.13181/mji.v26i1.1401>
 136. Mathur RK, Sahu K, Saraf S, Patheja P, Khan F, Gupta PK. Low-level laser therapy as an adjunct to conventional therapy in the treatment of diabetic foot ulcers. *Laser Med Sci*. 2017;32(2):275-282. <https://doi.org/10.1007/s10103-016-2109-2>
 137. Kajagar BM, Godhi AS, Pandit A, Khatri S. Efficacy of low level laser therapy on wound healing in patients with chronic diabetic foot ulcers-a randomised control trial. *Indian J Surg*. 2012;74(5):359-363. <https://doi.org/10.1007/s12262-011-0393-4>
 138. de Alencar Fonseca Santos J, Campelo MBD, de Oliveira RA, Nicolau RA, Rezende VEA, Arisawa E. Effects of low-power light therapy on the tissue repair process of chronic wounds in diabetic feet. *Photomed Laser Surg*. 2018;36(6):298-304. <https://doi.org/10.1089/pho.2018.4455>
 139. Moretti B, Notarnicola A, Maggio G, et al. The management of neuropathic ulcers of the foot in diabetes by shock wave therapy. *BMC Musculoskelet Disord*. 2009;10(1):54. <https://doi.org/10.1186/1471-2474-10-54>
 140. Snyder R, Galiano R, Mayer P, Rogers LC, Alvarez O. Diabetic foot ulcer treatment with focused shockwave therapy: two multicentre, prospective, controlled, double-blinded, randomised phase III clinical trials. *J Wound Care*. 2018;27(12):822-836. <https://doi.org/10.12968/jowc.2018.27.12.822>
 141. Omar MT, Alghadir A, Al-Wahhabi KK, Al-Askar AB. Efficacy of shock wave therapy on chronic diabetic foot ulcer: a single-blinded randomized controlled clinical trial. *Diabetes Res Clin Pract*. 2014;106(3):548-554. <https://doi.org/10.1016/j.diabres.2014.09.024>
 142. Jeppesen SM, Yderstraede KB, Rasmussen BS, Hanna M, Lund L. Extracorporeal shockwave therapy in the treatment of chronic diabetic foot ulcers: a prospective randomised trial. *J Wound Care*. 2016;25(11):641-649. <https://doi.org/10.12968/jowc.2016.25.11.641>
 143. Shaked G, Czeiger D, Abu Arar A, Katz T, Harman-Boehm I, Sebbag G. Intermittent cycles of remote ischemic preconditioning augment diabetic foot ulcer healing. *Wound Repair Regen*. 2015;23(2):191-196. <https://doi.org/10.1111/wrr.12269>
 144. Piaggese A, Sambataro M, Nicoletti C, Goretti C, Lacopi E, Coppelli A. Safety and effectiveness of therapeutic magnetic resonance in diabetic foot ulcers: a prospective randomised controlled trial. *J Wound Care*. 2016;25(12):704-711. <https://doi.org/10.12968/jowc.2016.25.12.704>
 145. Joseph LH, Paungmali A, Dixon J, Holey L, Naicker AS, Htwe O. Therapeutic effects of connective tissue manipulation on wound healing and bacterial colonization count among patients with diabetic foot ulcer. *J Bodyw Mov Ther*. 2016;20(3):650-656. <https://doi.org/10.1016/j.jbmt.2016.01.010>
 146. Edmonds M. Apligraf in the treatment of neuropathic diabetic foot ulcers. *Int J Low Extrem Wounds*. 2009;8(1):11-18. <https://doi.org/10.1177/1534734609331597>
 147. Gentzkow GD, Iwasaki SD, Hershon KS, et al. Use of dermagraft, a cultured human dermis, to treat diabetic foot ulcers. *Diabetes Care*. 1996;19(4):350-354. <https://doi.org/10.2337/diacare.19.4.350>
 148. Hanft JR, Surprenant MS. Healing of chronic foot ulcers in diabetic patients treated with a human fibroblast-derived dermis. *J Foot Ankle Surg*. 2002;41(5):291-299. [https://doi.org/10.1016/s1067-2516\(02\)80047-3](https://doi.org/10.1016/s1067-2516(02)80047-3)
 149. Marston WA, Hanft J, Norwood P, Pollak R. The efficacy and safety of dermagraft in improving the healing of chronic diabetic foot ulcers: results of a prospective randomized trial. *Diabetes Care*. 2003;26(6):1701-1705. <https://doi.org/10.2337/diacare.26.6.1701>
 150. Tchanque-Fossuo CN, Dahle SE, Lev-Tov H, et al. Cellular versus acellular matrix devices in the treatment of diabetic foot ulcers: interim results of a comparative efficacy randomized controlled trial. *J Tissue Eng Regen Med*. 2019;13(8):1430-1437. <https://doi.org/10.1002/term.2884>
 151. Veves A, Falanga V, Armstrong DG, Sabolinski ML. Graftskin, a human skin equivalent, is effective in the management of noninfected neuropathic diabetic foot ulcers: a prospective randomized multicenter clinical trial. *Diabetes Care*. 2001;24(2):290-295. <https://doi.org/10.2337/diacare.24.2.290>
 152. Binienko MA, Kotslova AA, Davydenko VV, Vlasov TD. Application of graftskin to accelerate healing of ulcers in diabetic foot syndrome. *Vestn Khirurgii Im I I Grekova*. 2016;175(5):63-68. <https://doi.org/10.24884/0042-4625-2016-175-5-63-68>
 153. Zelen CM, Gould L, Serena TE, Carter MJ, Keller J, Li WW. A prospective, randomised, controlled, multi-centre comparative effectiveness study of healing using dehydrated human amnion/chorion membrane allograft, bioengineered skin substitute or standard of care for treatment of chronic lower extremity diabetic ulcers. *Int Wound J*. 2015;12(6):724-732. <https://doi.org/10.1111/iwj.12395>
 154. Lipkin S, Chaikof E, Isseroff Z, Silverstein P. Effectiveness of bilayered cellular matrix in healing of neuropathic diabetic foot ulcers: results of a multicenter pilot trial. *Wounds*. 2003;15(7):230-236.
 155. Gould LJ, Orgill DP, Armstrong DG, et al. Improved healing of chronic diabetic foot wounds in a prospective randomised controlled multi-centre clinical trial with a microvascular tissue allograft. *Int Wound J*. 2022;19(4):811-825.
 156. Campitiello F, Mancone M, Della Corte A, Guerniero R, Canonico S. To evaluate the efficacy of an acellular flowable matrix in comparison with a wet dressing for the treatment of patients with diabetic foot ulcers: a randomized clinical trial. *Updat Surg*. 2017;69(4):523-529. <https://doi.org/10.1007/s13304-017-0461-9>
 157. Driver VR, Lavery LA, Reyzelman AM, et al. A clinical trial of Integra Template for diabetic foot ulcer treatment. *Wound Repair Regen*. 2015;23(6):891-900. <https://doi.org/10.1111/wrr.12357>
 158. Zelen CM, Orgill DP, Serena TE, et al. An aseptically processed, acellular, reticular, allogenic human dermis improves healing in

- diabetic foot ulcers: a prospective, randomised, controlled, multicentre follow-up trial. *Int Wound J*. 2018;15(5):731-739. <https://doi.org/10.1111/iwj.12920>
159. Lantis JC, Snyder R, Reyzelman AM, et al. Fetal bovine acellular dermal matrix for the closure of diabetic foot ulcers: a prospective randomised controlled trial. *J Wound Care*. 2021;30(Suppl 7):S18-s27. <https://doi.org/10.12968/jowc.2021.30.sup7.s18>
 160. Lullove EJ, Liden B, Winters C, McEaney P, Raphael A, Lantis Li JC. A multicenter, blinded, randomized controlled clinical trial evaluating the effect of omega-3-rich fish skin in the treatment of chronic, nonresponsive diabetic foot ulcers. *Wounds*. 2021;33(7):169-177. <https://doi.org/10.25270/wnds/2021.169177>
 161. Cetinkalp S, Gokce EH, Simsir I, et al. Comparative evaluation of clinical efficacy and safety of collagen laminin-based dermal matrix combined with resveratrol microparticles (Dermalix) and standard wound care for diabetic foot ulcers. *Int J Low Extrem Wounds*. 2021;20(3):217-226. <https://doi.org/10.1177/1534734620907773>
 162. Cazzell S, Vayser D, Pham H, et al. A randomized clinical trial of a human acellular dermal matrix demonstrated superior healing rates for chronic diabetic foot ulcers over conventional care and an active acellular dermal matrix comparator. *Wound Repair Regen*. 2017;25(3):483-497. <https://doi.org/10.1111/wrr.12551>
 163. Reyzelman A, Crews RT, Moore JC, et al. Clinical effectiveness of an acellular dermal regenerative tissue matrix compared to standard wound management in healing diabetic foot ulcers: a prospective, randomised, multicentre study. *Int Wound J*. 2009;6(3):196-208. <https://doi.org/10.1111/j.1742-481x.2009.00585.x>
 164. Brigido SA. The use of an acellular dermal regenerative tissue matrix in the treatment of lower extremity wounds: a prospective 16-week pilot study. *Int Wound J*. 2006;3(3):181-187. <https://doi.org/10.1111/j.1742-481x.2006.00209.x>
 165. Hahn HM, Lee DH, Lee IJ. Ready-to-use micronized human acellular dermal matrix to accelerate wound healing in diabetic foot ulcers: a prospective randomized pilot study. *Adv Skin Wound Care*. 2021;34(5):1-6. <https://doi.org/10.1097/01.asw.0000741512.57300.6d>
 166. Armstrong DG, Orgill DP, Galiano RD, et al. Use of a purified reconstituted bilayer matrix in the management of chronic diabetic foot ulcers improves patient outcomes vs standard of care: results of a prospective randomised controlled multi-centre clinical trial. *Int Wound J*. 2022;19(5):1197-1209.
 167. Montanaro M, Meloni M, Anemona L, et al. Macrophage activation and M2 polarization in wound bed of diabetic patients treated by dermal/epidermal substitute Nevelia. *Int J Low Extrem Wounds*. 2020.
 168. Armstrong DG, Orgill DP, Galiano R, et al. A multicentre, randomised controlled clinical trial evaluating the effects of a novel autologous, heterogeneous skin construct in the treatment of Wagner one diabetic foot ulcers: interim analysis. *Int Wound J*. 2022;19(1):64-75. <https://doi.org/10.1111/iwj.13598>
 169. Caravaggi C, De Giglio R, Pritelli C, et al. HYAFF 11-based autologous dermal and epidermal grafts in the treatment of noninfected diabetic plantar and dorsal foot ulcers: a prospective, multicenter, controlled, randomized clinical trial. *Diabetes Care*. 2003;26(10):2853-2859. <https://doi.org/10.2337/diacare.26.10.2853>
 170. Uccioli L, Giurato L, Ruotolo V, et al. Two-step autologous grafting using HYAFF scaffolds in treating difficult diabetic foot ulcers: results of a multicenter, randomized controlled clinical trial with long-term follow-up. *Int J Low Extrem Wounds*. 2011;10(2):80-85. <https://doi.org/10.1177/1534734611409371>
 171. Manning L, Ferreira IB, Gittings P, et al. Wound healing with "spray-on" autologous skin grafting (ReCell) compared with standard care in patients with large diabetes-related foot wounds: an open-label randomised controlled trial. *Int Wound J*. 2021;19(3):470-481. <https://doi.org/10.1111/iwj.13646>
 172. Armstrong DG, Galiano RD, Orgill DP, et al. Multi-centre prospective randomised controlled clinical trial to evaluate a bioactive split thickness skin allograft vs standard of care in the treatment of diabetic foot ulcers. *Int Wound J*. 2022;19(4):932-944. <https://doi.org/10.1111/iwj.13759>
 173. 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. <https://doi.org/10.1016/j.avsg.2016.04.023>
 174. Driver VR, Hanft J, Fylling CP, Beriyou JM. A prospective, randomized, controlled trial of autologous platelet-rich plasma gel for the treatment of diabetic foot ulcers. *Ostomy/Wound Manag*. 2006;52(6):68-70; 2, 4 passim.
 175. Elsaid A, El-Said M, Emile S, Youssef M, Khafagy W, Elshobaky A. Randomized controlled trial on autologous platelet-rich plasma versus saline dressing in treatment of non-healing diabetic foot ulcers. *World J Surg*. 2020;44(4):1294-1301. <https://doi.org/10.1007/s00268-019-05316-0>
 176. Gude W, Hagan D, Abood F, Clausen P. Aurix gel is an effective intervention for chronic diabetic foot ulcers: a pragmatic randomized controlled trial. *Adv Skin Wound Care*. 2019;32(9):416-426. <https://doi.org/10.1097/01.asw.0000577140.19174.9e>
 177. Gupta A, Channaveera C, Sethi S, Ranga S, Anand V. Efficacy of intralesional platelet-rich plasma in diabetic foot ulcer. *J Am Podiatric Med Assoc*. 2021;111(3). <https://doi.org/10.7547/19-149>
 178. Li L, Chen D, Wang C, et al. Autologous platelet-rich gel for treatment of diabetic chronic refractory cutaneous ulcers: a prospective, randomized clinical trial. *Wound Repair Regen*. 2015;23(4):495-505. <https://doi.org/10.1111/wrr.12294>
 179. Jeong SH, Han SK, Kim WK. Treatment of diabetic foot ulcers using a blood bank platelet concentrate. *Plastic Reconstr Surg*. 2010;125(3):944-952. <https://doi.org/10.1097/prs.0b013e3181cb6589>
 180. Singh SP, Kumar V, Pandey A, Pandey P, Gupta V, Verma R. Role of platelet-rich plasma in healing diabetic foot ulcers: a prospective study. *J Wound Care*. 2018;27(9):550-556. <https://doi.org/10.12968/jowc.2018.27.9.550>
 181. Steed DL, Goslen JB, Holloway GA, Malone JM, Bunt TJ, Webster MW. Randomized prospective double-blind trial in healing chronic diabetic foot ulcers. CT-102 activated platelet supernatant, topical versus placebo. *Diabetes Care*. 1992;15(11):1598-1604. <https://doi.org/10.2337/diacare.15.11.1598>
 182. Xie J, Fang Y, Zhao Y, Cao D, Lv Y. Autologous platelet-rich gel for the treatment of diabetic sinus tract wounds: a clinical study. *J Surg Res*. 2020;247:271-279. <https://doi.org/10.1016/j.jsr.2019.09.069>
 183. Alamdari NM, Sha A, Mirmohseni A, Besharat S. Evaluation of the efficacy of platelet-rich plasma on healing of clean diabetic foot ulcers: a randomized clinical trial in Tehran, Iran. *Diabetes Metabol Syndr*. 2021;15(2):621-626. <https://doi.org/10.1016/j.dsx.2021.03.005>
 184. Yang L, Gao L, Lv Y, Wang JN. Autologous platelet-rich gel for lower-extremity ischemic ulcers in patients with type 2 diabetes. *Int J Clin Exp Med*. 2017;10(9):13796-13801.
 185. Hosseini SE, Molavi B, Goodarzi A, et al. The efficacy of platelet gel derived from umbilical cord blood on diabetic foot ulcers: a double-blind randomized clinical trial. *Wound Med* 2020;28:100178. <https://doi.org/10.1016/j.wndm.2020.100178>
 186. Volpe P, Marcuccio D, Stilo G, et al. Efficacy of cord blood platelet gel application for enhancing diabetic foot ulcer healing after lower limb revascularization. *Semin Vasc Surg*. 2017;30(4):106-112. <https://doi.org/10.1053/j.semvascsurg.2017.12.001>
 187. Orban YA, Soliman MAE, Hegab YH, Alkilany MM. Autologous platelet-rich plasma vs conventional dressing in the management of chronic diabetic foot ulcers. *Wounds*. 2022;34(2):36-42. <https://doi.org/10.25270/wnds/2022.3642>
 188. Game F, Jeffcoate W, Tarnow L, et al. LeucoPatch system for the management of hard-to-heal diabetic foot ulcers in the UK,

- Denmark, and Sweden: an observer-masked, randomised controlled trial. *Lancet Diabetes Endocrinol.* 2018;6(11):870-878. [https://doi.org/10.1016/s2213-8587\(18\)30240-7](https://doi.org/10.1016/s2213-8587(18)30240-7)
189. Han SK, Kim HR, Kim WK. The treatment of diabetic foot ulcers with uncultured, processed lipoaspirate cells: a pilot study. *Wound Repair Regen.* 2010;18(4):342-348. <https://doi.org/10.1111/j.1524-475x.2010.00593.x>
 190. Lonardi R, Leone N, Gennai S, Borsari GT, Covic T, Silingardi R. Autologous micro-fragmented adipose tissue for the treatment of diabetic foot minor amputations: a randomized controlled single-center clinical trial (MiFrAADiF). *Stem Cell Res Ther.* 2019;10(1):223. <https://doi.org/10.1186/s13287-019-1328-4>
 191. Moon KC, Suh HS, Kim KB, et al. Potential of allogeneic adipose-derived stem cell-hydrogel complex for treating diabetic foot ulcers. *Diabetes.* 2019;68(4):837-846. <https://doi.org/10.2337/db18-0699>
 192. Smith OJ, Leigh R, Kanapathy M, et al. Fat grafting and platelet-rich plasma for the treatment of diabetic foot ulcers: a feasibility-randomised controlled trial. *Int Wound J.* 2020;17(6):1578-1594. <https://doi.org/10.1111/iwj.13433>
 193. Kesavan R, Sheela Sasikumar C, Narayanamurthy VB, Rajagopalan A, Kim J. Management of diabetic foot ulcer with MA-ECM (minimally manipulated autologous extracellular matrix) using 3D bio-printing technology - an innovative approach. *Int J Low Extrem Wounds.* 2021;153473462110456. <https://doi.org/10.1177/15347346211045625>
 194. You HJ, Han SK, Rhie JW. Randomised controlled clinical trial for autologous fibroblast-hyaluronic acid complex in treating diabetic foot ulcers. *J Wound Care.* 2014;23(11):521-522; 4, 6-30. <https://doi.org/10.12968/jowc.2014.23.11.521>
 195. You HJ, Han SK, Lee JW, Chang H. Treatment of diabetic foot ulcers using cultured allogeneic keratinocytes--a pilot study. *Wound Repair Regen.* 2012;20(4):491-499. <https://doi.org/10.1111/j.1524-475x.2012.00809.x>
 196. Bayram Y, Deveci M, Imirzalioglu N, Soysal Y, Sengezer M. The cell based dressing with living allogenic keratinocytes in the treatment of foot ulcers: a case study. *Br J Plast Surg.* 2005;58(7):988-996. <https://doi.org/10.1016/j.bjps.2005.04.031>
 197. Dubsy M, Husakova J, Bem R, et al. Comparison of the impact of autologous cell therapy and conservative standard treatment on tissue oxygen supply and course of the diabetic foot in patients with chronic limb-threatening ischemia: a randomized controlled trial. *Front Endocrinol.* 2022;13:10. <https://doi.org/10.3389/fendo.2022.888809>
 198. Arango-Rodríguez ML, Solarte-David VA, Becerra-Bayona SM, et al. Role of mesenchymal stromal cells derivatives in diabetic foot ulcers: a controlled randomized phase 1/2 clinical trial. *Cytotherapy.* 2022;24(10):1035-1048. <https://doi.org/10.1016/j.jcyt.2022.04.002>
 199. Landsman A, Agnew P, Parish L, Joseph R, Galiano RD. Diabetic foot ulcers treated with becaplermin and TheraGauze, a moisture-controlling smart dressing: a randomized, multicenter, prospective analysis. *J Am Podiatric Med Assoc.* 2010;100(3):155-160.
 200. Ma C, Hernandez MA, Kirkpatrick VE, Liang LJ, Nouvong AL, Gordon II. Topical platelet-derived growth factor vs placebo therapy of diabetic foot ulcers offloaded with windowed casts: a randomized, controlled trial. *Wounds.* 2015;27(4):83-91.
 201. Samuel A, Mahajan A, Mam MK, Prakash JS. Platelet derived growth factor in diabetic lower extremity ulcer: a randomized, double blind, placebo controlled study in Indian condition. *Int J Pharm Sci Res.* 2016;7(9):3887-3892.
 202. Smiell JM, Wieman TJ, Steed DL, Perry BH, Sampson AR, Schwab BH. Efficacy and safety of becaplermin (recombinant human platelet-derived growth factor-BB) in patients with nonhealing, lower extremity diabetic ulcers: a combined analysis of four randomized studies. *Wound Repair Regen.* 1999;7(5):335-346. <https://doi.org/10.1046/j.1524-475x.1999.00335.x>
 203. Tofigh AM, Tajik M. Comparing the standard surgical dressing with dehydrated amnion and platelet-derived growth factor dressings in the healing rate of diabetic foot ulcer: a randomized clinical trial. *Diabetes Res Clin Pract.* 2022;185:6.
 204. Wieman TJ, Smiell JM, Su Y. Efficacy and safety of a topical gel formulation of recombinant human platelet-derived growth factor-BB (becaplermin) in patients with chronic neuropathic diabetic ulcers. A phase III randomized placebo-controlled double-blind study. *Diabetes Care.* 1998;21(5):822-827. <https://doi.org/10.2337/diacare.21.5.822>
 205. Bhansali A, Venkatesh S, Dutta P, Dhillon MS, Das S, Agrawal A. Which is the better option: recombinant human PDGF-BB 0.01% gel or standard wound care, in diabetic neuropathic large plantar ulcers off-loaded by a customized contact cast? *Diabetes Res Clin Pract.* 2009;83(1):e13-e16.
 206. Gough A, Clapperton M, Rolando N, Foster AV, Philpott-Howard J, Edmonds ME. Randomised placebo-controlled trial of granulocyte-colony stimulating factor in diabetic foot infection. *Lancet.* 1997;350(9081):855-859. [https://doi.org/10.1016/s0140-6736\(97\)04495-4](https://doi.org/10.1016/s0140-6736(97)04495-4)
 207. de Lalla F, Pellizzer G, Strazzabosco M, et al. Randomized prospective controlled trial of recombinant granulocyte colony-stimulating factor as adjunctive therapy for limb-threatening diabetic foot infection. *Antimicrob Agents Chemother.* 2001;45(4):1094-1098. <https://doi.org/10.1128/aac.45.4.1094-1098.2001>
 208. Kästenbauer T, Hörnlein B, Sokol G, Irsigler K. Evaluation of granulocyte-colony stimulating factor (Filgrastim) in infected diabetic foot ulcers. *Diabetologia.* 2003;46(1):27-30. <https://doi.org/10.1007/s00125-002-0998-z>
 209. Gomez-Villa R, Aguilar-Rebolledo F, Lozano-Platonoff A, et al. Efficacy of intralesional recombinant human epidermal growth factor in diabetic foot ulcers in Mexican patients: a randomized double-blinded controlled trial. *Wound Repair Regen.* 2014;22(4):497-503. <https://doi.org/10.1111/wrr.12187>
 210. Hanft JR, Pollak RA, Barbul A, et al. Phase I trial on the safety of topical rhVEGF on chronic neuropathic diabetic foot ulcers. *J Wound Care.* 2008;17(1):30-32, 34-37.
 211. Park KH, Han SH, Hong JP, et al. Topical epidermal growth factor spray for the treatment of chronic diabetic foot ulcers: a phase III multicenter, double-blind, randomized, placebo-controlled trial. *Diabetes Res Clin Pract.* 2018;142:335-344. <https://doi.org/10.1016/j.diabres.2018.06.002>
 212. Tsang MW, Wong WK, Hung CS, et al. Human epidermal growth factor enhances healing of diabetic foot ulcers. *Diabetes Care.* 2003;26(6):1856-1861. <https://doi.org/10.2337/diacare.26.6.1856>
 213. Richard JL, Parer-Richard C, Daures JP, et al. Effect of topical basic fibroblast growth factor on the healing of chronic diabetic neuropathic ulcer of the foot. A pilot, randomized, double-blind, placebo-controlled study. *Diabetes Care.* 1995;18(1):64-69. <https://doi.org/10.2337/diacare.18.1.64>
 214. Uchi H, Igarashi A, Urabe K, et al. Clinical efficacy of basic fibroblast growth factor (bFGF) for diabetic ulcer. *Eur J Dermatol.* 2009;19(5):461-468. <https://doi.org/10.1684/ejd.2009.0750>
 215. Xu J, Min D, Guo G, Liao X, Fu Z. Experimental study of epidermal growth factor and acidic fibroblast growth factor in the treatment of diabetic foot wounds. *Exp Ther Med.* 2018;15(6):5365-5370. <https://doi.org/10.3892/etm.2018.6131>
 216. Zelen CM, Serena TE, Denoziere G, Fetterolf DE. A prospective randomised comparative parallel study of amniotic membrane wound graft in the management of diabetic foot ulcers. *Int Wound J.* 2013;10(5):502-507. <https://doi.org/10.1111/iwj.12097>
 217. Lavery LA, Fulmer J, Shebetka KA, et al. The efficacy and safety of Grafix® for the treatment of chronic diabetic foot ulcers: results

- of a multi-centre, controlled, randomised, blinded, clinical trial. *Int Wound J*. 2014;11(5):554-560. <https://doi.org/10.1111/iwj.12329>
218. Snyder RJ, Shimozaki K, Tallis A, et al. A Prospective, randomized, multicenter, controlled evaluation of the use of dehydrated amniotic membrane allograft compared to standard of care for the closure of chronic diabetic foot ulcer. *Wounds*. 2016;28(3):70-77.
 219. Tettelbach W, Cazzell S, Reyzelman AM, Sigal F, Caporusso JM, Agnew PS. A confirmatory study on the efficacy of dehydrated human amnion/chorion membrane dHACM allograft in the management of diabetic foot ulcers: a prospective, multicentre, randomised, controlled study of 110 patients from 14 wound clinics. *Int Wound J*. 2018;16(1):19-29. <https://doi.org/10.1111/iwj.12976>
 220. Tettelbach W, Cazzell S, Sigal F, et al. A multicentre prospective randomised controlled comparative parallel study of dehydrated human umbilical cord (EpiCord) allograft for the treatment of diabetic foot ulcers. *Int Wound J*. 2018;16(1):122-130. <https://doi.org/10.1111/iwj.13001>
 221. DiDomenico LA, Orgill DP, Galiano RD, et al. Use of an aseptically processed, dehydrated human amnion and chorion membrane improves likelihood and rate of healing in chronic diabetic foot ulcers: a prospective, randomised, multi-centre clinical trial in 80 patients. *Int Wound J*. 2018;15(6):950-957. <https://doi.org/10.1111/iwj.12954>
 222. Thompson P, Hanson DS, Langemo D, Anderson J. Comparing human amniotic allograft and standard wound care when using total contact casting in the treatment of patients with diabetic foot ulcers. *Adv Skin Wound Care*. 2019;32(6):272-277. <https://doi.org/10.1097/01.asw.0000557831.78645.85>
 223. Game F, Gray K, Davis D, et al. The effectiveness of a new dried human amnion derived membrane in addition to standard care in treating diabetic foot ulcers: a patient and assessor blind, randomised controlled pilot study. *Int Wound J*. 2021;18(5):692-700. <https://doi.org/10.1111/iwj.13571>
 224. Zelen CM, Serena TE, Gould L, et al. Treatment of chronic diabetic lower extremity ulcers with advanced therapies: a prospective, randomised, controlled, multi-centre comparative study examining clinical efficacy and cost. *Int Wound J*. 2016;13(2):272-282. <https://doi.org/10.1111/iwj.12566>
 225. Al-Nimer M, Ratha R, Mahwi T. Pentoxifylline improves the quality of life in type-2 diabetes foot syndrome. *Pak J Med Sci*. 2019;35(5):1370-1375. <https://doi.org/10.12669/pjms.35.5.11>
 226. Bashmakov YK, Assaad-Khalil SH, Abou Seif M, et al. Resveratrol promotes foot ulcer size reduction in type 2 diabetes patients. *ISRN Endocrinol*. 2014;2014:816307. <https://doi.org/10.1155/2014/816307>
 227. Chatzikyrkou C, Bahlmann FH, Sushakova N, et al. Low-dose erythropoietin promotes wound-healing of ulcers in diabetics: evidence from a phase-IIa clinical study. *Diabetes Metabol*. 2016;42(6):466-470. <https://doi.org/10.1016/j.diabet.2016.05.010>
 228. Kalani M, Apelqvist J, Blombäck M, et al. Effect of dalteparin on healing of chronic foot ulcers in diabetic patients with peripheral arterial occlusive disease: a prospective, randomized, double-blind, placebo-controlled study. *Diabetes care*. 2003;26(9):2575-2580. <https://doi.org/10.2337/diacare.26.9.2575>
 229. Koblik T, Sieradzki J, Sendur R, et al. The effect of insulin and sulodexide (Vessel Due F) on diabetic foot syndrome: pilot study in elderly patients. *J Diabetes Complicat*. 2001;15(2):69-74. [https://doi.org/10.1016/s1056-8727\(00\)00134-3](https://doi.org/10.1016/s1056-8727(00)00134-3)
 230. Larijani B, Heshmat R, Bahrami A, et al. Effects of intravenous Semelil (ANGIPARS™) on diabetic foot ulcers healing: a multicenter clinical trial. *Daru*. 2008;16(Suppl 1):35-40.
 231. Squadrito F, Bitto A, Altavilla D, et al. The effect of PDRN, an adenosine receptor A2A agonist, on the healing of chronic diabetic foot ulcers: results of a clinical trial. *J Clin Endocrinol Metabol*. 2014;99(5):E746-E753.
 232. Ko CH, Yi S, Ozaki R, et al. Healing effect of a two-herb recipe (NF3) on foot ulcers in Chinese patients with diabetes: a randomized double-blind placebo-controlled study. *J Diabetes*. 2014;6(4):323-334. <https://doi.org/10.1111/1753-0407.12117>
 233. Kim S, Kim J, Choi J, Jeong W, Kwon S. Polydeoxyribonucleotide improves peripheral tissue oxygenation and accelerates angiogenesis in diabetic foot ulcers. *Arch Facial Plast Surg*. 2017;44(6):482-489.
 234. Kamble A, Ambad RS, Padamwar M, Kakade A, Yeola M. To study the effect of oral vitamin d supplements on wound healing in patient with diabetic foot ulcer and its effect on lipid metabolism. *Int J Res Pharm Sci*. 2020;11(2):2701-2706. <https://doi.org/10.26452/ijrps.v11i2.2290>
 235. Mohseni S, Bayani M, Bahmani F, et al. The beneficial effects of probiotic administration on wound healing and metabolic status in patients with diabetic foot ulcer: a randomized, double-blind, placebo-controlled trial. *Diabetes/Metabol Res Rev*. 2018;34(3):e2970. <https://doi.org/10.1002/dmrr.2970>
 236. Soleimani Z, Hashemdokht F, Bahmani F, Taghizadeh M, Memarzadeh MR, Asemi Z. Clinical and metabolic response to flaxseed oil omega-3 fatty acids supplementation in patients with diabetic foot ulcer: a randomized, double-blind, placebo-controlled trial. *J Diabetes Complicat*. 2017;31(9):1394-1400. <https://doi.org/10.1016/j.jdiacomp.2017.06.010>
 237. Yarahmadi A, Saeed Modaghegh MH, Mostafavi-Pour Z, et al. The effect of platelet-rich plasma-fibrin glue dressing in combination with oral vitamin E and C for treatment of non-healing diabetic foot ulcers: a randomized, double-blind, parallel-group, clinical trial. *Expert Opin Biol Ther*. 2021;21(5):687-696. <https://doi.org/10.1080/14712598.2021.1897100>
 238. Armstrong DG, Hanft JR, Driver VR, et al. Effect of oral nutritional supplementation on wound healing in diabetic foot ulcers: a prospective randomized controlled trial. *Diabet Med*. 2014;31(9):1069-1077. <https://doi.org/10.1111/dme.12509>
 239. Wong LY, Leung PC, Wong WN, Wong WC, Lau TW, Cheng KF. Clinical research on diabetic foot ulcers: Demonstration of a comprehensive methodology. *J Compl Integr Med*. 2010;7(1):54. <https://doi.org/10.2202/1553-3840.1077>
 240. Chellan G, Neethu K, Varma AK, et al. Targeted treatment of invasive fungal infections accelerates healing of foot wounds in patients with type 2 diabetes. *Diabet Med*. 2012;29(9):e255-e262. <https://doi.org/10.1111/j.1464-5491.2012.03574.x>
 241. Mokhtari M, Razzaghi R, Momen-Heravi M. The effects of curcumin intake on wound healing and metabolic status in patients with diabetic foot ulcer: a randomized, double-blind, placebo-controlled trial. *Phytother Res*. 2021;35(4):2099-2107. <https://doi.org/10.1002/ptr.6957>
 242. Bonora BM, Cappellari R, Mazzucato M, et al. Stem cell mobilization with plerixafor and healing of diabetic ischemic wounds: a phase IIa, randomized, double-blind, placebo-controlled trial. *Stem Cell Transl Med*. 2020;9(9):965-973.
 243. Normandin S, Safran T, Winocour S, et al. Negative pressure wound therapy: mechanism of action and clinical applications. *Semin Plast Surg*. 2021;35(3):164-170. <https://doi.org/10.1055/s-0041-1731792>
 244. Malekpour Alamdari N, Mehraneroodi B, Gholizadeh B, Zeinalpour A, Safe P, Besharat S. The efficacy of negative pressure wound therapy compared with conventional dressing in treating infected diabetic foot ulcers: a randomized controlled trial. *Int J Diabetes Dev Ctries*. 2021;41(4):664-668. <https://doi.org/10.1007/s13410-021-00941-9>
 245. Campitiello F, Mancone M, Corte AD, Guerniero R, Canonico S. Expanded negative pressure wound therapy in healing diabetic foot ulcers: a prospective randomised study. *J Wound Care*. 2021;30(2):121-129. <https://doi.org/10.12968/jowc.2021.30.2.121>

246. Chiang N, Rodda OA, Sleigh J, Vasudevan T. Effects of topical negative pressure therapy on tissue oxygenation and wound healing in vascular foot wounds. *J Vasc Surg.* 2017;66(2):564-571. <https://doi.org/10.1016/j.jvs.2017.02.050>
247. Hu X, Ni Y, Lian W, Kang L, Jiang J, Li M. Combination of negative pressure wound therapy using vacuum-assisted closure and ozone water flushing for treatment of diabetic foot ulcers. *Int J Diabetes Dev Ctries.* 2020;40(2):290-295. <https://doi.org/10.1007/s13410-019-00769-4>
248. Karatepe O, Eken I, Acet E, et al. Vacuum assisted closure improves the quality of life in patients with diabetic foot. *Acta Chir Belg.* 2011;111(5):298-302. <https://doi.org/10.1080/00015458.2011.11680757>
249. Lone AM, Zaroo MI, Laway BA, Pala NA, Bashir SA, Rasool A. Vacuum-assisted closure versus conventional dressings in the management of diabetic foot ulcers: a prospective case-control study. *Diabet Foot Ankle.* 2014;5(1):23345. <https://doi.org/10.3402/dfa.v5.23345>
250. Maranna H, Lal P, Mishra A, et al. Negative pressure wound therapy in grade 1 and 2 diabetic foot ulcers: a randomized controlled study. *Diabetes Metabol Syndr.* 2021;15(1):365-371. <https://doi.org/10.1016/j.dsx.2021.01.014>
251. McCallon SK, Knight CA, Valiulus JP, Cunningham MW, McCulloch JM, Farinas LP. Vacuum-assisted closure versus saline-moistened gauze in the healing of postoperative diabetic foot wounds. *Ostomy/Wound Manag.* 2000;46(8):28-32.
252. Nain PS, Uppal SK, Garg R, Bajaj K, Garg S. Role of negative pressure wound therapy in healing of diabetic foot ulcers. *J Surg Tech Case Rep.* 2011;3(1):17-22. <https://doi.org/10.4103/2006-8808.78466>
253. Sajid MT, Mustafa Q, Shaheen N, Hussain SM, Shukr I, Ahmed M. Comparison of negative pressure wound therapy using vacuum-assisted closure with advanced moist wound therapy in the treatment of diabetic foot ulcers. *J Coll Phys Surg Pakistan.* 2015;25(11):789-793.
254. Zhang X, Wan L, Yang R, et al. Expression of connective tissue growth factor and periostin of wound tissue in patients with diabetes who had vacuum sealing drainage. *Int J Clin Exp Med.* 2017;10(8):12942-12950.
255. Blume PA, Walters J, Payne W, Ayala J, Lantis J. Comparison of negative pressure wound therapy using vacuum-assisted closure with advanced moist wound therapy in the treatment of diabetic foot ulcers: a multicenter randomized controlled trial. *Diabetes Care.* 2008;31(4):631-636. <https://doi.org/10.2337/dc07-2196>
256. Seidel D, Storck M, Lawall H, et al. Negative pressure wound therapy compared with standard moist wound care on diabetic foot ulcers in real-life clinical practice: results of the German DiaFu-RCT. *BMJ Open.* 2020;10(3):e026345. <https://doi.org/10.1136/bmjopen-2018-026345>
257. Armstrong DG, Lavery LA. Negative pressure wound therapy after partial diabetic foot amputation: a multicentre, randomised controlled trial. *Lancet.* 2005;366(9498):1704-1710. [https://doi.org/10.1016/s0140-6736\(05\)67695-7](https://doi.org/10.1016/s0140-6736(05)67695-7)
258. Lavery LA, Davis KE, La Fontaine J, et al. Does negative pressure wound therapy with irrigation improve clinical outcomes? A randomized clinical trial in patients with diabetic foot infections. *Am J Surg.* 2020;220(4):1076-1082. <https://doi.org/10.1016/j.amjsurg.2020.02.044>
259. Vaidhya N, Panchal A, Anchalia MM. A new cost-effective method of NPWT in diabetic foot wound. *Indian J Surg.* 2015;77(S2):S525-S529. <https://doi.org/10.1007/s12262-013-0907-3>
260. Lavery LA, La Fontaine J, Thakral G, Kim PJ, Bhavan K, Davis KE. Randomized clinical trial to compare negative-pressure wound therapy approaches with low and high pressure, silicone-coated dressing, and polyurethane foam dressing. *Plast Reconstr Surg.* 2014;133(3):722-726. <https://doi.org/10.1097/01.prs.0000438046.83515.6a>
261. Apelqvist J, Armstrong DG, Lavery LA, Boulton AJ. Resource utilization and economic costs of care based on a randomized trial of vacuum-assisted closure therapy in the treatment of diabetic foot wounds. *Am J Surg.* 2008;195(6):782-788. <https://doi.org/10.1016/j.amjsurg.2007.06.023>
262. Driver VR, Blume PA. Evaluation of wound care and health-care use costs in patients with diabetic foot ulcers treated with negative pressure wound therapy versus advanced moist wound therapy. *J Am Podiatric Med Assoc.* 2014;104(2):147-153. <https://doi.org/10.7547/0003-0538-104.2.147>
263. Subrata SA, Phuphaibul R, Grey M, Siripitayakunkit A, Piaseu N. Improving clinical outcomes of diabetic foot ulcers by the 3-month self- and family management support programs in Indonesia: a randomized controlled trial study. *Diabetes Metabol Syndr.* 2020;14(5):857-863. <https://doi.org/10.1016/j.dsx.2020.05.028>
264. Vas P, Rayman G, Dhatariya K, et al. Effectiveness of interventions to enhance healing of chronic foot ulcers in diabetes: a systematic review. *Diabetes Metab Res Rev.* 2020;36(Suppl 1):e3284. <https://doi.org/10.1002/dmrr.3284>
265. Yelland AC, Meace C, Knighton P, et al. Impact of case-mix adjustment on observed variation in the healing of diabetic foot ulcers at 12 weeks using data from the National Diabetes Foot Care Audit of England and Wales: a cohort study. *Diabet Med.* 2023;40(1):e14959. <https://doi.org/10.1111/dme.14959>

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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