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Research

COMPARATIVE EFFECTIVENESS OF DEBRIDEMENT MODALITIES FOR DIABETIC FOOT ULCERS: A SYSTEMATIC LITERATURE REVIEW

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Abstract

Diabetic foot ulcers (DFUs) represent a severe complication of diabetes mellitus associated with significant risks of infection, lower-extremity amputation, and substantial healthcare burden. Although debridement is established as an essential component of DFU management, the comparative clinical effectiveness across different debridement modalities remains varied. This systematic literature review evaluated and synthesized current evidence regarding various debridement methods in DFU management following the PRISMA 2020 guidelines and SWiM framework. A structured search was performed across PubMed, ScienceDirect, SpringerLink, Wiley Online Library, MDPI, and Google Scholar for publications from 2018 to 2025. Methodological quality was appraised using the Joanna Briggs Institute (JBI) Critical Appraisal Tools. Twelve primary studies (7 RCTs, 1 quasi-experimental, 1 prospective comparative, and 3 case series) met the inclusion criteria. Current evidence suggests that enzymatic debridement and ultrasonic-assisted wound debridement (UAWD) demonstrate promising trends in accelerating tissue preparation and wound size reduction. Sharp or surgical debridement remains the primary first-line approach for immediate removal of nonviable tissue and biofilm disruption. Autolytic, biological, and hydrosurgical modalities offer potential benefits in specific clinical contexts, though available comparative data remain limited. Overall, while several advanced modalities show favorable evidence for specific parameters, no single debridement technique can be conclusively defined as universally superior across all clinical outcomes.

Keywords: Clinical Outcomes, Diabetic Foot Ulcer, Debridement, Wound Healing, Systematic review

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INTRODUCTION

Diabetic foot ulcers (DFUs) constitute one of the most severe, complex, and costly chronic complications associated with diabetes mellitus worldwide. According to recent epidemiological estimates from the International Diabetes Federation (IDF) and global vascular registries, approximately 18.6 million individuals suffer from active DFUs annually, with a lifetime incidence ranging between 19% and 34% among diabetic populations (Armstrong et al., 2023). DFUs are the primary antecedent pathway for lower-extremity complications, accounting for up to 85% of all diabetes-related lower-limb amputations globally. The economic implications are equally staggering; direct healthcare expenditures for diabetic foot care exceed billions of dollars annually, placing immense pressures on both primary health systems and specialized tertiary wound care centers.

The pathogenesis of DFUs is inherently multifactorial, driven by a complex triad of peripheral neuropathy, peripheral arterial disease (PAD), and persistent systemic hyperglycemia (Dawi et al., 2025; Liang et al., 2024). Somatic sensory neuropathy leads to a loss of protective sensation (LOPS), rendering patients oblivious to minor repetitive mechanical trauma, ill-fitting footwear pressure, or thermal injuries. Autonomic neuropathy contributes to sudomotor dysfunction, resulting in dry, fissured skin susceptible to bacterial invasion, as well as microvascular shunting that impairs nutrient blood flow. Concurrently, macrovascular and microvascular PADfrequently characterized by distal, infrapopliteal arterial calcificationinduces persistent tissue hypoxia and ischemia, severely restricting the delivery of oxygen, systemic antibiotics, and essential cellular nutrients required for tissue regeneration. At the cellular level, chronic hyperglycemia induces systemic low-grade inflammation, leukocyte dysfunction, blunted neutrophil chemotaxis, and impaired phagocytosis (Aditya et al., 2025). This persistent metabolic insult creates a hostile wound microenvironment marked by excessive matrix metalloproteinase (MMP) activity, degraded extracellular matrix (ECM) proteins, and an inability to transition from the inflammatory phase to the proliferative phase of healing.

Within this chronic non-healing environment, devitalized necrotic tissue, fibrinous slough, senescent fibroblasts, and microbial biofilms accumulate rapidly. Bacterial biofilmsstructured polymicrobial communities encased in a self-produced extracellular polymeric substance (EPS) matrixare present in over 80% of chronic DFUs. Biofilms confer profound tolerance against host immune defenses and systemic antimicrobial agents, perpetuating persistent localized infection and sustained cellular senescence. Consequently, the systematic and continuous removal of devitalized tissue, senescent cells, and microbial burdena process defined as debridementis universally recognized as an indispensable cornerstone of standard DFU care (IWGDF Guidelines, 2023).

By converting a stagnant, chronic wound bed into an acute, physiologically active environment, effective debridement stimulates the release of endogenous growth factors, promotes functional angiogenesis, reduces toxic inflammatory cytokines, and facilitates healthy granulation tissue formation and re-epithelialization. Over the past two decades, clinical wound care has evolved significantly from traditional mechanical and surgical procedures to encompass a broad spectrum of advanced debridement modalities. These modalities are broadly classified into six major categories: (1) Sharp and surgical debridement, utilizing scalpel, curette, or scissors for rapid physical clearance; (2) Enzymatic debridement, applying exogenous proteolytic enzymes (e.g., collagenase, papain, P1G10) to digest necrotic collagen anchors; (3) Autolytic debridement, utilizing moisture-retentive dressings (e.g., hydrogels, alginates) to enhance endogenous enzymatic breakdown; (4) Ultrasonic-assisted wound debridement (UAWD), delivering low-frequency ultrasound energy via liquid cavational mist to disrupt tissue and biofilm; (5) Biological debridement (Maggot Therapy), deploying sterile larvae (Lucilia sericata or Lucilia cuprina) for selective enzymatic digestion and mechanical ingestion; and (6) Hydrosurgical debridement, utilizing high-velocity fluid jets operating under the Venturi effect to cut and aspirate debris simultaneously.

RESEARCH METHOD

Research Design

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). Adherence to the PRISMA 2020 framework is intended to enhance the transparency, methodological rigor, and reproducibility of the review process, thereby enabling future readers and researchers to critically evaluate and replicate the search, selection, and synthesis procedures used in this study.

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). Meta-analysis was not performed due to heterogeneity in study design, intervention type, outcomes, and follow-up duration between studies. Therefore, data were synthesized narratively (*narrative synthesis*) by grouping studies based on debridement method and comparing the effectiveness of each method on predetermined clinical outcomes. Reporting of narrative synthesis refers to the Synthesis Without Meta-analysis (SWiM) guidelines to increase transparency and consistency in the presentation of results (Campbell et al., 2020)

Research Target/Subject

Article selection using the PICOS framework (Population, Intervention, Comparison, Outcomes, Study Design)

Table 1. PICOS Framework for the Systematic Literature Review

PICOS	Description
Population (P)	Adult patients with a diagnosis of diabetic foot ulcer (DFU)
Intervention (I)	Debridement methods, including sharp debridement, surgical debridement, mechanical debridement, autolytic debridement, enzymatic debridement, biological debridement (maggot therapy), and ultrasonic assisted debridement
Comparison (C)	Other debridement methods
Outcome (O)	Clinical outcomes include wound healing rate, healing time, wound area reduction, infection control, amputations, quality of life, and adverse events.
StudyDesign (S)	Randomized Controlled Trials (RCTs), prospective comparative studies, cohort studies, observational comparative studies, and case series.

Studies were deemed eligible for inclusion based on pre–established inclusion and exclusion criteria, as summarized in Table 2.

Table 2. Inclusion and Exclusion Criteria

Inclusion	Exclusion
Human studies (2018–2025)	Case reports, editorials, letters to the editor
Adult patients with DFU	Conference abstracts, animal research
Evaluating more than 1 debridement method	Research protocol
Reporting clinical healing result	
Original research article	

Research Procedure

The study began with the formulation of research questions using the Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) framework. Based on this framework, the population was adult patients with diabetic foot ulcers (DFU). The interventions studied included various debridement methods, while the comparator was either another debridement method or standard care. The outcomes of the study focused on wound healing rate, healing time, wound size reduction, infection control, need for amputation, and adverse events. Eligible studies included randomized controlled trials (RCTs), quasi–experimental, cohort, and case series (Schardt et al., 2007)

A systematic literature search was conducted in the databases PubMed/MEDLINE, PubMed Central (PMC), ScienceDirect, SpringerLink, Wiley Online Library, MDPI, and Google Scholar. The search strategy was developed using a combination of Medical Subject Headings (MeSH) terms, free–text, Boolean operators (AND and OR), and the use of parentheses to identify articles that align with the research objectives.

The identified articles were then selected based on inclusion and exclusion criteria. Included articles were english language primary studies published between 2018 and 2025, available in full text, involving adult patients with diabetic foot ulcers, and evaluating the effectiveness of debridement methods on clinical outcomes. Conversely, articles in the form of literature reviews, systematic reviews, meta-analyses, editorials, letters to the editor, case reports, conference proceedings, abstracts, animal studies, or studies not addressing diabetic foot ulcers were excluded from the review process.

All retrieved articles were then exported to reference management software to remove duplicate articles. The next stage involved screening based on title and abstract, followed by an eligibility assessment through full text review according to established criteria. Articles meeting all requirements then underwent data extraction and methodological quality assessment before being included in the synthesis stage. The entire process of identification, screening, eligibility assessment, and determination of articles for analysis followed the PRISMA 2020 process, resulting in 12 primary studies meeting the criteria for further analysis (*JBI Critical Appraisal Tools | JBI*, n.d.; Page et al., 2021)

Instruments, and Data Collection Techniques

Data were systematically extracted using a pre designed extraction form. Information collected included author names, year of publication, study design, sample characteristics, type of intervention, comparison group, and key findings. All data obtained was then double–checked for completeness and consistency.

The methodological quality of each study was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Tools, tailored to each study's design. The assessment covered methodological aspects, internal validity, potential bias, and the appropriateness of the analyses used in each study. The results of the quality assessment were used to interpret the strength of evidence, but were not used to exclude studies that met the inclusion criteria.

Data Analysis Technique

Data extracted from each article was analyzed using a narrative synthesis approach. The analysis was conducted by grouping the study results based on the type of debridement method used and then comparing the findings in each group. Outcomes described included wound healing rate, healing time, wound size reduction, infection control, and reported side effects in each study. Comparisons were conducted descriptively to identify similarities, differences, and trends in the effectiveness of each debridement method. Meta-analysis was not performed due to significant variation in study design, intervention characteristics, outcome indicators, and follow-up duration between studies. Therefore, the synthesis of the study results was prepared narratively, referring to the Synthesis Without Meta-analysis (SWiM) guidelines (Campbell et al., 2020)

RESULTS AND DISCUSSION

A total of 108 records were identified through a structured search of databases and indexed sources (PubMed, Wiley Online Library, MDPI, Springer, ScienceDirect, and Google Scholar) using a combination of keywords according to the PICO framework. After removing 71 duplicate records, 37 unique records were screened based on title and abstract. Twenty–one records were excluded at this stage because they were irrelevant to the DFU population, published before 2018, were narrative reviews without primary data, or were studies in animal models. Furthermore, 16 reports full text articles were assessed for eligibility, and four reports were excluded at this stage, one retracted article (a meta-analysis of UAWD that had been retracted by the publishing journal due to a proven compromised peer review process), two study protocols without final outcome reports, and one duplicate report from the same clinical trial. This selection process resulted in 12 primary studies: seven RCTs (including one pilot RCT) and five non–randomized studies (one quasi–experimental, one comparative case series, one prospective observational comparative study, and two prospective case series) published between 2018 and 2025 that met all inclusion criteria for narrative analysis. A flowchart of study selection following the PRISMA 2020 format is presented in Figure 1.

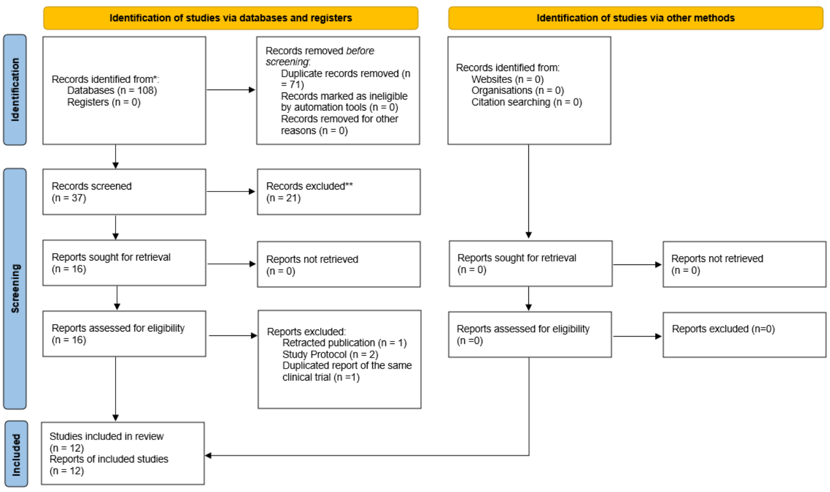

Figure 1. Prisma 2020 Flowchart Study Selection Process

The PRISMA flow diagram illustrates the systematic process of study identification, screening, eligibility assessment, and final inclusion in the review. The literature search initially identified 108 records from databases, including PubMed, Wiley Online Library, MDPI, Springer, ScienceDirect, and Google Scholar. After removing 71 duplicate records, 37 articles remained for title and abstract screening, during which 21 records were excluded because they did not meet the inclusion criteria, such as irrelevant populations, inappropriate publication years, review articles, or non-human studies. Subsequently, 16 full-text articles were assessed for eligibility, and four studies were excluded due to reasons including retracted publication, absence of final outcome data, or duplicate reporting. Finally, 12 primary studies were included in the systematic review and qualitative synthesis, representing the available evidence on the effectiveness of different debridement modalities for diabetic foot ulcers. The selection process followed the PRISMA 2020 framework to ensure transparency, methodological consistency, and reproducibility in the review process.

Table 3. Characteristics of Included Primary Studies

Studies (Year)	Design	Subject	Comparison	Key Findings
Michailidis et al. (2018)	RCT	n= 10 (14 ulcus)	Sharp debridement non surgical vs debridement ultrasonic frequency low	Sharp debridement is faster recovered (61,6±24,4 days) vs ultrasonik (117,6±40,3 days) The study was terminated early and was underpowered
Nube et al. (2021)	RCT pragmatic multicenter	NR (Not Reported)	Sharp debridement weekly vs bi–weekly	No difference significant inside and outside healing on 12 weeks
Rastogi et al. (2019)	Blinded RCT double	Multicenter	Ultrasound non contact (Glybetac) vs sham	Reported efficacy and security on Neuropathic DFU
Lázaro–Martínez et al. (2020)	RCT open label	n= 51 (UAWD=27, surgery=24)	UAWD debridement vs surgical/sharp debridement	UAWD increased cell proliferation and lower the load bacteria in a meaningful
Lázaro–Martínez et al. (2018)	Cse study comparative (case series)	NR (Not Reported)	UAWD debridement on DFU neuroischemic	Reduced bacterial load, improved the clinical appearance of the wound
Gao et al. (2022)	Quasi–experimental study (non–randomized controlled trial)	NR (Not Reported)	Debridement ultrasonic + cortex topical phellodendri vs Standart	Ultrasonic combination debridement and Cortex Phellodendri Compound Fluid increased clinical effectiveness (98% vs 68%).
Flores–Escobar et al. (2025)	RCT Pilot	n= 30 (10/10/10)	Ultrasonic weekly vs bi–weekly vs standard	Healing rate 70% vs 54,4% vs 33,3% insignificant (p=0,27)
Sharma et al. (2024)	Studies comparative prospective observational	n= 60 (30/30)	Hydrosurgery vs surgical debridement	Duration of diabetic & clinical profile compared to intergroup debridement
Tonaco et al.	Blinded RCT	n= 50	Debridemen	P1G10 significantly

(2018)	double		enzymatic P1G10 vs hydrogel	improved DFU healing (with a total healing rate 2.95 times higher) and is safe compared to hydrogel.
Della Pepa et al. (2023)	RCT open label	Monocenter, 12 weeks	Hydrogel/gauze Fitostimoline vs saline gauze	Compared to healing complete & reduction DFU size
Gustenelli Barbosa et al. (2018)	Case series	n= 8 (7 finish follow-up)	Amorphous hydrogel sodium enriched alginate, vitamin A and E (without control group)	After 12 weeks there is a reduction in mean wound area by 22.2%, drop in score PUSH, and 2 of the 7 patients experienced healing complete
Nair et al. (2021)	Case series	n= 30 (28 DFU)	Larva therapy (biological) on DFU difficult to cure	Effective sterile larva Debridement DFU is difficult to heal

Each article was assessed using the JBI instrument appropriate to its study design. Each item on the checklist was classified as "Yes," "No," "Unclear," or "Not Applicable." A quality score was calculated based on the number of items meeting the criteria ("Yes") and then used to describe the methodological quality of each study. The results of the quality assessment are presented in Table 5 and were used to interpret the strength of evidence, but not to exclude articles.

Table 4. JBI Study Quality Assesment

Author	**Study Design**	**Instrument JBI**	**Score**	**Category**
Michailidis et al. (2018)	Randomized Controlled Trial	JBI Critical Appraisal Checklist for RCT	10/13	High
Nube et al. (2021)	Randomized Controlled Trial	JBI Critical Appraisal Checklist for RCT	10/13	High
Rastogi et al. (2019)	Randomized Controlled Trial	JBI Critical Appraisal Checklist for RCT	12/13	High
Lázaro–Martínez et al. (2020)	Randomized Controlled Trial	JBI Critical Appraisal Checklist for RCT	9/13	Moderate
Lázaro–Martínez et al. (2018)	Comparative Case Series	JBI Checklist for Case Series	8 /10	High
Gao et al. (2022)	Quasi–experimental study	JBI Critical Appraisal Checklist for Quasi–Experimental Studies	8/9	High
Flores–Escobar et al. (2025)	Pilot Randomized Controlled Trial	JBI Critical Appraisal Checklist for RCT	12/13	High
Sharma et al. (2024)	Prospective Comparative Observational Study	JBI Checklist for Cohort Studies	8/11	Moderate
Tonaco et al. (2018)	Randomized Controlled Trial	JBI Critical Appraisal Checklist for RCT	12/13	High
Della Pepa et al. (2023)	Randomized Controlled Trial	JBI Critical Appraisal Checklist for RCT	9/13	Moderate

Gustinelli Barbosa et al. (2018)	Prospective Case Series	JBI Checklist for Case Series	9/10	High
Nair et al. (2021)	Prospective Case Series	JBI Checklist for Case Series	7/10	Moderate

Surgical and Sharp Debridement

Two studies evaluated sharp/surgical debridement as a modality. Treatment of diabetic foot ulcers. Nube et al. (2021) showed that weekly and biweekly sharp debridement frequencies provided comparable healing outcomes at 12 weeks. Conversely, Michailidis et al. (2018) reported that nonsurgical sharp debridement accelerated wound healing compared to low–frequency UAWD

Enzymatic Debridement

One RCT by Tonaco et al. (2018) compared enzymatic debridement using the proteolytic fraction P1G10 with a hydrogel as a control. The P1G10 group showed a 2.95–fold higher incidence of complete healing and a 2.52–fold higher incidence of ≥80% healing compared to the control group

Biological Debridement (Maggot Therapy)

Nair et al. (2021) reported the results of a case series on 30 patients with ulcers diabetic lower extremities, including 28 patients with diabetic foot ulcers. Maggot debridement therapy (MDT) uses sterile larvae Lucilia Cuprinaresulted in successful debridement in 96.6% of patients after a maximum of three applications, accompanied by reduced wound pain with no reported side effects

Autolytic Debridement

One randomized controlled trial and one prospective case series evaluated hydrogel–based autolytic debridement. Della Pepa et al. (2023) reported comparable healing outcomes between hydrogel dressings and saline gauze, Gustenelli Barbosa et al. (2018) reported that the use of hydrogel enriched with sodium alginate, vitamin A, and vitamin E for 12 weeks resulted in a 22.2% reduction in mean wound area, improvement in PUSH scores, and two out of seven patients achieved complete healing. However, because this study used a prospective case series design without a control group, the comparative effectiveness of hydrogel cannot be concluded

UAWD

Ultrasonic–based debridement is a modality with primary evidence. The most studies in this review (5 of 12 studies). Rastogi et al. (2019) reported the effectiveness and safety of noncontact ultrasound therapy for diabetic foot ulcers. Lázaro–Martínez et al. (2020) showed that ultrasound–assisted wound (UAWD) debridement resulted in a reduction in bacterial load and increased cell proliferation better than sharp debridement, in line with the findings of Lázaro–Martínez et al. (2018) who also reported a decrease in bacterial load after UAWD. Gao et al. (2022) found that the combination of UAWD with topical fluid cortex phellodendriproviding better clinical outcomes than standard care. Meanwhile, Flores–Escobar et al. (2025) reported a trend towards higher healing rates in the ultrasound group compared to standard care, although the difference was not statistically significant

Hydrosurgery Based Mechanical Debridement

(Sharma et al., 2024) (n=60) (n=60) comparing hydrosurgical debridement (waterjet technology) with conventional surgical debridement in DFU patients, reported differences in baseline clinical characteristics between groups (duration of diabetes and prevalence of foot deformity) without demonstrating consistent clinical superiority of either method on healing outcomes.

Tabel 5. Summary of Key Findings Based on Debridement Modality

Modality	Primary Studies & Supporting Syntesis	Synthesis Conclusion
Sharp / Surgical	Nube et al. (2021), Dayya et al. (2022)	The frequency of debridement can be reduced (from weekly to every two weeks) without compromising healing effectiveness, evidence of direct superiority remains limited
Enzymatic	Ning et al. (2023)	Highest ratings for healing rate (SUCRA0.919) and wound area reduction (SUCRA 0.931) high cost and contraindicated in coagulation disorders
Autolytic (hydrogel/alginat)	Dayya et al. (2022), Ning et al. (2023)	Superior to gauze/treatment Ning et al. (2023) standard (RR 1.84, 95% CI 1.30–2.61), easily accessible and low cost
Biological (larva)	Lin et al. (2025)	Effective for rapid debridement and infection control, DFU–specific comparative data are limited.
Ultrasonic	Liu et al. (2024), Flores–Escobar et al. (2025)	Consistent trend towards higher healing rates and greater wound area reduction, effect size varied between studies (OR 2.22–3.08 some nonsignificant)
Hydrosurgery Based Mechanical	Sharma et al. (2024)	The evidence is still very limited. Hydro–surgery shows clinical results comparable to those of conventional surgical debridement, but there is currently no evidence demonstrating its superiority in terms of DFU healing outcomes

Interpretation of the Effectiveness of Intermodality Debridement

In addition to the 12 primary studies that met the inclusion criteria, seven systematic review/meta-analysis is used as a supporting reference in interpreting the results. In an effort to minimize the possibility of missing studies, citation searching is carried out was conducted on the bibliography of eligible primary studies, but did not produce additional primary studies that met the inclusion criteria.

Debridement Sharp and surgical debridement remains recommended as the first line method.This recommendation was first recommended by the 2023 International Working Group on the Diabetic Foot (IWGDF) guidelines, although these recommendations were largely based on extensive clinical experience rather than high–quality comparative evidence. Mechanistically, sharp debridement works by disrupting the biofilm and removing nonviable tissue, callus, and senescent cells, thus preparing the wound bed for endogenous healing and subsequent therapy (Nube et al., 2021). Nube et al. (2021) finding that weekly and biweekly debridement frequencies produced equivalent outcomes indicates that the intensity of the procedure can be reduced without sacrificing effectiveness, potentially improving resource efficiency, particularly in healthcare facilities with limited wound care competency. The results of Michailidis et al. (2018), which actually supported the superiority of sharp debridement over UAWD, should be interpreted with caution, as the study was terminated early and was significantly underpowered (only 10 subjects), and therefore cannot be used to draw definitive conclusions regarding the superiority of one method over the other.

Evidence regarding ultrasonic based debridement shows a pattern. The most consistent results among all evaluated modalities. A primary study by Gao et al. (2022) demonstrated that the combination of UAWD and Cortex Phellodendri Compound Fluid improved clinical efficacy, accelerated wound healing, reduced wound area, and decreased the number of positive bacterial cultures compared to the control group without increasing the incidence of adverse events. Meanwhile, Lázaro–Martínez et al. (2020) reported that UAWD was associated with increased cell proliferation and decreased bacterial load (Gao et al., 2022; Lázaro–Martínez et al., 2020), consistent with the combined effect estimates from Liu et al. (2024) that demonstrated significant superiority of UAWD over standard care for healing rate, healing time, and wound area reduction. These findings are also consistent with the study by Lázaro–Martínez et al. (2018), which demonstrated a reduction in bacterial load after UAWD in patients with neuroischemic diabetic foot ulcers. Overall, the available evidence suggests that the benefits of UAWD are not only related to the removal of nonviable tissue, but also to the reduction of bacterial colonization, which likely contributes to the creation of a wound environment more conducive to the healing process.

However, not all evidence shows consistent results. Flores–Escobar et al. (2022) through a systematic review and meta-analysis of eight RCTs (263 participants) reported that UAWD showed a trend towards increased healing rates compared to control (OR 2.22), but the difference did not reach statistical significance (95% CI 0.96–5.11; p = 0.06). This finding is likely influenced by the limited number of studies and sample size. In line with that, a recent pilot RCT by Flores–Escobar et al. (2025) also found no significant difference between weekly, biweekly, and standardized wound care, which the authors attributed to the small sample size (n = 30) (Flores–Escobar et al., 2025). This variation confirms that the strength of the evidence for UAWD still depends heavily on the number and methodological quality of available RCT (H. Chen et al., 2023)

Enzymatic debridement shows promising results in both (Tonaco et al., 2018), with a nearly threefold higher incidence of complete healing compared to hydrogels) and a synthetic network meta-analysis (Ning et al., 2023) that ranked P1G10 as the highest SUCRA for healing rate. Despite its demonstrated efficacy, the 2023 IWGDF stated that the use of enzymatic debridement has implications for higher resource requirements than sharp debridement. Therefore, this modality is more appropriate to consider in certain circumstances, especially when sharp debridement is unavailable or access to trained healthcare professionals is limited (P. Chen et al., 2024)

Autolytic debridement through hydrogel dressings showed good results. Relatively varied at the primary study level (Della Pepa et al., 2023) reported that the use of hydrogel dressings provided comparable or better healing outcomes compared to saline gauze, while (Gustinelli Barbosa et al., 2018) in a prospective case series reported a 22.2% reduction in mean wound area, improvement in PUSH scores, and two of seven patients achieving complete healing after 12 weeks of using hydrogel enriched with sodium alginate, vitamin A, and vitamin E. However, because there was no control group, these findings only indicate potential clinical benefits and cannot be used to conclude the superiority of hydrogels over other modalities. These differences in findings are likely influenced by variations in hydrogel formulations, wound characteristics, relatively small sample sizes, and the outcomes used in each study. In contrast, meta-analysis by (Zhao et al., 2024) and (Zhou et al., 2025) consistently showed that hydrogel dressings were superior to conventional dressings in increasing healing rates and shortening healing time. The discrepancy between the results of individual studies and the synthesis of evidence suggests that the clinical benefits of hydrogels become clearer when the evidence from multiple studies is analyzed collectively. Therefore, autolytic debridement remains a rational option, especially in wounds with small amounts of necrotic tissue, when sharp debridement is not possible or indicated.

Biological debridement (larval therapy) shows good clinical results. Observational cohort studies (Nair et al., 2021) and systematic reviews (C.–J. Lin et al., 2025; Syam et al., 2021), have shown promising effects, including accelerated debridement and a contribution to infection control. These effects are mechanistically explained by the larvae's ability to selectively remove nonviable tissue while secreting antimicrobial compounds that inhibit biofilm formation. However, the available evidence is still predominantly observational, with only a few RCTs directly comparing MDT with other debridement modalities in diabetic foot ulcer patients during the period 2018–2025..Therefore, the definitive role of larval therapy still requires confirmation through randomized clinical trials with more robust designs.

Hydrosurgery is one of the debridement modalities that hydrosurgery has been developed as an alternative to conventional surgical debridement through precise removal of nonviable tissue with minimal damage to healthy tissue. However, in this review, evidence regarding hydrosurgery is still very limited because it is supported by only one observational study, so its effectiveness compared to other debridement modalities cannot be concluded conclusively. The limitations of the study design and the lack of randomized clinical trials with adequate sample sizes result in a low level of certainty in the evidence for hydrosurgery. Therefore, comparative studies with randomized controlled trials are still needed to assess the effectiveness and safety of hydrosurgery in patients with diabetic foot ulcers before this modality can be more widely recommended (Sharma et al., 2024)

Cross Clinical Outcome Comparison

Based on cross–modality synthesis, the strongest comparative evidence relates to Wound healing rates and healing times point to the superiority of enzymatic and ultrasonic based debridement, both of which have consistently demonstrated superiority over standard wound care in large–scale studies (Liu et al., 2024; Ning et al., 2023), although evidence at the individual primary study level shows greater variation. Infection control is most strongly associated with sharp debridement, through the mechanism of mechanical biofilm disruption, and biological debridement, through the antimicrobial activity of larval secretions. In contrast, evidence regarding granulation tissue formation, amputation rates, ulcer recurrence, and quality of life remains very limited across the modalities reviewed; none of the 12 primary studies included in this review considered amputation, recurrence, or quality of life as primary outcomes. Most available clinical trials were designed with statistical power oriented towards the outcomes of healing rate or wound area reduction, so these secondary outcomes constitute a continuing evidence gap and are consistent with the conclusion (Ning et al., 2023) that the optimal debridement method for DFU remains unclear and requires further research.

Methodological Limitations of the Scientific Evidence and This Review

Several methodological limitations limit the strength of the conclusions. Several limitations can be drawn from the overall evidence reviewed. First, most individual primary studies involved relatively small numbers of subjects (ranging from 10 to 60 subjects in the 12 included studies), reducing statistical power and widening the confidence intervals for the main effect estimates, as evidenced by some non–significant results despite showing promising directionality (e.g., Flores–Escobar et al., 2022). Second, there was considerable heterogeneity in the comparison groups, including standard care, placebo/sham, and different active debridement methods, making direct comparisons between studies difficult. Third, outcome definitions and follow-up durations varied across studies, and risk of bias assessments in the original clinical trials often identified issues related to allocation blinding and blinding of outcome assessors.

In addition, this review has methodological limitations. separate data that need to be disclosed transparently. The search was conducted using a combination of databases, academic search engines, and publisher platforms that index major academic sources of bibliometric exports. Therefore, the number of records identified (n = 108) is likely smaller than a fully systematic multi–database search, and a small number of relevant primary studies that are not extensively indexed may have been missed. Data screening and extraction were also conducted by two reviewers, rather than two independent reviewers as required by the PRISMA 2020 guidelines, to minimize selection bias. The number of primary studies meeting all inclusion criteria was relatively limited, requiring caution in interpreting the results. These various sources of clinical and methodological heterogeneity informed the choice of a narrative synthesis approach in this review, rather than a pooled quantitative meta-analysis.

Although some methods have better results than other methods, differences in findings between studies are likely influenced by heterogeneity in study characteristics. These variations include sample size, ulcer severity based on Wagner's classification, follow-up duration, debridement technique used, operator experience, and the use of complementary interventions such as dressing type and antibiotic therapy. Furthermore, patient characteristics, including glycemic control, peripheral vascular status, degree of infection, and comorbidities, can also influence the wound healing process. These findings align with various systematic reviews and clinical guidelines that emphasize that diabetic foot ulcer healing outcomes are influenced by a combination of patient factors, wound characteristics, and multidisciplinary management. Therefore, the effectiveness of a debridement method cannot be evaluated separately from its clinical context (Lazzarini & van Netten, 2025; Liu et al., 2024; Ning et al., 2023)

CONCLUSION

This systematic literature review evaluated and synthesized contemporary international evidence (2018–2025) regarding the comparative effectiveness of various debridement modalities in diabetic foot ulcer management. The synthesized evidence demonstrates that while advanced modalities offer distinct physiological and clinical advantages, no single debridement technique can be conclusively defined as universally superior across all core clinical outcomes.

Sharp and surgical debridement remains the fundamental, indispensable baseline modality for immediate, rapid tissue clearance and biofilm disruption. Enzymatic debridement (supported by high-quality double-blind RCT data) and ultrasonic-assisted wound debridement (UAWD) demonstrate highly promising, robust evidence for accelerating wound bed preparation, reducing bacterial colonization, and promoting percentage wound area reduction. However, high efficacy rates reported for UAWD often reflect synergistic combination therapies rather than standalone application, while high success rates for biological maggot therapy (96.6%) derive from uncontrolled case series representing preliminary evidence.

Wound care practitioners and multidisciplinary diabetic foot teams should adopt a balanced, patient-centered, individualized approachselecting and combining debridement modalities based on specific ulcer microenvironment features, underlying vascularity, patient comorbidities, cost-effectiveness, and local institutional resources. Future clinical research should prioritize large-scale, adequately powered, multi-center RCTs utilizing standardized outcome metrics, uniform offloading protocols, and rigorous economic evaluations to establish definitive comparative effectiveness guidelines.

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AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Methodology; Data curation; Formal analysis; Writing – original draft; Validation; Writing review and Editing; Project administration
Author 2: Conceptualization; Supervision.
Author 3: Validation.
Author 4: Validation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Aditya, C., Bukke, S., Anitha, K., Meeraraje, P., Goruntla, N., Yadesa, T., & Onohuean, H. (2025). A comprehensive review on diabetic foot ulcer addressing vascular insufficiency, impaired immune response, and delayed wound healing mechanisms. *Frontiers in Pharmacology*, *16*. https://doi.org/10.3389/fphar.2025.1622055

Armstrong, D. G., Tan, T.–W., Boulton, A. J. M., & Bus, S. A. (2023). Diabetic Foot Ulcers. *JAMA*, *330*(1), 62–75. https://doi.org/10.1001/jama.2023.10578

Campbell, M., McKenzie, J. E., Sowden, A., Katikireddi, S. V., Brennan, S. E., Ellis, S., Hartmann–Boyce, J., Ryan, R., Shepperd, S., Thomas, J., Welch, V., & Thomson, H. (2020). Synthesis without meta-analysis (SWiM) in systematic reviews: Reporting guideline. *BMJ*, l6890. https://doi.org/10.1136/bmj.l6890

Chen, H., Xiao, T., Zhang, L., Liu, N., Liang, X., Li, T., Wang, J., Peng, Y., Liu, Y., & Xu, J. (2023). Effect of ultrasound-supported wound debridement in subjects with diabetic foot ulcers: A meta-analysis. *International Wound Journal*, *20*(7), 2618–2625. https://doi.org/10.1111/iwj.14133

Chen, P., Vilorio, N. C., Dhatariya, K., Jeffcoate, W., Lobmann, R., McIntosh, C., Piaggesi, A., Steinberg, J., Vas, P., Viswanathan, V., Wu, S., & Game, F. (2024). Guidelines on interventions to enhance healing of foot ulcers in people with diabetes (IWGDF 2023 update). *Diabetes/Metabolism Research and Reviews*, *40*(3), e3644. https://doi.org/10.1002/dmrr.3644

Dawi, J., Tumanyan, K., Tomas, K., Misakyan, Y., Gargaloyan, A., Gonzalez, E., Hammi, M., Tomas, S., & Venketaraman, V. (2025). Diabetic Foot Ulcers: Pathophysiology, Immune Dysregulation, and Emerging Therapeutic Strategies. *Biomedicines*, *13*(5), 1076. https://doi.org/10.3390/biomedicines13051076

Dayya, D., O'Neill, O. J., Huedo–Medina, T. B., Habib, N., Moore, J., & Iyer, K. (2022). Debridement of Diabetic Foot Ulcers. *Advances in Wound Care*, *11*(12), 666–686. https://doi.org/10.1089/wound.2021.0016

Della Pepa, G., Lombardi, G., Gianfrancesco, S., Piccolo, R., Chirico, G., Pellegrino, M., Santella, L., Tecce, N., Volpicelli, A., Sollo, E., Bozzetto, L., Masulli, M., Riccardi, G., Rivellese, A. A., & Saldalamacchia, G. (2023). Triticum vulgare Extract and Polyhexanide (Fitostimoline® Hydrogel/Fitostimoline® Plus Gauze) versus Saline Gauze Dressing in Patients with Diabetic Foot Ulcers: Results of a Randomized Controlled Trial. *Journal of Clinical Medicine*, *12*(10), 3596. https://doi.org/10.3390/jcm12103596

Flores–Escobar, S., Álvaro-Afonso, F., García–Álvarez, Y., López–Moral, M., Lázaro–Martínez, J., & García–Morales, E. (2022). Ultrasound–Assisted Wound (UAWD) Debridement in the Treatment of Diabetic Foot Ulcer: A Systematic Review and Meta-analysis. *Journal of Clinical Medicine*, *11*. https://doi.org/10.3390/jcm11071911

Flores–Escobar, S., García–Álvarez, Y., Álvaro–Afonso, F. J., López–Moral, M., García–Madrid, M., & Lázaro–Martínez, J. L. (2025). Clinical Effects of Weekly and Biweekly Low–Frequency Ultrasound Debridement Versus Standard of Wound Care in Patients with Diabetic Foot Ulcers: A Pilot Randomized Clinical Trial. *The International Journal of Lower Extremity Wounds*, 15347346251332795. https://doi.org/10.1177/15347346251332795

Gao, H., Chen, J., Zhao, Z., & Wang, G. (2022). A combination of UAWD and topical cortex phellodendri compound fluid in patients with diabetic foot ulcers. *Medicine*, *101*(32), e29604. https://doi.org/10.1097/MD.0000000000029604

Gustinelli Barbosa, M. A., Paggiaro, A. O., Carvalho, V. F. D., Isaac, C., & Gemperli, R. (2018). Effects of Hydrogel With Enriched Sodium Alginate in Wounds of Diabetic Patients. *Plastic Surgical Nursing*, *38*(3), 133–138. https://doi.org/10.1097/PSN.0000000000000228

JBI Critical Appraisal Tools | JBI. (n.d.). Retrieved July 29, 2026, from https://jbidevlin03.services.adelaide.edu.au/critical–appraisal–tools?utm_source=chatgpt.com

Lázaro–Martínez, J. L., Álvaro–Afonso, F. J., Sevillano–Fernández, D., García–Álvarez, Y., Sanz–Corbalan, I., & García–Morales, E. (2020). Cellular Proliferation, Dermal Repair, and Microbiological Effectiveness of UAWD (UAWD) Versus Standard Wound Treatment in Complicated Diabetic Foot Ulcers (DFU): An Open–Label Randomized Controlled Trial. *Journal of Clinical Medicine*, *9*(12), 4032. https://doi.org/10.3390/jcm9124032

Lazzarini, P. A., & van Netten, J. J. (2025). Best practice offloading treatments for diabetic foot ulcer healing, remission, and better plans for the healing–remission transition. *Seminars in Vascular Surgery, Interdisciplinary Limb Preservation: What Every Vascular Surgeon Needs to Know*, *38*(1), 110–120. https://doi.org/10.1053/j.semvascsurg.2025.01.012

Liang, J., Gong, X., Hu, X., You, C., Zhou, J., Gao, Y., Zong, J., & Liu, Y. (2024). Integrated genetic analysis of diabetic complications: Bioinformatics insights into foot ulcers, neuropathy and peripheral artery disease. *International Wound Journal*, *21*(2), e14748. https://doi.org/10.1111/iwj.14748

Lin, C., Liu, J., & Sun, H. (2020). Risk factors for lower extremity amputation in patients with diabetic foot ulcers: A meta-analysis. *PLOS ONE*, *15*(9), e0239236. https://doi.org/10.1371/journal.pone.0239236

Lin, C.–J., Lin, C.–W., Wu, S.–H., & Cheng, H.–M. (2025). Effectiveness of Maggot Debridement Therapy for Chronic Wounds: A Systematic Review and Meta-analysis of Randomised Controlled Trials. *Wound Repair and Regeneration*, *33*(5), e70095. https://doi.org/10.1111/wrr.70095

Lin, C.–W., Armstrong, D. G., Lin, C.–H., Liu, P.–H., Hung, S.–Y., Lee, S.–R., Huang, C.–H., & Huang, Y.–Y. (2019). Nationwide trends in the epidemiology of diabetic foot complications and lower–extremity amputation over an 8–year period. *BMJ Open Diabetes Research & Care*, *7*(1), e000795. https://doi.org/10.1136/bmjdrc–2019–000795

Liu, E., Hu, X., Zhang, W., Xiao, W., Shen, Y., Luo, Y., Zheng, Z., Zhou, P., He, Y., & Que, H. (2024). Efficacy and safety of UAWD in the treatment of diabetic foot ulcers: A systematic review and meta-analysis of 11 randomized controlled trials. *Frontiers in Endocrinology*, *15*, 1393251. https://doi.org/10.3389/fendo.2024.1393251

McDermott, K., Fang, M., Boulton, A. J. M., Selvin, E., & Hicks, C. W. (2023). Etiology, Epidemiology, and Disparities in the Burden of Diabetic Foot Ulcers. *Diabetes Care*, *46*(1), 209–221. https://doi.org/10.2337/dci22–0043

Nair, H. K., Ahmad, N. W., Ismail, A. A., Alabed, A. A. A., Zheming, B. O., Kaur, G., Hassan, H., & Supaat, N. I. (2021). Maggot debridement therapy to treat hard–to–heal diabetic foot ulcers: A single–centre study. *Journal of Wound Care*, *30*(Sup12), S30–S36. https://doi.org/10.12968/jowc.2021.30.Sup12.S30

Ning, P., Liu, Y., Kang, J., Cao, H., & Zhang, J. (2023). Comparison of healing effectiveness of different debridement approaches for diabetic foot ulcers: A network meta-analysis of randomized controlled trials. *Frontiers in Public Health*, *11*. https://doi.org/10.3389/fpubh.2023.1271706

Nube, V. L., Alison, J. A., & Twigg, S. M. (2021). Frequency of sharp wound debridement in the management of diabetes–related foot ulcers: Exploring current practice. *Journal of Foot and Ankle Research*, *14*, 52. https://doi.org/10.1186/s13047–021–00489–1

Olamoyegun, M. A., Afolabi, S. A., Alare, K., Olamoyegun, O. D., Adeyemi, T., & Olopade, O. B. (2026). Epidemiology and Outcome of Diabetic Foot Ulcers in Nigeria: A Systematic Review and meta-analysis of 2 Decades: 2005 – 2024. *Journal of Epidemiology and Global Health*, *16*(1), 19. https://doi.org/10.1007/s44197–025–00509–4

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo–Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, n71. https://doi.org/10.1136/bmj.n71

Schardt, C., Adams, M. B., Owens, T., Keitz, S., & Fontelo, P. (2007). Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Medical Informatics and Decision Making*, *7*(1), 16. https://doi.org/10.1186/1472–6947–7–16

Sharma, D. J., Singh, R., Bahl, I., & Singh, G. (2024). Role of hydrosurgery in the management of diabetic foot disease– new application of an age–old technique. *International Surgery Journal*, *11*(7), 1103–1111. https://doi.org/10.18203/2349–2902.isj20241737

Silva, M. A., Hamilton, E. J., Russell, D. A., Game, F., Wang, S. C., Baptista, S., & Monteiro–Soares, M. (2025). Diabetic Foot Ulcer Classification Models Using Artificial Intelligence and Machine Learning Techniques: Systematic Review. *Journal of Medical Internet Research*, *27*(1), e69408. https://doi.org/10.2196/69408

Syam, K., Joiya, S. A., Khan, S., & Unnikrishnan, P. N. (2021). Maggot Debridement Therapy for Chronic Leg and Foot Ulcers: A Review of Randomized Controlled Trials. *Advances in Skin & Wound Care*, *34*(11), 603–607. https://doi.org/10.1097/01.ASW.0000792928.08722.ae

Tonaco, L. A. B., Gomes, F. L., Velasquez–Melendez, G., Lopes, M. T. P., & Salas, C. E. (2018). The Proteolytic Fraction from Latex of Vasconcellea cundinamarcensis (P1G10) Enhances Wound Healing of Diabetic Foot Ulcers: A Double–Blind Randomized Pilot Study. *Advances in Therapy*, *35*(4), 494–502. https://doi.org/10.1007/s12325–018–0684–2

Wernecke, J., Wernecke, M., Ebenau, O., Spruth, B., Krämer, M., Vogelmann, T., & Zöllner, Y. (2025). Epidemiology and the Medical Burden of Diabetic Foot Ulcers Especially in Patients With Infection A Population-Based Analysis From Germany. *International Wound Journal*, *22*(4), e70157. https://doi.org/10.1111/iwj.70157

Zhao, H., Wu, Y., Xie, Y., Li, Y., Chen, C., Li, C., Yang, F., Zhang, D., Wang, Y., & Yuan, J. (2024). Hydrogel dressings for diabetic foot ulcer: A systematic review and meta-analysis. *Diabetes, Obesity and Metabolism*, *26*(6), 2305–2317. https://doi.org/10.1111/dom.15544

Zhou, X., Chen, S., Savitz, B., Yu, N., Perdikis, G., Duckworth, K., Dean, Y., Long, X., & Lineaweaver, W. (2025). Comparative efficacy of different functional hydrogel dressings in healing diabetic foot ulcer: A systematic review and network meta-analysis. *Diabetes, Obesity and Metabolism*, *27*(6), 3431–3441. https://doi.org/10.1111/dom.16367