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Zinc-Chitosan Nanofibers for Necrotic Wound Bed Preparation in High-Grade Diabetic Foot Ulcers: A Prospective Case Series

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Abstract

Background: Severe diabetic foot ulcers (DFUs) with extensive necrotic tissue require effective wound-bed preparation to reduce bioburden and promote granulation. Zinc-chitosan nanofibers possess antimicrobial, immunomodulatory, and moisture balance properties that may enhance wound healing. However, clinical evidence for their use in high-grade necrotic DFUs remains limited.
Aims: This case series evaluated the effectiveness of zinc-chitosan nanofibers as a primary dressing for high-grade diabetic foot ulcers with extensive necrosis.
Methods: This prospective observational case series included three purposefully selected adults with high-grade DFUs containing ≥80% slough. Wounds were assessed at baseline and week 1, 2, and 4 using the DMIST scoring system. Tissue perfusion was evaluated using the ankle brachial pressure index (ABPI), while laboratory investigations included blood glucose, glycated hemoglobin, serum albumin, and leukocyte count. Standardized wound care comprised hypochlorous acid cleansing, staged autolytic and mechanical debridement, moisture balance optimization, zinc-chitosan nanofibers as the primary dressing, foam and multilayer secondary dressings, and culture-guided antibiotic therapy**.**
Results: Baseline DMIST score ranged from 23 to 24, reflecting severe inflammation, purulent exudate, and 80 to 100% slough. ABPI values of 0.8 to 0.9 conformed adequate perfusion for debridement. By week 2, DMIST scores decreased to 21 to 23, with reduced necrosis and early granulation. By week 4, all wounds achieved a DMIST score of 10, with 80 to 95% granulation tissue, marked reductions in exudate and infection, resolution of inflammation, and early epithelialization
Conclusion: Zinc-chitosan nanofibers showed promising clinical benefit as a primary dressing by accelerating wound-bed preparation in severe necrotic DFUs. Large controlled studies are needed to confirm efficacy and establish clinical recommendations.

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INTRODUCTION

The global prevalence of diabetes continues to rise steadily. In 2019, approximately 463 million people (9.3% of the world population) were living with diabetes. This number is projected to reach 578 million (10.2%) by 2030 and 700 million (10.9%) by 2045 (Saeedi et al., 2019). Indonesia faces a substantial burden of diabetes and its complications. Approximately 15% of people with diabetes are estimated to develop diabetic foot ulcers (DFUs)(Yunir et al., 2023). With an estimate 10.3 million people living with diabetes, Indonesia ranks among the countries with the highest diabetes prevalence globally (Ceriello & Colagiuri, 2025). DFUs contribute substantially to disability and lower-limb amputation, accounting for up to 80% of diabetes-related amputations (Andhika, 2020). DFUs often present at an advanced stage because many patients remain underdiagnosed or seek care only after ulcer progression. Infection is a major clinical concern, with

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studies reporting infection in up to 50–60% of DFUs and a high proportion of patients presenting with severe ulcers. Approximately 70% of cases have been reported as Wagner grade >3, while infection may occur in up to 100% of patients with active DFUs (Armstrong et al., 2023; Sitompul et al., 2015).

Delayed intervention leads to impaired healing, increased complications, and the need for repeated debridement. Another report shows that approximately 18.2% of patients require multiple debridement procedures due to inadequate initial wound care (Jain & Viswanath, 2015). The challenge becomes even greater in high-grade DFUs dominated by necrotic or slough tissue. Heavy and persistent bioburden perpetuates the inflammatory phase, inhibits new granulation formation, and significantly delays healing (Atkin et al., 2019; Perrucini et al., 2021). This necessitates efficient and measurable wound-bed preparation strategies (Dayya et al., 2022). Nanomaterial-based technologies, including zinc–chitosan nanofibers, offer promising benefits for managing extensive necrosis by reducing bioburden, stimulating tissue regeneration, and optimizing moisture balance (Davies et al., 2025; Samuel et al., 2024). Zinc–chitosan has long been recognized as a wound-care material capable of accelerating tissue repair (Singh et al., 2017; Yadav et al., 2023). However, structured clinical evidenceon the application of zinc–chitosan nanofibers as a primary wound-bed preparation agent in severe DFU cases with extensive necrosis remain scarce in international literature.

Severe DFUs often follow an unpredictable and prolonged healing trajectory, making structured assessment tools essential for detecting meaningful changes over time. The DMIST scoring system, which evaluates depth, maceration, infection/inflammation, size, tissue type, wound edges, and tunnelling, provides a sensitive and standardized framework for monitoring healing progression and predicting potential treatment failure at an early stage (Oe et al., 2020). Other studies also emphasize that structured wound assessment enhances clinical decision-making, reduces delays in intervention, and supports tailored treatment strategies (Jais & Pratama, 2023). Thus, DMIST is more than an assessment tool; it is a clinically meaningful method for understanding the patient's healing trajectory in a systematic and actionable way.

Therefore, this case series aimed to describe the clinical outcome of zinc–chitosan nanofibers dressing application in managing bioburden and necrotic tissue and promoting wound-bed improvement in three patients with high-grade diabetic foot ulcers (DFUs). In contrast to previous research focusing primarily on zinc-chitosan biomaterial fabrication and laboratory-based evaluation, this study evaluates its real-world clinical application as a primary dressing in three high-grade diabetic foot ulcer cases. Using DMIST scoring, the study documents wound-bed changes, particularly reductions in bioburden and necrotic tissue, and provides a structured clinical protocol for applying this nanofiber-based dressing in severe DFUs.

METHOD

This study employed a prospective observational case series design involving three patients with high-grade diabetic foot ulcers (DFUs) presenting with extensive necrotic or slough tissue covering at least 80% of the wound bed and accompanied by clinical signs of local or systemic infection. A case series design was considered appropriate because the study aimed to provide an in-depth clinical description of wound-bed preparation and healing progression following the application of zinc-chitosan nanofibers in patients with severe DFUs, a clinical presentation that is relatively uncommon and frequently encountered in advanced wound-care practice. Three cases were included using consecutive case sampling during the study period. All patients presenting to the study site who met the predefined eligibility criteria were considered for inclusion until three eligible cases were enrolled. The small number of cases reflects the limited availability of patients who simultaneously met the specific clinical criteria, including high-grade ulcer severity, extensive necrotic tissue, active infection, adequate peripheral perfusion, and completion of the four-week treatment protocol. Cases were therefore not selected based on treatment response. The three patients had comparable baseline wound severity and fulfilled the same eligibility criteria, allowing consistent longitudinal observation of treatment response while limiting clinical heterogeneity.

The study was conducted at WOCARE Center Bogor, West Java, Indonesia. Ethical approval was obtained from the WOCARE Center Research and Development Committee (Approval No.

019/EC-WOCARE/VI/2026). Written informed consent was obtained from all participants before enrollment, and all patient information and clinical photographs were anonymized to maintain confidentiality and protect participant privacy. Eligible participants were adults aged 50-63 years presenting with diabetic foot ulcers containing at least 80% necrotic or slough tissue, clinical evidence of local infection, adequate peripheral perfusion, and willingness to participate in the study and publication process. Patients were excluded if they had severe lower-limb ischemia indicated by an ankle-brachial pressure index (ABPI) below 0.5, osteomyelitis requiring surgical intervention, or were receiving immunosuppressive therapy, as these conditions could substantially alter wound healing and confound interpretation of treatment outcomes.

A commercially available zinc-chitosan nanofiber dressing was used as the primary dressing following standardized wound-bed preparation. Metcovazin Regular, a topical formulation zinc oxide and chitosan, was used as the zinc-chitosan component, while Fibercelle, a gelling fiber dressing composed of sodium carboxymethyl cellulose (sodium-CMC), served as the fiber-based carrier. After wound cleansing and assessment, Metcovazin Regular was applied evenly to the Fiber celle dressing to coat the dressing surface. The Metcovazin-coated Fibercelle was then placed directly onto the wound bed as the primary dressing, allowing the zinc-chitosan formulation to remain in contact with the wound surface while the fiber dressing provided absorption and structural support. This combined dressing was subsequently covered with an appropriate secondary dressing and changed according the predefined dressing protocol. Both materials were applied in their original commercial form without modification and directly to the prepared wound bed according to the standardized wound-care protocol. The dressing was applied and changed according to wound condition and exudate level throughout the four-week observation period. All participants received a standardized four-week wound-care protocol based in the principles of modern wound care. Wound management was delivered within a multidisciplinary service involving certified wound care nurses, general practitioners, and other healthcare professionals experienced in diabetic foot management. Tissue management consisted of autolytic and mechanical debridement to remove non-viable tissue and optimize the wound bed. Infection and inflammation were controlled through wound irrigation using hypochlorous acid (HOCl) with topical antimicrobial therapy administered when clinically indicated. Zinc-chitosan nanofibers were applied directly to the wound bed as the primary dressing and changed twice weekly throughout the treatment period and covered with a foam dressing as the secondary dressing to maintain an optimal moist wound environment and reduce the risk of peri-wound maceration. All procedures followed standardized protocols for wound cleansing, wound-bed preparation, dressing selection, and nursing assessment implemented in the clinical practice setting.

Clinical evaluation was performed at baseline and weekly throughout the four-week observation period using the validated DMIST scoring system, which assesses seven dimensions of wound healing, including Depth, Maceration, Infection/Inflammation, Size, Tissue Type, Wound Edge, and Tunnelling. Weekly DMIST assessment enabled objective monitoring of wound healing progression over time. Peripheral perfusion was evaluated using the ankle-brachial pressure index (ABPI), while laboratory parameters, including leukocyte count, glycated hemoglobin (HbA1c), and random blood glucose levels, were recorded at baseline and during follow-up to assess systemic infection status and glycemic control. Standardized digital wound photographs were obtained at each visit using consistent imaging procedures to provide visual documentation of tissue changes throughout treatment. “The primary outcome measures were reduction of necrotic tissue, increase in granulation tissue formation, improvement in DMIST scores, and resolution of clinical signs of infection. Because this investigation employed a case series design, data analysis focused on descriptive longitudinal evaluation rather than inferential statistical testing. Clinical findings from each patient were analyzed individually using within-case analysis to describe temporal changes in wound characteristics, DMIST scores, perfusion status, laboratory findings, and photographic documentation over the four-week treatment period. Subsequently, cross-case analysis was performed to compare similarities and differences in healing trajectories among the three patients, identify recurring clinical response pattens, and explore potential factors associated with successful wound-bed preparation following zinc-chitosan nanofiber application. This standardized assessment strategy enabled objective documentation of wound healing while providing a

comprehensive description of the biological responses to zinc-chitosan nanofibers in preparing the wound bed high-grade necrotic diabetic foot ulcers.

RESULTS AND DISCUSSION

Results

Case Presentation 1

A 63-year-old man presented to the wound care clinic with a non-healing wound on the left foot (Figure Case 1). The ulcer was located in the metatarsal region and developed after accidental contact with a hot object, followed by inadequate initial wound management. The patient had poorly controlled type 2 diabetes mellitus, with an HbA1c of 13% and random blood glucose of 365 mg/dL. Initial laboratory findings showed hypoalbuminemia (3.1 g/dL) and marked leukocytosis ($26.7 \times 10^3/\mu L$), indicating compromised nutritional status and active systemic inflammation. The patient had previously received routine wound cleansing and dressing at another healthcare facility and was prescribed oral cefadroxil 500 mg three times daily. However, the wound continued to show persistent exudate and local inflammatory signs, His work required prolonged standing and mobility, which increased the importance of wound healing for returning to daily activities and work.

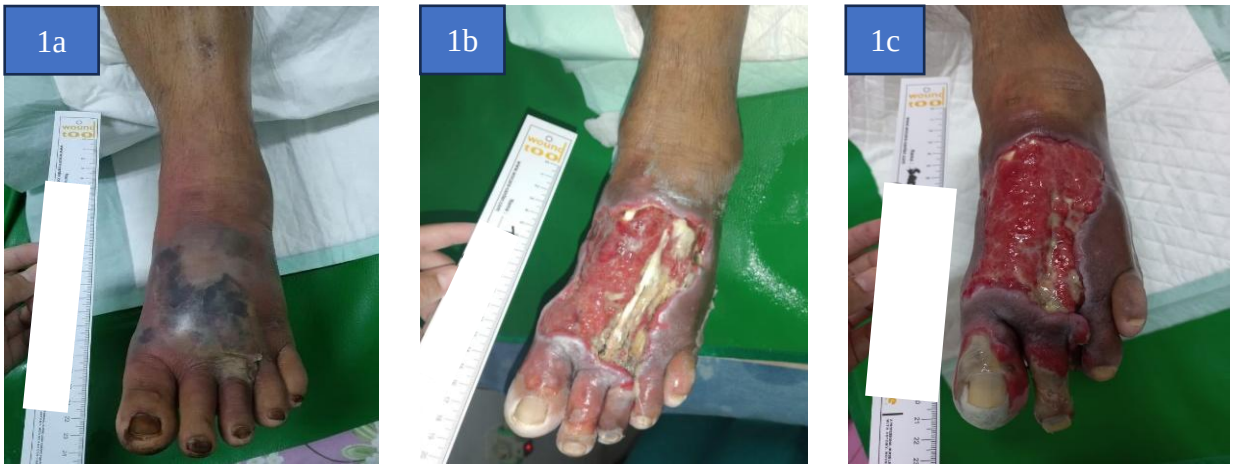

Figure Case 1: S 63-year-old man with a diabetic foot ulcer on the left metatarsal foot. Observation showed 95% granulation of the wound bed later (1c). The infection signs are reduced, such as improvement in oedema and erythema, lower exudate levels, and decreased malodor.

At the initial assessment, the ulcer showed extensive tissue loss and was not assigned a stage. The wound presented with erythema extending to the ankle, abundant purulent exudate, malodor, and 100% slough covering the wound bed. The foot also showed wet necrotic, edema, and violaceous discoloration on the dorsum, raising concern for impaired local tissue perfusion. Wound culture identified *Escherichia coli*, and antibiotic therapy was subsequently adjusted to oral cefixime 200 mg twice daily for three days according to the sensitivity results. Nutritional support included oral albumin supplementation (2 x 3 tablets/day), vitamin D, and vitamin C.

A structured wound-care approach was implemented, including mechanical and autolytic debridement, wound cleansing with hypochlorous acid (HOCl), application of zinc-chitosan nanofiber as the primary dressing, and foam dressing as the secondary dressing. The healing trajectory was monitored using the DMIST scoring system. The DMIST score decreased from 24 at week 1 to 10 at week 4, accompanied by reductions in wound depth and size, resolution of inflammatory signs, and progressive wound-bed improvement (Figure Case 1). The wound bed changed from 100% slough to approximately 95% healthy granulation tissue. Malodor resolved, purulent exudate decreased substantially, and early epithelialization was observed at the wound margins.

Case Presentation 2

A 60-year-old man presented to the wound care clinic with a persistent ulcer in the metatarsal region of the right foot that had developed following an automobile accident (Figure Case 2). Before receiving appropriate wound care, the patient had used conventional approaches, including massage and herbal treatments, which may have contributed to additional tissue trauma and delayed healing. The patient appeared generally weak and had poorly controlled diabetes mellitus. Initial laboratory findings showed Leukocytosis (14.1 × 10^3/µL), serum albumin (3.5 g/dL), HbA1c (13%), and a random blood glucose level of 283 mg/dL, indicating active inflammation, suboptimal nutritional status, and poor glycemic control. Wound culture identified *Escherichia coli*, and antibiotic therapy was adjusted to oral cefixime 200 mg twice daily for seven days according to the susceptibility results. Supportive therapy included oral albumin supplementation (2 x 3 tablets/day), vitamin D, and vitamin C.

Figure Case 2: H 60-year-old man with a chronic wound on the right metatarsal foot Significant improvement was observed, such as complete granulation (2c). The infection signs showed considerable enhancement, such as reduced oedema and erythema.

The patient occupation required prolonged standing and regular physical activity, which represented a potential challenge to activity restriction and offloading during wound treatment. Prior to referral, he had received routine wound care with daily dressing changes; however, the wound showed limited clinical improvement. A structured wound-care protocol was subsequently implemented. Non-viable tissue was managed through mechanical and autolytic debridement, followed by wound cleansing with HOCl. Zinc-chitosan nanofibers were applied as the primary dressing, with foam dressing as the secondary layer to maintain an appropriate moist wound environment and protect the developing granulation tissue.

Wound progression was monitored using the DMIST score. The score decreased from 24 in week 1 to 23 in week 2 and subsequently to 10 in week 4. This improvement was accompanied by a reduction in wound size and necrotic tissue, resolution of inflammatory signs, and progressive granulation tissue formation. The wound bed changed from 100% slough to approximately 95% granulation tissue, with no apparent clinical signs of infection at week 4 (Figure Case 2). Overall, the patient demonstrated substantial wound-bed improvement during the four-week multimodal wound-care protocol.

Case Presentation 3

A 50-year-old man presented to the wound care clinic with a three-week-old ulcer on the posterior aspect of the left foot (Figure Case 3). The wound developed after a foot injury while gardening. Before presentation, the patient managed the wound independently using rivanol and 0.9% NaCl compresses without professional wound assessment. At initial examination, the ulcer was deep and extensive, with thick yellow slough, purulent exudate, and surrounding inflammatory signs, indicating a chronic wound complicated by local infection. The patient appeared generally weak. Laboratory findings showed leukocytosis (11.8 × 10^3/µL), hypoalbuminemia (3.3 g/dL), an

HbA1c of 10%, and a random blood glucose level of 206 mg/dL, indicating poor glycemic control, active inflammation sigs, and suboptimal nutritional status. Wound culture identified *Escherichia coli*, and antibiotic therapy was adjusted to oral cefixime 200 mg twice daily for seven days according to the susceptibility results. Nutritional support included oral albumin supplementation and vitamins D and C.

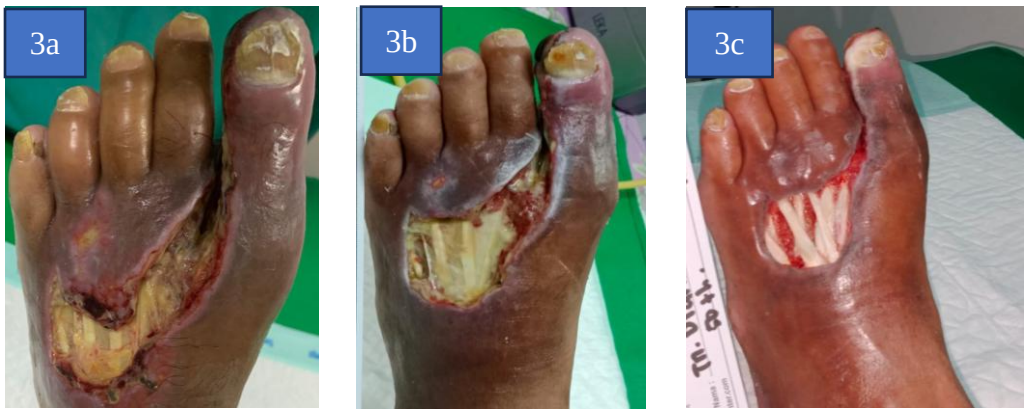

Figure Case 3: D 50 -year-old man with a chronic wound on the lift metatarsal foot Significant improvement was observed, such as complete granulation and tendon expose (3c). The infection signs showed considerable enhancement, such as reduced oedema and erythema.

The patient's occupation involved daily agricultural activities in wet environments and prolonged mobility, which presented potential challenges for wound protection, offloading, and infection prevention. The depth and extent of the ulcer also impaired walking and occupational activities. Peripheral perfusion was assessed using the ankle-brachial index (ABI) with a value of 0.90 indicating adequate peripheral perfusion. Wound management consisted of mechanical and autolytic debridement to remove non-viable tissue, wound cleansing with HOCl, and application of zinc-chitosan nanofiber as the primary dressing. Foam dressing was used as the secondary dressing to maintain an appropriate moist wound environment and protect the developing tissue. The wound was assessed weekly using DMIST scoring.

The total DMIST score was 24 at week 1, decreased to 23 at week 2, and reached 10 by week 4. The improvement was accompanied by reduction in wound size and necrotic tissue, resolution of clinical signs infection and inflammation, and progressive development of granulation tissue. The wound-bed changed from 100% slough at baseline to approximately 80% granulation tissue with aclean appearing wound bed and visible tendon at week 4 (Figure Case 3). These findings indicate substantial wound-bed improvement during the four-week multimodal wound-care protocol.

Table 1. DMIST Score and Wound Progression

Case	Week 1	Week 2	Week 4	Clinical Wound Progression
Case 1	24	23	10	**Week 1:** Severe ulcer with 100% slough, heavy purulent exudate, malodor, edema, and extensive inflammation. **Week 2:** Slough 30% with tendon exposure, 70% early granulation tissue formation, persistent inflammation, increased maceration, and the appearance of small tunneling. **Week 4:** Granulation reached 95%, slough 5%, no signs of infection, minimal odor and exudate, and wound edges showing early epithelialization.
Case 2	24	23	10	**Week 1:** Large ulcer with 100% thick necrotic tissue, purulent discharge, peri-wound inflammation, and positive *E. coli* culture. **Week 2:** Slough 90% and 10% granulation

Case	Week 1	Week 2	Week 4	Clinical Wound Progression
				tissue in wound bed, reduction in wound size, mild tunneling persisted, and inflammation remained present. **Week 4:** Wound appeared clean, granulation reached 95%, slough 5%, infection resolved, and a stable wound environment was achieved.
Case 3	23	21	10	**Week 1:** Extensive ulcer with 100% thick yellow slough, purulent discharge, intense inflammation, and irregular wound edges. **Week 2:** Slough 95% with tendon expose, presence of small tunneling, and early granulation formation of 5%. **Week 4:** Inflammation resolved, maceration controlled, granulation reached 80%, slough 20% and exposed tendon appeared healthier and ready for the proliferative phase.

Overall, the three cases demonstrated a consistent improvement in wound status throughout the four-week follow-up as reflected by a progressive reduction in DMIST score. Scores decreased from 23-24 at baseline to 21-23 in week 2 and reached 10 by week 4. This improvement indicates a reduction in wound severity, necrotic burden, inflammation, and other adverse wound characteristics, accompanied by progressive granulation and stabilization of the wound bed. Although minor tunneling was observed in some cases during the healing process, it did not interfere with the overall positive wound progression. By week 4, the wounds had reached a more stable condition that supported the transition toward the proliferative phase of healing.

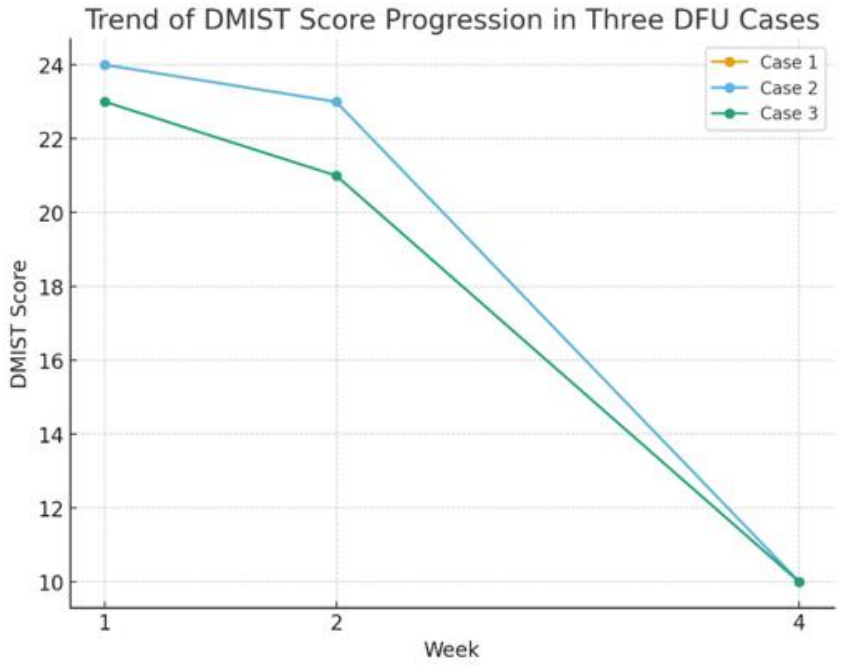

Figure 4. DMIST Score Progression

Overall, the three cases demonstrated an almost identical pattern of clinical improvement, reflected by a 13 –14-point reduction in DMIST scores within four weeks. This trend confirms that the combined use of HOCl cleansing, targeted debridement, moisture management, infection control, and zinc-chitosan nanofiber primary dressing provides consistent therapeutic benefits in high-grade diabetic foot ulcers (DFUs). The DMIST trajectory graph illustrates a steep and

sustained decline across all cases, reinforcing the effectiveness and reproducibility of the implemented wound-care protocol.

Discussion

The findings case series demonstrated that zinc-chitosan nanofibers, incorporated into a standardized multidisciplinary wound-care protocols, were associated with substantial improvement in wound-bed preparation among patients with severe diabetic foot ulcers characterized by extensive necrotic tissue. Across all three patients, zinc-chitosan nanofibers consistently accelerated autolytic debridement, reduced wound bioburden, and promoted early granulation tissue formation during the first four weeks of treatment. Necrotic tissue burden decreased markedly from 80% to 100% at baseline to minimal residual necrosis by week four, while healthy granulation tissue increased to approximately 80% to 95% of the wound bed. Concurrently, clinical signs of inflammation and infection progressively resolved, indicating successful transition from the inflammatory phase toward the proliferative phase of wound healing. Rather than indicating that zinc-chitosan nanofibers alone were responsible for these outcomes, the present findings suggest that their integration into a comprehensive wound-bed preparation strategy may facilitate biological process essential for tissue regeneration in complex DFUs. This observation is clinically important because extensive necrotic tissue is one of the principal barriers to healing and is strongly associated with persistent infection, delayed epithelialization, prolonged hospitalization, and increased amputation risk.

The favorable healing trajectory observed in this series is biologically plausible and supported by recent advances in biomaterial research. Chitosan exhibits broad-spectrum antimicrobial activity, modulates macrophage polarization toward an anti-inflammatory phenotype, regulates cytokine production, scavenges reactive oxygen species, and stimulates fibroblast proliferation. Collagen deposition, angiogenesis, and extracellular matrix remodeling (Afrose et al., 2025; Ji et al., 2022; Wang et al., 2025). Experimental studies have further shown that incorporating zinc into chitosan-based materials can enhance antimicrobial, anti-inflammatory, antioxidant, and cell-migration properties (Mutlu et al., 2022). Electrospun chitosan /PVA/zinc oxide nanofibers have also demonstrated antibacterial and antioxidant activity with improved wound healing in diabetic wound models (Ahmed et al., 2018). More recently, zinc-ion coordinated chitosan/polycaprolactone composite nanofibers demonstrated enhanced antimicrobial and immunomodulatory activity, supporting the potential of zinc-containing chitosan nanofibers as multifunctional wound-care materials (Zhou et al., 2023). These findings provide biological support for clinical observations in the present case series, although direct extrapolation from experimental biomaterial studies to clinical effectiveness should be made cautiously. Incorporating zinc into the nanofiber matrix may further enhance keratinocyte migration, collagen synthesis, epithelial regeneration, antioxidant defense, and innate immune responses while maintaining structural integrity of the dressing. In addition, the porous nanofiber architecture provides an optimally moist and oxygen-permeable microenvironment that supports cell migration and tissue repair. These complementary biological mechanisms likely explain the rapid reduction in necrotic tissue and consistent development of healthy granulation tissue observed across all three cases. Similar therapeutic benefits have been reported in regional studies evaluating chitosan-based dressings for chronic DFUs, where reduced infection indices, accelerated granulation tissue formation, and shorter healing times were consistently observed (Bahri et al., 2024; Gitarja et al., 2018; Samuel et al., 2024; Shah et al., 2025).

Objective assessment using the DMIST instrument further strengthened the interpretation of wound healing progression. DMIST was developed specifically for monitoring diabetic foot ulcers across seven wound characteristics, including wound depth, tissue composition, inflammation, infection control, wound size, wound edges, and tunnelling. Validity has been demonstrated through correlations with established wound assessment instruments and its ability to discriminate wound severity and predict non-healing at fourweeks (Oe et al., 2020). In the present case series, the progressive reduction in DMIST score from 24, 24, and 23 at baseline to 10 by week four provided a standardized representation of changes in wound characteristics. The use of a validated multidimensional assessment tool minimized subjective interpretation and enabled

standardized longitudinal evaluation of healing progression, thereby strengthening clinical decision-making (Tsuchiya, 2023; Yotsu et al., 2023). However, these improvements should not be interpreted as evidence of the isolated efficacy of zinc-chitosan nanofibers. This interpretation is consistent with the principles of contemporary wound-bed preparation. The 2024 Delphi consensus on foot ulcer management emphasizes systematic assessment and management of wound tissue, infection and inflammation, moisture balance, and other local and systematic factors as interconnected components of wound-bed preparation (Stacey et al., 2024). Instead, wound healing likely resulted from synergistic interactions between advanced biomaterial therapy and comprehensive multidisciplinary wound management. Patients received sequential wound-bed preparation consisting of autolytic debridement during the initial week, followed by combined autolytic and conservative sharp wound debridement (CSWD) during the second week, together with culture-guided antimicrobial therapy, glycemic optimization, nutritional support, and maintenance of an optimal moist wound environment (Afiani et al., 2019; Frykberg & Banks, 2015; Lipsky et al., 2020; Nair et al., 2024). Consequently, the observed clinical outcomes should be viewed as the result of an integrated therapeutic strategy rather than a single intervention. This approach is consistent with the IWGDF framework, which positions appropriate wound-bed preparation, debridement, basic wound dressing, and multidisciplinary standard care as the foundation of DFUs management before adjunctive wound-healing interventions are considered (Chen et al., 2024).

An additional factor that may have contributed substantially to wound healing was the incorporation of hypochlorous acid (HOCl) into the wound cleansing protocols. HOCl possesses rapid antimicrobial activity against Gram-positive bacteria, Gram-negative bacteria, fungi, and mature biofilms while demonstrating excellent tissue compatibility and minimal cytotoxicity toward viable cells (Burian et al., 2022; Serena et al., 2023). Previous clinical evaluation of super-oxidized solution in chronic wound also supports its potential role as a wound-cleansing agent for controlling wound bioburden and supporting wound management (Bahri, 2024). Reducing wound bioburden before application of zinc-chitosan nanofibers likely optimized the wound microenvironment and facilitated tissue regeneration. Current international guidelines similarly recommend integrating effective wound cleansing and infection control into multimodal DFU management due to successful wound-bed preparation requires simultaneous control of microbial burden, maintenance of moisture balance, and preservation of viable tissue (Armstrong et al., 2017; Hinchliffe et al., 2020; Lipsky et al., 2020). Therefore, the favorable outcomes observed in this case series probably reflect the combined effects of advanced dressing technology and evidence-based wound-bed preparation principles.

Overall, the present findings are consistent with previous studies reporting beneficial effects of chitosan-based and metal-containing biomaterials in chronic wound management. In a recent case series from WOCARE Indonesia, nano-colloidal silver-zinc cream was associated with progressive infection control and complete wound closure in three patients with DFUs, although the follow-up period was substantially longer than that used in the present study (Mokti et al., 2025). Clinical evidence is also emerging. In the CHITOWOUND randomized placebo-controlled trial, chitosan -based gel was associated with a greater median reduction in wound surface area than placebo after 10 weeks of treatment (Slivnik et al., 2024). Nevertheless, evidence regarding chitosan dressing remains heterogeneous. Several clinical investigations have demonstrated only modest improvements or no significant differences compared with other advanced wound dressings, particularly among patients with uncontrolled hyperglycemia, critical limb ischemia, persistent biofilm infection, extensive osteomyelitis, or poor adherence to multidisciplinary treatment. Differences in wound severity, biomaterial composition, treatment duration, outcome measures, and concomitant therapies may explain these discrepancies across studies. Compared with these reports, patients included in the present case series demonstrated preserved peripheral perfusion, standardized multidisciplinary care, and complete adherence to the treatment protocols, factors that may have enhanced the biological effectiveness of zinc-chitosan nanofibers and contributed to the consistent healing trajectories observed.

Preserved peripheral circulation also appeared to support favorable healing responses. ABPI values ranging from 0.8 to 0.9 confirmed adequate lower-extremity perfusion and suggested that delayed wound healing was primary attributable to inflammatory, infectious, and metabolic

disturbances rather than critical ischemia (Kim et al., 2023; Morozova et al., 2018). Consequently, optimization of infection control and wound-bed preparation was likely sufficient to restore progression toward tissue regeneration. The reproducibility of healing trajectories across the three patients further suggests that this standardized treatment protocol may be feasible for implementation within specialized community-based wound-care services in Indonesia where multidisciplinary management is available. These findings also have implementation of community-based wound care services. A standardized wound-bed preparation protocol that combines wound assessment, debridement, infection control, appropriate dressing selection, nutritional support, and glycemic management can provide a structured approach for managing complex DFUs outside tertiary hospital settings when appropriate clinical expertise and referral pathways are available. In community-based services, such an approach may support earlier identification of delayed healing, facilitate timely wound-bed optimization, and improve continuity of care for patients who require repeated wound assessment. The use of DMIST as structured assessment tool may further support consistent monitoring and communication among wound care professionals. Although the present case series cannot establish the effectiveness or cost-effectiveness of this model, the observed clinical trajectories provide preliminary evidence of its practical feasibility and generate a basic for further evaluation in larger community-based populations. This implementation perspective is particularly relevant to wound-care and community health settings because it emphasizes the translations of advanced dressing technology into structured, multidisciplinary clinical practice rather than evaluating the biomaterial solely under experimental conditions.

Despite these encouraging findings, several limitations should be acknowledged. This investigation involved only three patients treated at a single wound-care center using a case series design without a comparison group. Consequently, causal relationships cannot be attributed exclusively to zinc-chitosan nanofibers because debridement, antimicrobial therapy, glycemic optimization, nutritional support and other components of multidisciplinary care may also have substantially contributed to wound healing. Furthermore, the relatively short follow-up period precluded assessment of complete wound closure, ulcer recurrence, functional recovery, and long-term durability of treatment outcomes. Therefore, the present findings should be regarded as preliminary clinical evidence that generates hypotheses rather than definitive proof of treatment efficacy.

Implications

The prospective clinical value of zinc-chitosan nanofibers as a primary dressing for wound-bed preparation in high-grade DFUs with extensive necrotic tissue is illustrated in this case series. The integrated use of zinc-chitosan nanofibers in comprehensive wound care protocols may enhance early wound healing outcomes as evidenced by the consistent reduction in DMIST scores, resolution of infection and inflammation observed in all three cases. The results also lend credence to the utilization of structured wound assessment I conjunction with the DMIST scoring system to objectively monitor treatment response and inform clinical decision making. The method may aid in the reduction of prolonged inflammation, the reduction of repeated debridement, and the earlier progression to the proliferation phase of wound healing in clinical practice.

Research contribution

This study offers preliminary clinical evidence supporting the use of zinc-chitosan nanofibers as a primary dressing in high-grade DFUs that are distinguished by extensive necrotic-tissue. The case series, in contrast to previous research that primarily reported laboratory or biomaterial development, illustrates real world clinical implementation through the use of a standardized wound care protocol and serial DMIST assessment in a four-week period. The study also emphasizes the integration of nanofiber therapy with infection control, moisture support, perfusion assessment and staged debridement, thereby providing practical evidence for the management of modern DFUs particularly in resource-limited clinical settings.

Limitations

Several limitations should be acknowledged. First, the findings have limited generalizability because the case series included only three consecutive patients from a single wound-care center.

Although consecutive case inclusion reduced investigator-driven selection, selection bias cannot be completely excluded because only patients who met the specific eligibility criteria and were treated at the study site were included. Second, the absence of a control group precludes direct comparison with standard wound care or other advanced wound dressings and limits the ability to determine whether the observed improvement was attributable specifically to zinc-chitosan nanofibers. Third, the four-week follow-up period was relatively short and therefore did not allow assessment of complete wound closure, ulcer recurrence, functional recovery, or long-term treatment outcomes. Finally, the effect of zinc-chitosan nanofibers could not be isolated from the concurrent interventions, including mechanical and autolytic debridement, HOCl wound cleansing, antimicrobial therapy, nutritional supplementation, glycemic management, and multidisciplinary wound care. Therefore, the observed improvements should be interpreted as preliminary clinical observations rather than definitive evidence of treatment efficacy. Larger prospective studies with appropriate comparison groups and longer follow-up are needed to confirm these findings.

Suggestions

Zinc-chitosan nanofibers dressing should be assessed in future research through adequately powered RCTs with a more diverse patient population. In order to evaluate cost-effectiveness, limb salvage, recurrence rates, and complete wound closure, a longer follow-up is necessary. Additionally, comparative studies with other advanced wound dressing are required to ascertain their relative clinical efficacy. Additionally, further research investigating the biological mechanisms of zinc-chitosan nanofibers such as their impact on inflammation, angiogenesis, collagen deposition, and biofilm control, wound offer more robust evidence in support of their routine clinical application in the management of diabetic foot ulcers.

CONCLUSION

Zinc–chitosan nanofibers show strong potential as an effective wound-bed preparation agent for diabetic foot ulcers with extensive necrotic burden. When integrated into a comprehensive wound-care protocol including infection control, moisture management, and structured debridement, these nanofibers contribute to substantial clinical improvement within 2-4 weeks. Combined with objective evaluation using DMIST, the intervention consistently produced marked reductions in necrosis, resolution of inflammation, and robust granulation formation across all three cases. This case series supports zinc-chitosan nanofibers as a promising therapeutic option for improving outcomes in severe DFUs, while underscoring the need for larger controlled studies to validate these findings across diverse clinical settings.

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AUTHOR CONTRIBUTION STATEMENT

KB, TK, HH and KF were involved in the conception of this study. Data Collection was conducted by KH and KF, with disputes between the case study that were selected settled by KB and KF. KB and KF drafted the case study, while TK and HH did a critical revision of the case study. Final approval of the version to be published was granted by all authors.

AI DISCLOSURE STATEMENT

The author used AI technology (Google Gemini) during the preparation of this work for (grammar correction, sentence-structure refinement, and translation). After using the tool/service, the author thoroughly reviewed and edited the content as needed and takes full responsibility for the content of the publication.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest, whether financial, personal, or professional, with any party that could influence the objectivity, execution or results of this research.

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