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Original Research

A Pharmacy practice perspective on the performance of a non-pharmacological device for wound protection in contaminated water exposure

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Abstract

Background: Wound exposure to water significantly increases the risk of infection and delayed healing, particularly in seawater immersion wounds (SWIs) where microbial contamination exceeds 100 million organisms per liter. NU_Woundguard, a medical-grade silicone protective device, was designed to maintain a watertight seal over standard dressings and reduce contamination risk. **Objective:** To rigorously evaluate the efficacy and safety of NU_Woundguard in preventing water ingress under control, reproducible laboratory conditions simulating freshwater and seawater immersion. **Methods: A** controlled laboratory experiment was conducted using anatomically accurate, 3D-printed foot models with clinically validated normal and SWI wound simulations. Models were randomly assigned to Control (standard dressing only) or Intervention (standard dressing plus NU_Woundguard) groups. Both groups underwent standardized immersion at 10, 30, and 60 minutes in freshwater and seawater (n = 5 per condition). The primary efficacy outcome was water penetration, quantified by analytical weighing of absorbent detection sheets pre- and post-immersion. Safety outcomes included structural integrity, tensile strength retention, and dressing compatibility following 10 immersion cycles and 30 mechanical stress cycles. All measurements were performed in duplicate by blinded assessors using calibrated instruments. **Results:** NU_Woundguard achieved zero leakage across all conditions (0/30 samples; 0.00 ± 0.00 g), while controls exhibited 100% leakage. At 60 minutes, mean penetration in controls was 1.85 ± 0.42 g (freshwater) and 2.14 ± 0.39 g (seawater). Tensile strength retention was 94.6% ± 2.1%, with no structural defects observed. **Conclusion:** Under validated, standardized conditions, NU_Woundguard demonstrated complete prevention of water penetration and maintained mechanical durability, supporting its clinical potential as a non-pharmacological wound protection strategy.

Keywords: wound protection device, seawater immersion wound, water penetration prevention, non-pharmacological intervention

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INTRODUCTION

Exposure of a wound to water increases the risk of inflammation, secondary infection, and, in severe cases, sepsis[1]. These complications delay healing, prolong treatment, and negatively impact quality of life. For individuals with diabetes, the consequences can include lower-limb amputation and mortality[1-3]. Diabetic foot ulcers also contribute to significant physical, emotional, and socioeconomic burdens, highlighting the need for integrated care approaches that address both medical and psychosocial aspects[3]. Recent scoping reviews identify preventing wound exposure to water as an essential non-pharmacological strategy to reduce complications[4]. Reported adverse outcomes include delayed wound healing, increased infection rates, and progression to systemic infection in high-risk patients, all of which contribute to greater morbidity and healthcare utilization[3-4].

Although randomized controlled trials have demonstrated that surgical wounds may be safely exposed to clean water in the immediate postoperative period without increasing infection rates or compromising cosmetic outcomes[5], the evidence regarding seawater immersion wound (SWI) management is markedly different[6]. SWI wounds are subjected to more than 100 million microbial organisms per liter of seawater, including pathogenic species such as *Vibrio vulnificus*, *Pseudomonas* spp., and antibiotic-resistant *Escherichia coli*, which substantially elevates the risk of infection and impedes the healing process[6]. To address these challenges, advanced interventions—such as vacuum-assisted closure at negative pressures of 120–180 mmHg, application of human adipose-derived stem cells to promote angiogenesis via EGFR/MEK/ERK signaling, and collagen-hydrogel dressings that provide seawater protection for up to four hours—have demonstrated improved wound healing and infection control compared to standard terrestrial wound management protocols.

Therefore, the development of equipment capable of protecting SWI wounds from microbial contamination and other harmful environmental factors would offer substantial benefits to users by reducing the risk of complications and indirectly improving the overall quality of life.

The Medical and Pharmacy Innovation Research and Development Unit, Faculty of Pharmaceutical Sciences, Naresuan University, Phitsanulok, Thailand, has developed an innovative device called NU_Woundguard, designed to protect wounds from seawater immersion (SWI) and contaminated environments. NU_Woundguard (Figure 1) is a highly durable, thick silicone-based protective sock with excellent elasticity and moisture control, allowing it to fit comfortably over standard wound dressings. When used during bathing or water exposure, it prevents pain and protects the wound from contact with contaminated water, thereby reducing the risk of inflammation and infection. This innovation is particularly beneficial for individuals with a high likelihood of water exposure, such as military personnel, agricultural workers, and others in similar environments.

Pharmacy practice innovation plays a critical role in addressing infection risks associated with wound exposure to contaminated water. Beyond pharmacological interventions, pharmacists are positioned to implement non-drug strategies that complement antimicrobial stewardship and infection prevention. Integrating devices such as NU_Woundguard into wound care protocols aligns with contemporary pharmacy practice models that emphasize patient education, multidisciplinary collaboration, and preventive care. Pharmacists can provide counseling on device selection, correct application, and maintenance during routine dispensing of wound care products or chronic disease medications. Additionally, incorporating NU_Woundguard into community and hospital pharmacy services supports continuity of care for high-risk populations, including patients with diabetic foot ulcers and individuals in flood-prone regions. By leveraging pharmacists' accessibility and clinical expertise, these innovations can reduce unnecessary antibiotic use, lower the incidence of wound infections, and ultimately improve patient outcomes while containing healthcare costs.

The aim of this research was to evaluate the efficacy and safety of the device through a series of relevant laboratory-based experimental designs. This study did not involve human participants and posed no biosafety concerns.

RESEARCH METHODOLOGY

This research was conducted in two primary phases: efficacy assessment and safety evaluation. All experimental procedures were carried out in a controlled laboratory environment utilizing simulated foot models and wound types. The simulated wounds were designed to replicate the characteristics of both normal wounds and SWI wounds. Figure 2 illustrates the representations of the simulated wound models employed in this investigation.

The Figure 2 illustrates simulated wound models representing progressive stages of foot condition, from normal skin to increasingly severe wounds. Panel A shows an intact human foot model with normal skin and no visible lesions, serving as the baseline. Panel B depicts a simulated normal wound on the dorsal aspect of the foot, characterized by a shallow, circular lesion with a red granulating surface and mild surrounding erythema, indicative of early inflammation without necrosis. Panel C demonstrates a simulated seawater immersion wound, featuring a central dark necrotic area with irregular margins and pronounced erythema, along with skin maceration suggestive of infection and tissue damage. These simulated models are designed to replicate real-world clinical scenarios, highlighting the progression of wound severity and the increased risk of complications associated with contaminated water exposure. Panel C demonstrates the proper use of NU_Woundguard.

The simulated wound models employed in this study were meticulously conceptualized and designed by wound care specialists to ensure clinical relevance and fidelity to real-world wound characteristics. Fabrication was achieved using advanced 3D printing technology, enabling precise reproduction of anatomical structures and pathological features. Each model underwent rigorous validation by physicians with expertise in infectious diseases and wound management to confirm accuracy and alignment with clinical standards. Models that failed to meet predefined quality or anatomical criteria were systematically revised and re-fabricated through an iterative process until an optimal and clinically acceptable representation was obtained. The details of checklists demonstrate in Table 1.

Study Design

A controlled laboratory-based experimental study was conducted to evaluate the efficacy and safety of NU_Woundguard, a wound protection device, under simulated conditions using 3D-printed foot models with clinically validated wound simulations (normal wound and seawater immersion wound).

Objectives

1. **Efficacy:** To determine the ability of NU_Woundguard to prevent water penetration and contamination during simulated exposure to clean water and seawater.

2. **Safety:** To assess material durability, sealing integrity under stress, and compatibility with wound dressings under repeated exposure conditions.

Materials

The experimental setup employed the NU_Woundguard device, which was tested in its final production prototype form. Simulated foot models were fabricated using high-resolution 3D printing technology to ensure anatomical precision. Two wound types were created on these models to replicate clinically relevant conditions: (1) a normal wound featuring granulation tissue with mild erythema and (2) a SWI wound characterized by a necrotic core and macerated skin margins. Standard wound dressings, consisting of sterile gauze combined with hydrocolloid layers, were applied to maintain clinical comparability. For the immersion tests, two fluid environments were prepared: tap

Table 1. Development and Validation Checklist for Simulated Wound Models

Phase	Criteria	Key Requirements
Design	Clinical Relevance	Wound type defined (normal vs SWI), includes pathological features
	Dimensions & Shape	Accurate size, depth, and margin characteristics
Fabrication	Material Selection	Biocompatible, skin-like texture
	3D Printing Accuracy	≤0.2 mm deviation; color differentiation
	Structural Integrity	No cracks or deformation; durable for handling
Verification	Anatomical Accuracy	Correct wound position and surface morphology
	Pathological Accuracy	Normal wound: granulation, mild erythema; SWI: necrosis, maceration
	Functional Performance	Compatible with dressing and moisture-protection tests
	Visual Fidelity	Clear differentiation of healthy vs infected tissue
Acceptance	Validation Outcome	≥90% checklist compliance and expert consensus approval

Note: All simulated wound models underwent a rigorous multi-step validation process conducted by a panel of clinical and technical experts. The review team included two board-certified physicians specializing in infectious diseases and wound care, one plastic surgeon experienced in reconstructive wound management, and one senior wound care nurse with expertise in chronic and traumatic wounds. To ensure accurate wound type representation (normal wound vs seawater immersion wound), each model was compared against high-resolution clinical reference images and standard diagnostic criteria for wound staging and infection characteristics, including depth, tissue viability, color patterns, and presence of necrosis or maceration. The technical evaluation, performed by a biomedical engineer and a 3D printing specialist, verified structural integrity, dimensional accuracy, and material properties. Validation followed a standardized scoring checklist assessing anatomical fidelity, pathological accuracy, and functional performance, such as compatibility with dressing application and moisture-protection testing. Models failing to meet any critical criteria were revised and re-fabricated through an iterative process until they achieved full compliance. Final approval required expert consensus with a minimum score of 90% across all domains, confirming both clinical accuracy and functional suitability.

water representing typical freshwater exposure and artificial seawater formulated to a salinity of 35 parts per thousand (ppt) with a pH of 8.1 to simulate marine conditions.

Characteristics of NU_Woundguard and Control Group

The intervention group utilized the NU_Woundguard device, a silicone-based wound protection covers specifically developed to prevent water penetration during wound care scenarios such as bathing or accidental immersion. It is currently in the process of being registered for a patent in Thailand. NU_Woundguard is constructed from medical-grade, thick silicone material designed to provide high elasticity, mechanical durability, and moisture control while maintaining a watertight seal. Its structural design ensures compatibility with standard wound dressings, minimizing the risk of adhesive disruption or dressing displacement. The device was tested in its final production prototype form, ensuring clinical applicability and manufacturing consistency.

In contrast, the control group consisted of wound models covered only with standard dressings composed of sterile gauze combined with a hydrocolloid layer. This configuration represents conventional wound management practice without any additional protective barrier against water exposure. Both groups were subjected to identical testing protocols, including immersion in freshwater and seawater under controlled laboratory conditions, ensuring that any observed differences in performance could be attributed solely to the presence or absence of the NU_Woundguard device.

The Efficacy Experimental Design

The study followed a controlled laboratory-based design comprising two main groups: Intervention Group: Foot model dressed in standard wound covering and additionally protected by the NU_Woundguard device. Control Group: Foot model with standard wound dressing only, without additional protection. Each group underwent immersion testing under two specific conditions: (1) freshwater exposure using tap water for the normal wound model and (2) seawater exposure for the SWI wound model. The immersion durations were standardized at 10, 30, and 60 minutes to replicate varying levels of water contact risk. For statistical robustness, each condition was repeated in five independent replicates (n = 5), ensuring reproducibility and validity of the results.

Primary Outcome

The primary outcome was the prevention of water penetration to the wound dressing during simulated immersion. This outcome reflects the device's protective function in maintaining a dry wound environment under both freshwater and seawater exposure.

Outcome Measurement

Water penetration was assessed by placing an absorbent detection sheet beneath the wound dressing on each foot model prior to immersion. After each exposure interval (10, 30, and 60 minutes), the detection sheet was inspected for moisture presence. If moisture was observed, the absorbent sheet was weighed using an analytical balance to determine the volume of penetrated water in milligrams (mg). The result was recorded as both binary data (presence/absence of leakage) and quantitative data (weight of absorbed water).

Safety Experimental Design

The safety evaluation focused on assessing the physical durability, sealing integrity, and dressing compatibility of the NU_Woundguard device under controlled laboratory conditions. Simulated foot models with validated wound types were used to replicate clinical scenarios. The device was subjected to repeated immersion in both freshwater and seawater, mechanical stress simulating foot movement, and multiple handling cycles to replicate typical use. Three specific tests were performed: a material durability test, a seal integrity assessment under mechanical stress, and a dressing compatibility evaluation. The material durability test involved exposing the device to 10 repeated immersion cycles of five minutes each, followed by air drying at room temperature. After these cycles, the device was visually examined for signs of structural compromise such as cracks, deformation, or surface degradation, and tensile strength was measured and compared with baseline values.

The seal integrity test assessed whether mechanical stress compromised the device's ability to maintain a watertight seal. The device was applied to the foot model and subjected to 30 cycles of controlled dorsiflexion and plantarflexion using a mechanical rig. Lateral stretching of up to 10% elongation for one minute was also applied. Following these stress simulations, the model underwent a 10-minute immersion test, and seal performance was verified.

The dressing compatibility test examined whether the device altered the wound dressing's structure or adhesive properties. After each immersion cycle, the wound dressing was inspected for signs of detachment, fiber shedding, or structural damage.

Primary Safety Outcome

The primary safety outcome was the ability of NU_Woundguard to maintain structural integrity and sealing performance after repeated exposure to water and mechanical stress simulations. This included sustaining its physical properties and ensuring the wound area remained protected throughout the testing conditions.

Outcome Measurements

Safety was measured through three distinct parameters. First, material integrity was evaluated by visual inspection for cracks, deformation, or surface irregularities, and by performing tensile strength tests using a universal testing machine. Post-test tensile strength was expressed as a percentage of the baseline value, with a pass criterion of at least 90% retention. Second, seal integrity was assessed by applying an absorbent detection sheet beneath the wound dressing during the post-stress immersion test. Leakage was recorded as a binary outcome (presence or absence).

Third, dressing compatibility was assessed qualitatively by inspecting the wound dressing for adhesive residue, structural disruption, or fiber shedding after each removal of the protective device.

Human Ethics and Biosafety Considerations

This study did not involve human participants, live animals, or biological specimens and therefore did not require approval from an Institutional Review Board (IRB) or Ethics Committee. All experimental procedures were performed exclusively in a controlled laboratory environment using non-biological 3D-printed foot models with simulated wound types. These models were fabricated and validated for research purposes without any contact with human or animal tissue.

For microbial contamination simulation, only heat-inactivated bacterial preparations (*Escherichia coli*, *Pseudomonas aeruginosa*, and *Vibrio vulnificus*) were used to ensure biosafety. No viable microorganisms or pathogenic agents were employed during the study, thereby eliminating the risk of laboratory-acquired infection or environmental contamination. All procedures adhered to standard laboratory safety protocols consistent with ISO and institutional guidelines.

As a result, this research was classified as low risk with no biosafety or ethical concerns, and no additional protective measures beyond routine laboratory safety requirements were necessary.

RESULTS

Efficacy Assessment

NU_Woundguard completely prevented water penetration across all experimental conditions, whereas the control group demonstrated significant leakage at every immersion duration. No leakage was observed in any intervention samples (0/30), while 100% of control samples showed water ingress. At 60 minutes of immersion, the mean absorbed water for control samples was 1.85 ± 0.42 g in the freshwater (normal wound) setting and 2.14 ± 0.39 g in the seawater (SWI wound) setting (Table 2 and Figure 3).

Figure 3 illustrates the comparative water penetration results between the intervention (NU_Woundguard) and control groups under two conditions: freshwater exposure to normal wounds and seawater exposure for SWI wounds. The control group exhibited measurable water penetration in both scenarios, with mean values of approximately 1.85 g for freshwater immersion and 2.14 g for seawater immersion. In contrast, NU_Woundguard consistently prevented water leakage across all test conditions, with recorded penetration values of 0.00 g in every replicate. This result indicates that the protective device maintained an effective barrier function during immersion testing, while standard wound dressings alone were unable to prevent fluid ingress.

Safety Assessment

NU_Woundguard maintained its structural and functional integrity following repeated immersion and mechanical stress. After 10 immersion cycles and 30 flexion-stress cycles, no cracks, deformation, or surface degradation were observed. Tensile strength retention was 94.6% ± 2.1% relative to baseline, meeting the predefined acceptance criterion of ≥90%. Post-stress immersion testing confirmed that the device maintained its sealing performance, with zero leakage across all samples. Dressing compatibility remained unaffected, with no adhesive failure, fiber shedding, or surface damage detected (Table 3).

DISCUSSION

Multiple studies have demonstrated that wounds exposed to contaminated water carry a substantially higher risk of infection and clinical deterioration[1-6]. Contact with polluted freshwater or seawater allows rapid entry of pathogenic organisms—including *Staphylococcus aureus*, *Streptococcus* spp., *Vibrio vulnificus*, *Aeromonas* spp., *Pseudomonas aeruginosa*, and *Escherichia coli*—which may lead to serious complications ranging from cellulitis to necrotizing soft tissue infections and septicemia[7]. Mortality rates associated with *Vibrio vulnificus* can reach 30%[7], and evidence from flood-affected populations consistently shows increased rates of skin and soft tissue infections (SSTIs), particularly among individuals with traumatic wounds, diabetes, or immunocompromise[8]. For community pharmacies, these infection patterns directly influence frontline wound-care decision-making.

In this context, pharmacists play a central role as accessible first-contact professionals who often encounter contaminated-water wounds before any other healthcare provider. Their responsibilities extend beyond recommending basic OTC products: pharmacists must rapidly assess wound severity, advise on appropriate cleansing and moisture control, recommend suitable dressings, and identify warning signs that require escalation or urgent referral. Non-pharmacological wound-protection devices, such as NU_Woundguard, are increasingly important tools within this practice. They support antimicrobial stewardship by preventing environmental contamination and reducing inappropriate or premature antibiotic use—an especially relevant consideration in injuries exposed to floodwater or seawater containing high microbial loads. When evaluating these cases, pharmacists must adjust OTC recommendations toward mechanical protection, strict wound dryness, and early referral, rather than defaulting to topical antimicrobials. Devices like NU_Woundguard enable patients to safely shower and carry out daily activities while

Table 2. Water Penetration Outcomes in Intervention vs Control Groups

Condition	Group	Leakage Rate (n=5)	Mean Water Penetration (g ± SD)
Freshwater (Normal wound)	Control	5/5 (100%)	1.85 ± 0.42
	NU_ Woundguard	0/5 (0%)	0.00 ± 0.00
Seawater (SWI wound)	Control	5/5 (100%)	2.14 ± 0.39
	NU_ Woundguard	0/5 (0%)	0.00 ± 0.00

Table 3. Safety Evaluation Outcomes

Parameter	Acceptance Criteria	Result No cracks or deformation	Interpretation
Material Integrity (Visual)	No visible defects	94.6% ± 2.1%	
Tensile Strength Retention	≥90% of baseline	0/30 leaks	Pass
Seal Integrity Post-Stress	No leakage	No disruption or fiber loss	

Table 4. Risk of Infection and Complications from Foot Exposure to Contaminated Water[7-11]

Exposure Context	Common Pathogens	Clinical Manifestations	Complications	Key Evidence
Saltwater (Brackish Water)	*Vibrio vulnificus*	Rapid-onset cellulitis, hemorrhagic bullae	Necrotizing fasciitis, septicemia, death (mortality up to 30%)	Major flood events, hurricanes[6,8,9]
Freshwater	*Aeromonas spp.* (*A. hydrophila*), *Burkholderia pseudomallei*	Cellulitis, abscesses, foul odor	Necrotizing infections, melioidosis, sepsis	Indian Ocean tsunami, Thai floods[8,9]
General Flood Exposure	*Staphylococcus aureus*, *Streptococcus spp.*, polymicrobial (e.g., *Pseudomonas aeruginosa*, *E. coli*)	Impetigo, cellulitis, myositis, wound infection	Limb loss, systemic infection	Global flood and tsunami data[7,8,9]
Secondary Risks	Soil-borne pathogens (*Clostridium tetani*), fungi (*Tinea pedis*, *Chromoblastomycosis*, *Mucormycosis*)	Irritant contact dermatitis, immersion foot, fungal infections	Chronic wounds, secondary bacterial infection	Post-flood dermatological reports[8,9]
Predisposing Factors	—	Wound contamination due to prolonged immersion, compromised hygiene, traumatic injuries	Increased infection severity in immunocompromised patients	Observational studies in flood zones[7,8,9]

Table 5. Future Research Directions for NU_Woundguard and Advanced Wound Care Innovations[11,12]

Research Area	Current Evidence	Proposed Future Work	Rationale
Clinical Validation	NU_Woundguard prevented 100% water penetration under lab conditions using silicone foot models.	Conduct randomized controlled clinical trials in patients with acute and chronic wounds (e.g., diabetic foot ulcers).	Ensure generalizability and evaluate real-world performance.
Comparative Effectiveness	Current study compared NU_ Woundguard only to standard dressings.	Compare NU_Woundguard with modern dressings (hydrocolloid, alginate, hydrogel, foam, film) under clinical conditions.	Determine relative benefits and integration into advanced wound care protocols.
Antimicrobial Integration	NU_Woundguard provides physical protection but lacks antimicrobial activity.	Incorporate silver nanoparticles, iodine, or bioactive agents to prevent microbial colonization.	Reduce infection risk in high-contaminated environments (e.g., floods, SWI wounds).
Smart Wound Monitoring	No monitoring capability in current device.	Develop integrated sensors (pH, temperature, moisture) similar to smart hydrogel and film dressings.	Enable real-time wound status tracking and early infection detection.
Durability Testing in Dynamic Use	The current test simulated immersion and flexion cycles under controlled settings.	Evaluate performance during prolonged wear, patient mobility, and repetitive exposure in community settings.	Assess mechanical integrity and water resistance under real-life stress conditions.
Cost-Effectiveness Analysis	No economic evaluation performed.	Model cost-effectiveness compared to traditional and modern wound dressing in hospital and home care.	Support policy decisions and large-scale adoption in resource-limited settings.
Disaster and Flood Preparedness	Evidence shows increased infection risk after floods and contaminated water exposure (Vibrio, Aeromonas).	Test NU_Woundguard in disaster response protocols for high-risk populations in flood-prone areas.	Improve emergency wound care and infection prevention in humanitarian crises.

Figure 1. NU_Woundguard

minimizing infection risk, offering a practical intervention for high-risk groups such as older adults, people with diabetes, and those living in flood-prone communities. Incorporating such devices into pharmacy triage algorithms strengthens wound-care counseling, supports safer self-management, and aligns pharmacy practice with contemporary antimicrobial stewardship priorities.

Regional data, including reports from the 2011 Thai floods and the 2004 Indian Ocean tsunami, highlight a substantial burden of SSTIs, fungal infections (e.g., tinea pedis), immersion foot syndrome, and contact dermatitis due to prolonged exposure to contaminated water and chemicals[9]. Preventive strategies, such as wound protection and timely medical intervention, are essential to reduce morbidity and mortality. The risk of infection and complications from foot exposure to contaminated water has been shown in Table 4.

This study demonstrated that NU_Woundguard, an innovative silicone-based wound protection device, offers a highly effective non-pharmacological approach for maintaining a controlled wound environment during water exposure. Under simulated immersion conditions, the device completely prevented water penetration in both freshwater and seawater scenarios, with zero leakage recorded across all replicates. In contrast, conventional wound dressings without additional protection showed significant water ingress, averaging 1.85 g in freshwater and 2.14 g in seawater. These findings highlight NU_Woundguard's ability to provide a watertight seal—an essential component of contemporary wound care strategies aimed at reducing infection risk and optimizing healing.

Preserving a dry wound environment is a cornerstone of non-pharmacological management, as moisture from uncontrolled water exposure can compromise dressing integrity and facilitate pathogen entry. This risk is particularly critical for individuals with chronic wounds, such as diabetic foot ulcers, where even

Figure 2. The study simulated wound models

Note: A = silicone foot prosthesis, B = normal wound under bandage, C = seawater immersion wound and D = Nu_ Woundguard. The study will utilize silicone foot prostheses rather than human feet, with models allocated to an intervention group and a control group.

minor contamination can result in infection, delayed healing, and severe complications including sepsis and amputation. By effectively preventing water pressure during activities like bathing or unintentional immersion, NU_Woundguard addresses a significant clinical gap and aligns global priorities in infection prevention and wound healing optimization.

Unlike traditional waterproofing methods, such as adhesive films or improvised plastic barriers, which often fail under mechanical stress or prolonged exposure, NU_Woundguard combines structural durability with flexibility. The device maintained mechanical integrity after 10 immersion cycles and 30 simulated movement cycles, retaining more than 90% of its original tensile strength without visible defects. Importantly, it preserved dressing adhesion and structural integrity, demonstrating compatibility with standard wound care protocols. These characteristics position NU_ Woundguard as a sustainable, reusable, and patient-friendly solution within non-pharmacological wound management frameworks. Beyond routine home-based wound care, NU_

Woundguard holds relevance for populations at elevated risk of waterborne contamination, including patients in coastal regions, agricultural workers, and military personnel. The device's protective function becomes especially critical in marine environments, where microbial loads can exceed 100 million organisms per liter, including highly pathogenic species such as Vibrio vulnificus and Pseudomonas aeruginosa. Integrating NU_Woundguard into wound care protocols could therefore reduce the incidence of secondary infections, minimize reliance on systemic antimicrobials, and contribute to antibiotic stewardship strategies.

Key Strengths and Clinical Impact of NU_Woundguard as a Non-Pharmacological Wound Protection Strategy

This research highlights several key strengths of NU_Woundguard as an innovative non-pharmacological solution for wound protection. The device achieved complete prevention of water leakage under both freshwater and seawater immersion conditions, significantly outperforming standard wound dressings, which exhibited measurable ingress. By ensuring a watertight seal, NU_Woundguard addresses a critical clinical need for maintaining a sterile wound environment during routine activities such as bathing or accidental immersion. Its structural durability and reusability were demonstrated through consistent performance after repeated immersion and flexion-stress cycles, retaining over 90% of baseline tensile strength without visible defects. Additionally, the device showed excellent compatibility with standard wound dressings, preserving their adhesive and structural integrity, which facilitates integration into existing clinical protocols. NU_Woundguard's patient-centered design makes it suitable for home-based care and populations at elevated risk of waterborne contamination, such as individuals with chronic wounds, diabetic foot ulcers, and those in marine or agricultural environments. By reducing exposure to pathogens, this device has the potential to lower infection rates, minimize reliance on systemic antimicrobials, and contribute to global strategies aimed at infection prevention and antimicrobial resistance reduction. Furthermore, its design offers a foundation for future enhancements, including antimicrobial coatings or embedded sensors for moisture and infection monitoring, reinforcing its role as a forward-thinking innovation in wound care management.

Practical Implications for Pharmacy Practice

Community and hospital pharmacists frequently encounter patients seeking immediate wound-care advice, especially in flood-prone or coastal regions where exposure to contaminated water substantially increases the risk of skin and soft-tissue infections[1,7,8]. Such environments commonly contain high concentrations of pathogens—including *Staphylococcus aureus*, *Streptococcus* spp., *Vibrio vulnificus*, *Aeromonas* spp., *Pseudomonas aeruginosa*, and *Escherichia coli*—which can rapidly progress from localized cellulitis to necrotizing infections, septicemia, or amputation, particularly among individuals with diabetes or chronic illness[1,2,3,7,9]. Consequently, pharmacists play a critical frontline role in assessing wound severity, recommending appropriate cleansing techniques, maintaining moisture balance, advising on dressing selection, and identifying infection-related red flags that necessitate referral. Integrating non-pharmacological protective devices such as NU_Woundguard into pharmacy-led wound-care services supports antimicrobial stewardship by reducing unnecessary antibiotic use and preventing avoidable infections—an approach consistent with recent evidence highlighting the importance of physical barriers and modern wound-care biomaterials in reducing pathogen exposure and improving outcomes[11,12]. Practical counseling should include instructions on correct application, duration of use during bathing or water exposure, cleaning and maintenance of the device, and monitoring for signs of complications requiring escalation of care. Stocking such devices in community pharmacies enables pharmacists to incorporate them into clinical decision support (CDS) pathways, helping determine when NU_Woundguard is appropriate (e.g., minor traumatic wounds, diabetic foot ulcers requiring water protection, chronic ulcers during hygiene routines) and when direct medical evaluation is required. This is particularly beneficial in flood-affected communities and among patients receiving ambulatory chronic-disease management, where pharmacies often serve as the first point of contact. However, further research is needed to evaluate patient adherence, comfort, and long-term device durability under real-world conditions[4,10]. From a health-system perspective, integrating protective devices into pharmacy workflows may help reduce minor infection-related clinic visits, decrease antibiotic dispensing, and potentially prevent hospital admissions associated with contaminated-water wound infections[5,6].

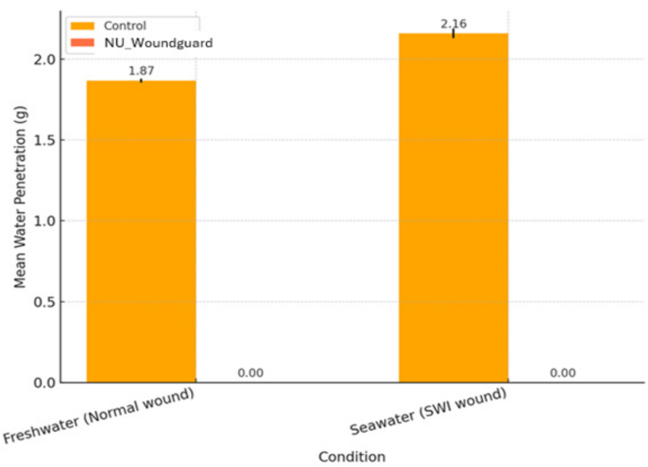

Figure 3. Water Penetration Comparison Between Groups

Note: this figure clearly shows zero leakage for NU_Woundguard under all conditions compared to significant leakage in the control group.

The suggestion of research generalization

The findings of this study, obtained under controlled laboratory conditions using validated simulated wound models, suggest that NU_Woundguard has strong potential as an effective non-pharmacological strategy for preventing water penetration during wound care. While these results demonstrate the device's ability to maintain a watertight seal and preserve structural integrity under immersion and mechanical stress, generalization to clinical practice requires caution. Real-world scenarios involve variables such as patient mobility, long-term use, wound exudate, and diverse environmental conditions that were not assessed in this study. Therefore, additional research, including prospective clinical trials across different patient populations and care settings—is essential to confirm efficacy, safety, patient comfort, and cost-effectiveness. Exploring integration with standard wound care protocols and assessing performance in high-risk groups such as individuals with diabetes or chronic wounds, will further establish its clinical applicability. These steps will help ensure that the device's benefits observed in a controlled environment translate effectively to routine clinical and community-based wound care.

Limitations

This study was conducted exclusively under controlled laboratory conditions using simulated wound models, which cannot fully replicate the complexity of real-world patient scenarios. Factors such as variations in skin properties, patient mobility, long-term device application, and repeated exposure to environmental stress were not assessed. Furthermore, patient-centered outcomes—including comfort, usability, and adherence—were beyond the scope of this investigation. Additionally, the contamination model employed heat-inactivated microorganisms, which may not entirely represent the biological risk of viable pathogens in clinical practice**.**

Future Research Directions

Future research should focus on validating NU_Woundguard's performance in real-world clinical environments, as current evidence is derived from controlled laboratory conditions (as shown in Table 5). Clinical trials involving diverse patient populations—such as those with diabetic foot ulcers, chronic wounds, or high-risk occupations—are needed to evaluate its effectiveness, patient adherence, and long-term safety. Comparative studies should investigate how NU_Woundguard performs against advanced wound protection solutions, including hydrocolloid, alginate, and hydrogel dressings, as highlighted in recent biomedical material research, to determine combined or synergistic effects on healing and infection prevention. Furthermore, future work could explore integrating antimicrobial or bioactive components within the device to enhance infection control, particularly in contaminated or flood-prone environments. Durability testing under extended use and in dynamic, outdoor conditions will provide critical insights for global disaster preparedness and rural healthcare settings. Finally, cost-effectiveness analyses and implementation research will inform large-scale adoption in both hospital and community-based wound care protocols.

CONCLUSION

NU_Woundguard demonstrated superior performance in maintaining a dry wound environment compared to standard dressings under simulated immersion conditions, effectively preventing water penetration and preserving structural integrity after repeated stress and immersion cycles. These findings support its potential as an effective non-pharmacological intervention for reducing infection risk and promoting wound healing, particularly in high-risk populations such as patients with chronic wounds or those exposed to contaminated water. Clinical studies are warranted to validate real-world efficacy, patient acceptability, and long-term outcomes.

CONFLICT OF INTEREST

None to declare.

AUTHORS' CONTRIBUTIONS

Janyut Srihirun (The first author) conceptualized and designed the simulated wound models, led the 3D fabrication process, and contributed to the development of the experimental apparatus. He coordinated the visual design components, prepared the anatomical models used in efficacy and safety testing, and participated in data interpretation.

Prayuth Poowaruttanawiwit (corresponding author) conceived the study, developed the research methodology, and supervised all phases of the project. He oversaw laboratory procedures, ensured methodological rigor, performed statistical analysis, interpreted the findings, and drafted the full manuscript. Both authors critically revised the manuscript for important intellectual content, approved the final version, and agreed to be accountable for all aspects of the work. The corresponding author had full access to all study data and held final responsibility for the decision to submit the manuscript for publication.

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