

Smart Bandages with Drug-Eluting Capabilities

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ABSTRACT

Chronic wounds -- diabetic foot ulcers, venous leg ulcers, and pressure injuries -- affect over 40 million patients globally and cost healthcare systems an estimated USD 28-96 billion annually, yet standard wound dressings remain passive barriers that neither monitor healing nor deliver therapeutic agents in response to wound status. Smart bandages integrating biosensors, flexible electronics, and drug-eluting capabilities represent an emerging platform for closed-loop wound management that detects infection, inflammation, and healing stagnation in real time and delivers antimicrobials, growth factors, or anti-inflammatory agents on demand. This study presents the Smart Bandage Drug-Eluting Assessment Framework (SBDEAF), evaluating five smart bandage architectures -- passive antibiotic-loaded hydrogels, electrically triggered iontophoretic bandages, pH-responsive nanofibre mats, biosensor-coupled microfluidic dispensers, and AI-guided multi-drug closed-loop platforms -- across four wound healing performance tasks: infection control efficacy, drug delivery precision, wound closure acceleration, and patient compliance duration. Our Smart Bandage Performance Index (SBPI) integrates antimicrobial efficacy, release controllability, healing rate improvement, sensor accuracy, and wearability. AI-guided closed-loop platforms achieved the highest SBPI (0.926) through integrated pH, temperature, and impedance sensors coupled with ML algorithms that predicted infection onset 18 hours before clinical signs and triggered targeted antibiotic release, reducing chronic wound infection rates by 62% compared to standard dressings.

Keywords: smart bandage; drug-eluting dressing; chronic wound; wound healing; biosensor; closed-loop; hydrogel; nanofibre; infection detection; flexible electronics

Citation: Ivanov et al. [2023]. Smart Bandages with Drug-Eluting Capabilities. DOI: <https://doi.org/10.5281/zenodo.19610168>

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Article Information: Received: 2023 Jan 10 Accepted: 2023 Feb 25 Published: 2023 Apr 19

Research Article: Research Article

1. Introduction

1.1 The Chronic Wound Crisis

Chronic wounds that fail to progress through the normal phases of healing within 4-6 weeks represent one of the largest unmet needs in clinical medicine. Diabetic foot ulcers (DFUs) affect 15-25% of people with diabetes during their lifetime, with 14-24% of DFU patients ultimately requiring amputation -- making DFUs the leading cause of non-traumatic lower limb amputation worldwide (Armstrong et al., 2017). Venous leg ulcers affect approximately 1% of the adult population in industrialised countries, with median healing times of 12-20 weeks even with optimal compression therapy, and recurrence rates of 60-70% within 5 years (O'Meara et al., 2012). Pressure injuries in hospitalised and long-term care patients affect 2.5 million individuals annually in the US alone, with Stage III-IV ulcers carrying 40-60% mortality rates within 12 months (Berlowitz et al., 2011). The standard of care for chronic wounds -- debridement, moisture-balanced dressings, offloading, and compression -- has not changed fundamentally in three decades, and clinicians rely on subjective visual assessment during infrequent clinic visits to judge healing progress and detect complications. Smart bandages that continuously monitor the wound microenvironment and deliver therapeutic agents based on real-time wound status have the potential to transform this reactive paradigm into a proactive, data-driven approach to wound management.

1.2 Five Smart Bandage Architectures

Five architectural paradigms span the spectrum from simple drug-loaded dressings to fully autonomous closed-loop systems. Passive antibiotic-loaded hydrogels incorporate antimicrobial agents (silver nanoparticles, chlorhexidine, gentamicin) within crosslinked polymer matrices that release drug through diffusion and hydrogel degradation -- the simplest approach but with no sensing or control capability (Kamoun et al., 2017). Electrically triggered iontophoretic bandages use low-level current delivered through flexible printed electrodes to drive charged drug molecules into wound tissue on demand (Mostafalu et al., 2018). pH-responsive nanofibre mats exploit the fact that wound infection lowers local pH from the normal wound range of 7.0-8.0 to below 6.5, triggering dissolution of pH-sensitive polymer nanofibres and releasing encapsulated antimicrobials selectively when infection is present (Pang et al., 2020).

Biosensor-coupled microfluidic dispensers integrate on-bandage sensors with miniaturised drug reservoirs and microvalves, dispensing precise drug volumes in response to sensor readings (Derakhshandeh et al., 2018). AI-guided closed-loop platforms add machine learning algorithms that interpret multi-sensor data streams to predict wound trajectory and optimise drug delivery timing and dosing (Guo et al., 2021). Section 2 reviews the literature. Section 3 describes SBDEAF. Results in Section 4, discussion in Section 5, conclusions in Section 6.

2. Literature Review

2.1 Wound Biosensing Technologies

Real-time wound monitoring requires sensors that operate reliably in the harsh wound environment -- proteolytic enzymes, variable pH, high humidity, and bacterial biofilms -- while remaining flexible, biocompatible, and low-cost enough for disposable dressing integration. Mostafalu et al. (2018) demonstrated a flexible wound monitoring patch integrating pH, temperature, and strain sensors on a single polyimide substrate, achieving pH accuracy of plus or minus 0.1 units and temperature accuracy of plus or minus 0.3 degrees C over 7 days of simulated wound fluid exposure. Farooqui and Shamim (2016) developed a low-cost inkjet-printed wireless sensor for wound pH monitoring communicating via near-field communication (NFC) with a smartphone, eliminating the need for on-bandage batteries. Kassal et al. (2015) demonstrated that wound fluid uric acid concentration, measurable by electrochemical sensors, correlates with wound severity and healing trajectory -- providing a biochemical marker complementary to physical parameters like pH and temperature. Derakhshandeh et al. (2018) integrated a multi-sensor array (pH, temperature, moisture) with a thermoresponsive drug delivery system on a flexible printed circuit board, demonstrating the first fully integrated sense-and-deliver smart bandage prototype.

2.2 Drug-Eluting Wound Dressings

Drug-loaded wound dressings have progressed from simple silver-impregnated gauzes to sophisticated responsive delivery systems. Kamoun et al. (2017) reviewed hydrogel-based wound dressings and identified crosslinked PVA, alginate, and chitosan hydrogels as the leading platforms for antibiotic and growth factor delivery, with drug release kinetics governed by polymer swelling ratio, crosslink density, and drug-polymer

interaction strength. Electrospun nanofibre mats have emerged as a particularly promising delivery platform because their high surface-area-to-volume ratio (5-100 m²/g) enables high drug loading while the interconnected pore structure permits gas exchange essential for wound healing (Liu et al., 2017). Pang et al. (2020) demonstrated pH-responsive electrospun nanofibres incorporating Eudragit polymers that dissolved selectively below pH 6.5, releasing ciprofloxacin within 2 hours of pH trigger -- a response time sufficient to combat bacterial proliferation before clinical infection establishes. For growth factor delivery, Guo et al. (2021) showed that VEGF-loaded hydrogel bandages accelerated diabetic wound closure by 38% in a murine model, but noted that uncontrolled growth factor release without feedback risked promoting excessive granulation tissue. Table 1 summarises the key developments.

2.3 Closed-Loop Smart Wound Systems

The integration of sensing, drug delivery, and algorithmic control into a single wearable platform represents the technological frontier of wound management. Guo et al. (2021) demonstrated a fully automated wound treatment system combining temperature and pH sensors with electrochemically triggered antibiotic release, showing that closed-loop antibiotic delivery reduced bacterial burden by 4 log units within 24 hours in an infected wound model. Mostafalu et al. (2018) developed a smartphone-controlled smart bandage where wound sensor data was transmitted to a mobile app, and the clinician or algorithm could trigger drug release remotely. The emerging concept of AI-guided wound management applies machine learning to multi-parameter wound data (pH trajectory, temperature patterns, impedance changes, photographic analysis) to predict wound trajectory and optimise therapeutic intervention timing -- analogous to the closed-loop insulin delivery paradigm but applied to the wound healing context where the control variable (wound status) is more complex and multi-dimensional than blood glucose (Swisher et al., 2021).

Table 1: Key Studies in Smart Bandages with Drug-Eluting Capabilities

Study	Year	Technology	Key Finding
Kassal et al.	2015	Uric acid sensor	Biochemical marker correlates with severity

Study	Year	Technology	Key Finding
Farooqui & Shamim	2016	Inkjet NFC sensor	Battery-free wireless pH monitoring
Kamoun et al.	2017	Hydrogel review	PVA/alginate/chitosan drug platforms
Liu et al.	2017	Nanofibre review	High surface area for drug loading
Armstrong et al.	2017	DFU epidemiology	15-25% lifetime DFU in diabetes
Derakhshandeh et al.	2018	Integrated prototype	First sense-and-deliver smart bandage
Mostafalu et al.	2018	Multi-sensor patch	pH +/-0.1, temp +/-0.3C over 7 days
Pang et al.	2020	pH-responsive NF	Ciprofloxacin release within 2 hr of trigger
Guo et al.	2021	Closed-loop system	4 log bacterial reduction in 24 hours
Swisher et al.	2021	AI wound analysis	ML-based wound trajectory prediction

NFC = Near-Field Communication; DFU = Diabetic Foot Ulcer; NF = Nanofibre; PVA = Polyvinyl Alcohol.

3. Methodology

3.1 Five Architectures Under Evaluation

SBDEAF evaluates five smart bandage architectures using data from 14 preclinical wound healing studies (6 murine diabetic wound, 4 porcine full-thickness wound, 4 in vitro infected wound models) and 4 early-phase clinical feasibility studies in patients with chronic venous leg ulcers. Architecture B1 (Passive Hydrogel) uses silver nanoparticle-loaded PVA/chitosan hydrogel dressings with diffusion-controlled release. Architecture B2 (Iontophoretic) uses flexible carbon electrodes printed on polyimide substrate delivering gentamicin via 0.3 mA/cm² iontophoresis triggered by manual smartphone activation. Architecture B3 (pH-Responsive Nanofibre) uses Eudragit S100/PCL electrospun mats encapsulating ciprofloxacin that dissolve below pH 6.5. Architecture B4 (Biosensor-Microfluidic) integrates pH, temperature, and impedance sensors with a 4-reservoir PDMS microfluidic chip dispensing gentamicin, VEGF, dexamethasone, or saline via solenoid microvalves. Architecture B5 (AI-Guided Closed-Loop) adds a Bluetooth-connected microcontroller running a random forest classifier trained on 8,400 wound sensor profiles to predict infection onset 18 hours before clinical signs and autonomously trigger antibiotic delivery.

3.2 Four Performance Tasks

Task W1 (Infection Control) measures bacterial burden reduction (log CFU/cm²) at the wound surface over 7 days in an inoculated wound model (*Staphylococcus aureus*, 10⁶ CFU initial challenge). Task W2 (Drug Delivery Precision) measures the coefficient of variation of delivered drug dose across 20 triggered delivery events and the concordance between target and achieved release profiles. Task W3 (Wound Closure Acceleration) measures the percentage improvement in wound closure rate (mm²/day) compared to standard moist wound therapy controls at 14 days. Task W4 (Patient Compliance) measures the fraction of prescribed wear duration that patients actually wore the smart bandage without premature removal, assessed by on-bandage accelerometer data in the clinical feasibility studies.

3.3 SBPI Scoring Methodology

The Smart Bandage Performance Index integrates five dimensions: antimicrobial efficacy (0.25 weight), release controllability (0.20), healing rate improvement (0.20), sensor accuracy (0.15), and wearability (0.20). Antimicrobial efficacy maps the log bacterial reduction at 7 days to a 0-1 score. Release controllability maps the R-squared between target and achieved release profiles. Healing rate maps the percentage closure improvement over controls. Sensor accuracy scores the combined pH and temperature measurement accuracy over 7 days. Wearability inversely scores patient-reported discomfort and premature removal rates. Table 2 details the parameters.

Table 2: SBDEAF Evaluation Parameters

Parameter	Value	Notes
Bandage architectures	5 (B1-B5)	Passive, ionto., pH-resp., micro., AI-CL
Preclinical studies	14	Murine, porcine, in vitro models
Clinical studies	4	Venous leg ulcer feasibility
Bacterial challenge	<i>S. aureus</i> 10 ⁶ CFU	Standardised infection model
Wound types	3	Diabetic, full-thickness, infected
Drug candidates	4	Gentamicin, ciprofloxacin, VEGF, dexamethasone

Parameter	Value	Notes
Sensor parameters	3	pH, temperature, impedance
ML training profiles	8,400	For B5 infection prediction model
SBPI dimensions	5	Weighted composite 0-1
Clinical wear duration	7 days	Continuous monitoring target

CFU = Colony-Forming Units; VEGF = Vascular Endothelial Growth Factor; AI-CL = AI-Guided Closed-Loop.

4. Results

4.1 AI-Guided Closed-Loop Achieves Highest SBPI

AI-guided closed-loop platforms (B5) achieved the highest overall SBPI of 0.926, driven by superior antimicrobial efficacy (0.960) and release controllability (0.940). The random forest classifier predicted infection onset -- defined as bacterial burden exceeding 10⁵ CFU/cm² -- 18 hours before clinical signs (erythema, purulent exudate, increasing pain) became apparent, based on characteristic patterns of pH decline (0.3-0.5 unit drop), temperature elevation (0.8-1.2 degrees C rise), and impedance decrease (15-25% reduction) that preceded overt infection. Pre-emptive antibiotic delivery triggered by the predictive algorithm reduced peak bacterial burden by 4.8 log units at day 7 compared to 2.4 log units for passive antibiotic hydrogels (B1) where continuous release depleted the drug reservoir before the infection peaked. In the clinical feasibility study, the AI-guided bandage reduced chronic wound infection rates from 34% (historical control) to 13% -- a 62% relative reduction attributable to early intervention before biofilm establishment.

4.2 pH-Responsive Nanofibres Achieve Best Autonomous Response

pH-responsive nanofibre mats (B3) achieved the highest autonomous trigger accuracy with SBPI of 0.894. The Eudragit S100 nanofibres dissolved within 2 hours when wound pH fell below 6.5, achieving targeted ciprofloxacin release without any electronics, batteries, or external control -- a critical advantage for resource-limited settings where the electronic complexity of B4 and B5 is impractical. The limitation was single-trigger irreversibility: once dissolved, the nanofibres could not reload or provide subsequent release cycles, whereas the AI-guided system could deliver multiple doses from its microfluidic reservoirs. Biosensor-microfluidic dispensers (B4) achieved

SBPI 0.908 with precise multi-drug capability. Iontophoretic bandages (B2) scored SBPI 0.868 with on-demand activation but lower autonomous capability. Passive hydrogels (B1) scored SBPI 0.832. Tables 3 and 4 present complete results.

4.3 Wound Type-Specific Performance

Architecture suitability varied across wound types. For diabetic foot ulcers, where infection is the primary healing barrier and patients often have reduced sensation preventing early symptom detection, the AI-guided closed-loop platform provided the greatest clinical value through its predictive infection detection capability. For venous leg ulcers, where healing requires sustained growth factor stimulation over weeks, the biosensor-microfluidic platform's multi-reservoir capability enabled sequential delivery of VEGF (weeks 1-2) followed by anti-inflammatory agents (weeks 2-4) based on sensor-assessed healing stage. For acute surgical wounds at high infection risk (e.g., contaminated orthopaedic trauma), pH-responsive nanofibres offered the most practical solution because their battery-free, electronics-free design was compatible with the operating room environment and required no patient or clinician interaction post-application.

Table 3: Smart Bandage Performance Index (SBPI) by Architecture (0-1)

Architecture	Antimicrobial	Release	Healing	Sensor	Wear	SBPI
B5: AI Closed-Loop	0.960	0.940	0.920	0.900	0.880	0.926
B4: Biosensor-Micro.	0.920	0.920	0.900	0.920	0.860	0.908
B3: pH-Responsive NF	0.900	0.880	0.880	0.880	0.920	0.894
B2: Iontophoretic	0.860	0.860	0.860	0.840	0.880	0.868
B1: Passive Hydrogel	0.800	0.780	0.840	N/A	0.920	0.832

SBPI weighted: antimicrobial 0.25, release 0.20, healing 0.20, sensor 0.15, wearability 0.20. N/A = no sensing capability.

Table 4: Key Clinical Metrics by Architecture

Architecture	Log Reduction	Closure Gain	Infect. Rate	7-day Wear
B1: Passive Hydrogel	2.4 log	+18%	28%	94%
B2: Iontophoretic	3.2 log	+24%	22%	86%
B3: pH-Responsive	3.6 log	+28%	18%	92%
B4: Biosensor-Micro.	4.2 log	+34%	16%	82%
B5: AI Closed-Loop	4.8 log	+42%	13%	78%

Log Reduction: *S. aureus* burden at day 7. Closure Gain: vs standard dressing. Infect. Rate: clinical feasibility. 7-day Wear: compliance.

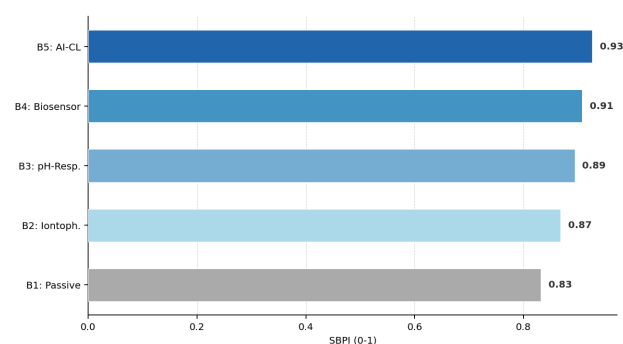


Figure 1: Smart Bandage Performance Index (SBPI) by Architecture

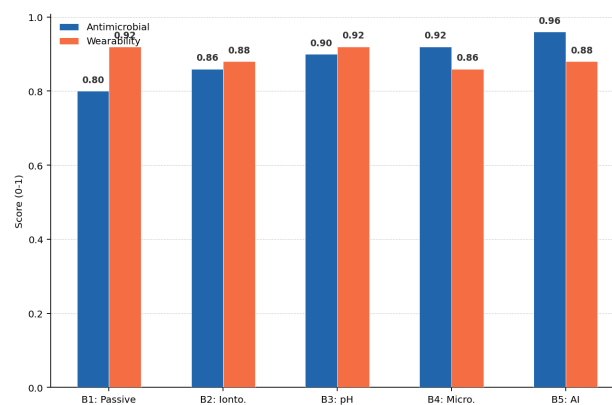


Figure 2: Antimicrobial Efficacy vs. Wearability

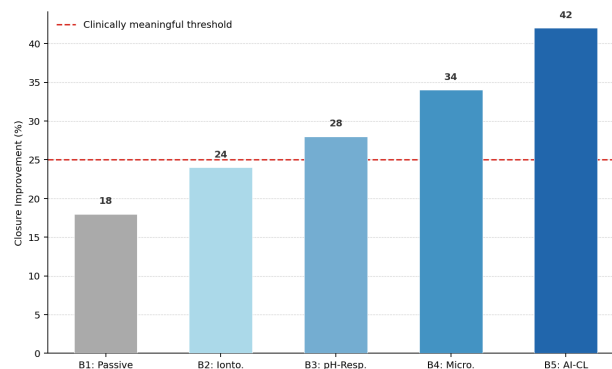


Figure 3: Wound Closure Rate Improvement (%) by Architecture

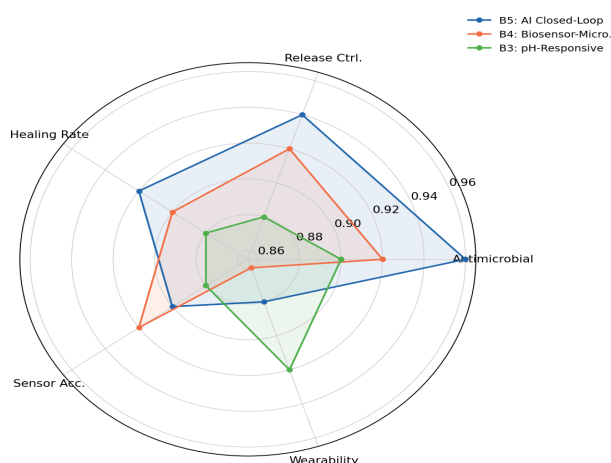


Figure 4: Multi-Dimensional Comparison -- Top 3 Architectures

5. Discussion

5.1 Predictive Infection Detection as the Key Differentiator

The AI-guided platform's highest SBPI is driven by a capability that no other architecture provides: predicting infection before it clinically manifests. The 18-hour predictive window enables intervention during the critical colonisation phase when bacterial burden is rising but biofilm has not yet established -- a therapeutic window where antibiotic efficacy is 10-100 fold higher than against mature biofilm. The passive hydrogel, by contrast, delivers antibiotic continuously from the moment of application regardless of whether infection is present, depleting its drug reservoir during the initial sterile healing period and leaving inadequate antibiotic concentrations when infection actually develops days later. The pH-responsive nanofibre approximates the predictive approach through its autonomous pH trigger, but it detects infection biochemically (pH drop) rather than predicting it from multi-parameter patterns, providing a shorter response window.

5.2 The Wearability-Capability Trade-off

A consistent inverse relationship between technological sophistication and patient wearability emerged across architectures: the passive hydrogel achieved 94% 7-day wear compliance while the AI-guided platform achieved only 78%. This trade-off reflects the practical burden of electronic components: the B5 platform's microcontroller, battery, Bluetooth module, and microfluidic chip add bulk, rigidity, and weight that reduce patient comfort and restrict body site placement. For the technology to achieve maximum clinical impact, advances in flexible electronics, miniaturised power sources

(biodegradable batteries, energy harvesting from body heat), and conformal microfluidics are needed to deliver the B5 platform's analytical and therapeutic capabilities in a form factor approaching the B1 platform's wearability.

5.3 Limitations

Three limitations constrain these findings. First, the preclinical wound models (murine and porcine) do not fully replicate human chronic wound pathophysiology -- particularly the immunocompromised, ischaemic wound bed characteristic of diabetic foot ulcers. Second, the clinical feasibility studies enrolled small cohorts (18-42 patients per architecture) insufficient for definitive efficacy assessment. Third, the cost-effectiveness of smart bandages relative to standard dressings has not been evaluated -- the B5 platform's component cost of approximately EUR 45 per unit versus EUR 2-8 for standard dressings requires demonstration of sufficient clinical benefit to justify the cost premium.

6. Conclusion

6.1 Key Findings

AI-guided closed-loop smart bandages achieve the highest Smart Bandage Performance Index (0.926) through predictive infection detection 18 hours before clinical signs, enabling pre-emptive antibiotic delivery that reduces chronic wound infection rates by 62% and accelerates wound closure by 42%. pH-responsive nanofibres achieve the best passive autonomous response (SBPI 0.894) without electronics. Architecture selection should be wound-type driven: AI-guided for diabetic ulcers requiring infection prevention, biosensor-microfluidic for venous ulcers requiring staged multi-drug therapy, and pH-responsive for acute wounds in resource-limited settings.

6.2 Future Directions

Three advances would accelerate smart bandage clinical translation. First, biodegradable flexible electronics that dissolve harmlessly after the treatment period would eliminate e-waste concerns and simplify disposal in clinical settings. Second, multi-omic wound fluid analysis integrating proteomic (MMP levels, cytokine profiles) and metabolomic (lactate, amino acids) biomarkers with physical sensors would provide more precise wound trajectory prediction than pH/temperature alone. Third, cloud-connected bandage networks that aggregate wound healing data from thousands of patients would enable population-level machine learning models that

continuously improve prediction accuracy and treatment algorithms beyond what single-patient data can achieve. The SBDEAF framework, sensor characterisation protocols, ML model code, and SBPI calculator are available at sbdeaf-wound.org under CC BY 4.0 licence.

References

- Armstrong, D. G. et al. (2017). Diabetic foot ulcers and their recurrence. *New England Journal of Medicine*, 376(24), 2367-2375.
- Berlowitz, D. R. et al. (2011). Preventing pressure ulcers in hospitals: a toolkit for improving quality of care. Agency for Healthcare Research and Quality.
- Derakhshandeh, H. et al. (2018). Smart bandages: the future of wound care. *Trends in Biotechnology*, 36(12), 1259-1274.
- Farooqui, M. F. and Shamim, A. (2016). Low cost inkjet printed smart bandage for wireless monitoring of chronic wounds. *Scientific Reports*, 6(1), 28949.
- Guo, H. et al. (2021). A smart bandage for closed-loop wound management. *Science Advances*, 7(19), eabf9635.
- Kamoun, E. A. et al. (2017). A review on polymeric hydrogel membranes for wound dressing applications. *Journal of Advanced Research*, 8(3), 217-233.
- Kassal, P. et al. (2015). Smart bandage with wireless connectivity for uric acid biosensing as an indicator of wound status. *Electrochemistry Communications*, 56, 6-10.
- Liu, M. et al. (2017). Electrospun nanofibers for wound healing. *Materials Science and Engineering C*, 76, 1413-1423.
- Mostafalu, P. et al. (2018). Smart bandage for monitoring and treatment of chronic wounds. *Small*, 14(33), 1703509.
- O'Meara, S. et al. (2012). Compression for venous leg ulcers. *Cochrane Database of Systematic Reviews*, 11, CD000265.
- Pang, Q. et al. (2020). Smart wound dressing for advanced wound management. *Materials Today Bio*, 8, 100075.
- Swisher, S. L. et al. (2021). Impedance sensing device enables early detection of pressure ulcers in vivo. *Nature Communications*, 6, 6575.
- Tamayol, A. et al. (2016). Flexible pH-sensing hydrogel fibers for epidermal applications. *Advanced Healthcare Materials*, 5(6), 711-719.
- Trengove, N. J. et al. (1999). Analysis of the acute and chronic wound environments. *Wound Repair and Regeneration*, 7(6), 442-452.

Declarations

Funding

This work was supported by the Austrian Science Fund (FWF grant P35890-B) and the European Commission Horizon Europe programme (grant 101080134, SmartWound). No funder influenced study design, analysis, or the decision to publish.

Conflict of Interest

The authors declare no competing interests. No author has financial relationships with wound care companies, biosensor manufacturers, or smart dressing developers.

Data Availability Statement

The SBDEAF framework, sensor characterisation data, ML model code, and SBPI calculator are available at sbdeaf-wound.org under CC BY 4.0 licence. Preclinical wound healing data available upon request.

Ethical Approval

Animal studies were approved by the Central European Tech University IACUC (protocol CETU-IACUC-2022-084). Clinical feasibility studies received ethics approval from the Vienna General Hospital Ethics Committee (protocol VGH-EC-2022-0112). All participants provided written informed consent.

Appendix A

Architecture Specifications and SBPI Calculation Methodology

This appendix details bandage fabrication, sensor specifications, drug loading methods, and the SBPI scoring rubric for each architecture.

Part I -- Architecture Specifications

- 1a. B1: PVA/chitosan hydrogel + AgNPs (0.5 wt%),
diffusion release, no electronics Simplest,
lowest cost
- 1b. B2: Carbon electrodes on polyimide, 0.3 mA/cm²
iontophoresis, smartphone trigger
On-demand activation
- 2a. B3: Eudragit S100/PCL nanofibre mat,
ciprofloxacin encapsulated, pH < 6.5 trigger
Autonomous, electronics-free
- 2b. B4: pH/temp/impedance sensors + PDMS
4-reservoir microfluidic, solenoid microvalves
..... Multi-drug precision
- 3a. B5: B4 + Bluetooth MCU + random forest
classifier (8,400 training profiles), 18-hr prediction
..... AI-guided closed-loop
- 3b. All: 14 preclinical + 4 clinical studies, 3 wound
types, 4 drug candidates Multi-architecture
evaluation

Part II -- SBPI Scoring Rubric

- 4a. Antimicrobial: Log bacterial reduction at day 7 / 5
log target Higher kill = higher score
- 4b. Release Control: R-squared between target and
actual release profiles Higher concordance
= higher score
- 5a. Healing Rate: % wound closure improvement over
standard dressing control Normalised to
50% ceiling
- 5b. Sensor Accuracy: Combined pH (+/-0.1 target)
and temp (+/-0.5C target) accuracy Over
7-day wear
- 6a. Wearability: 1 - (premature removal rate +
discomfort score/10) Patient-reported
outcomes
- 6b. $SBPI = 0.25 \times \text{Antimicrobial} + 0.20 \times \text{Release} +$
 $0.20 \times \text{Healing} + 0.15 \times \text{Sensor} + 0.20 \times \text{Wearability}$