An Overview of Antimicrobial Efficacy of an Electroceutical Wound Care Device

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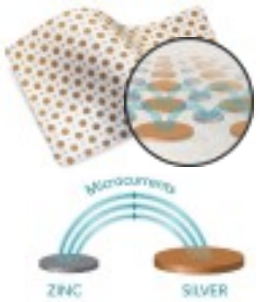
Next generation approaches to control and prevent hard-to-eradicate and antibiotic-resistant wound pathogens are being developed and used in clinical settings. Energy-based technologies have significant therapeutic utility in wound care, with growing recognition in the healthcare field. Procellera® is a microcurrent generating electroceutical dressing (ED). Its embedded silver and zinc microcell batteries generate a physiologic level of electrical energy in the presence of a conductive fluid. We provide an overview of antimicrobial efficacies of this ED against wound pathogens and their biofilms. We postulated that the ED could treat various wounds and exert an electricidal antimicrobial effect. It demonstrated *in vitro* broad-spectrum antimicrobial activities against most nosocomial wound pathogens as well as multidrug-resistant (MDR) isolates such as MDR Gram-negative bacilli (GNB), MRSA (methicillin-resistant *Staphylococcus aureus*), VRE (vancomycin-resistant *Enterococci*), VISA (vancomycin-intermediate *S. aureus*), and VRSA (vancomycin-resistant *S. aureus*). Its antimicrobial property is derived from effects of microcurrent in addition to silver and zinc.

Chronic wound pathogens are mostly engaged in biofilm formation, therefore the treatment and eradication for infection control and prevention becomes complicated and remains hard to treat. The ED was tested against biofilms using both poloxamer and colony drip-flow reactor (DFR) biofilm models. Using poloxamer biofilms, it demonstrated 2- or 3-fold $\log_{10}$ reductions against mono-species and 1- or 2-fold $\log_{10}$ reduction against multi-species biofilms. In the colony DFR biofilm model, the ED was applied directly onto the biofilms, which were continuously deposited onto a filter membrane for 72 h. The ED efficacy against the biofilms was more than 10-fold effective in reducing bacterial numbers compared to that of blank polyester, which in contrast showed accumulation of more than 10^9 CFU/ml The results presented herein describe antimicrobial efficacy of an ED against both planktonic and biofilm forms of wound pathogens.

A Novel Electroceutical Dressing (ED)

- **Procellera®/ JumpStart™ (Vomaris Wound Care, Inc., Tempe, AZ/ dist. by Arthrex, Inc., Naples, FL) is an antimicrobial wound dressing consisting of a dot-matrix pattern of elemental silver and zinc microcell batteries embedded on a flexible polyester substrate.**
- **The device is conformable, portable, and requires no external power source.**
- **When the ED comes in contact with a conductive medium (such as wound exudate or moisture), the device is electrically activated and generates continuous direct current (0.5-0.9 volts), which is essential to skin repair and regeneration as well as bioburden inhibition.**



Clinical Relevance

- **Electric stimulation has been recognized as a safe and effective wound care modality.**
- **The application of direct microcurrent to wounds as reported in the literature results in a reduction in pain, inflammation, and time to heal.**

Antimicrobial Efficacy Testing

- **Antibacterial efficacy testing against planktonic bacterial cultures (AATCC Test Method)**
- **Antibiofilm efficacy testing against bacterial biofilms [poloxamer (Fig. 1) and colony DFR biofilms (Fig. 2)]**

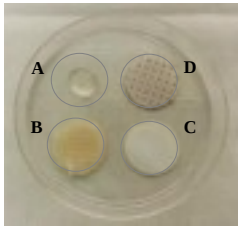


Fig. 1. A poloxamer biofilm model using glass coverslips. Bacterial cultures were mixed with 30% poloxamer hydrogels incorporated in Mueller-Hinton broth. Biofilms were formed in poloxamer hydrogels placed onto the coverslips. Sample dressings were directly applied onto the drops containing poloxamer hydrogels and bacteria. A. No treatment, B. Gauze, C. Blank Polyester, D. Procellera®

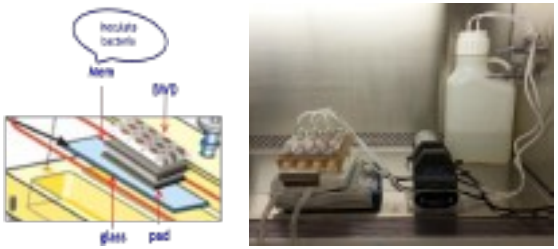


Fig. 2. Set up of a colony drip-flow reactor (DFR) biofilm applied with sample dressings (left) and preparation of antimicrobial efficacy testing in colony DFR biofilm model (right). Sample dressings were applied directly on the biofilms that continuously deposited onto hydrophobic filter membranes for 72 h incubation at room temperature.

Antimicrobial Properties of the Electroceutical Dressing

Pathogen	Bactericidal Efficacy[2,3]	Anti-Biofilm Efficacy: Poloxamer Biofilms[4] Mono-species	Poloxamer Biofilms[4] Multi-species	Colony DFR Biofilms[6]
Acinetobacter baumannii	✓	✓	✓	✓
Escherichia coli	✓	✓	✓	✓
Klebsiella pneumoniae	✓	✓	✓	✓
Pseudomonas aeruginosa	✓	✓		✓
Staphylococcus aureus	✓	✓		✓
Staphylococcus epidermidis	✓	✓		
Staphylococcus simulans	✓			
Enterococcus faecalis		✓	✓	✓
Corynebacterium amycolatum		✓		
Enterobacter aerogenes		✓		✓
Serratia marcescens		✓		✓
Enterobacter cloacae ATCC 13047	✓			
Acinetobacter calcoaceticus	✓			
Pseudomonas aeruginosa ATCC 27853	✓			
Staphylococcus aureus ATCC 25923	✓			

Multidrug Resistant (MDR) Pathogens	Bactericidal Efficacy[3,4]
Klebsiella pneumonia (ESBL)	✓
Pseudomonas aeruginosa (MDR)	✓
Staphylococcus aureus (MRSA)	✓
Enterococcus raffinosus (VRE)	✓
Vancomycin intermediate *S. aureus* (VISA) NRS1, NRS12, NRS73, NRS116	✓
Vancomycin resistant *S. aureus* (VRSA) VRS1, VRS9, VRS11b	✓

Conclusions

The electroceutical dressing demonstrated:

- **Effective and sustained antimicrobial efficacy[2]**
- **Ability to kill a broad spectrum of harmful pathogens, including multidrug resistant bacteria[3] to help reduce risk of infection.**
- **Anti-biofilm activity against both single-species and polymicrobial biofilms[4].**

1. Vanable JW Jr. (1989). Integumentary potentials and wound healing. In: Electric Fields in Vertebrate Repair, Borgens RB, Robinson KR, Vanable, JW Jr., and McGinnis, ME eds. New York: Liss, p. 171-224.
2. AATCC Test Method 100-1998
3. Kim H, Makin I, Skiba J, Ho A, Housler G, Stojadinovic A, Izadjoo M. (2014). Antibacterial Efficacy Testing of a Bioelectric Wound Dressing Against Clinical Wound Pathogens. The Open Microbiology Journal. 8:15-21.
4. Kim H and Izadjoo M. (2015). Antibiofilm efficacy evaluation of a bioelectric dressing in mono- and multi-species biofilms. J Wound Care. 24(2):S10-S16.
5. Determination of silver and zinc in the blood of rabbits following subcutaneous implantation of CMB (Procellera). Apptec Laboratories. Dec 2007. Data on file.
6. Lipp C, Kirker K, Agostinho A. et al. (2010). Testig wound dressings using an in vitro wound model. J Wound Care. 19(6):220-2266.