Nanocrystalline Silver Layer of Knitted Polyester Outperforms Other Silver-Containing Wound Dressings in an In Vitro Wound Model

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Introduction

The utilization of silver in wound care has been reported as early as 69 B.C. Silver's properties exert cytotoxic effects on fungal, bacterial, and viral microbes. The spectrum of bacterial coverage is wide and includes *Staphylococcus aureus* (*S. aureus)* and *Escherichia coli (E. coli),* two of the most commonly implicated bacteria in wound infections. Over the last two decades, studies on wound care products containing silver suggest that silver fulfills a valuable role in wound care. Silver-containing wound dressings (SCWDs) were designed to help decrease wound infection and have transformed the scope of wound care. Silver must be in a soluble form for it to be biologically active. Silver ions (Ag+) provide cytotoxic activity through the interruption of biofilms, the increased uptake of antibiotics, and the generation of reactive oxygen species. Previous studies have shown differences in wound treatment outcomes between a variety of wound dressings such as a silver hydrogel dressing, PolyMem Silver, and Acticoat. Among newer SCWDs, there is limited evidence that one SCWD significantly outperforms others. The different SCWDs are distinguishable by their unique silver compositions and the varied levels of silver embedded within the complex dressing matrices. As such, the goal of this study was to compare industry-leading SCWDs in their ability to control bacterial growth. In the absence of clear experimental evidence, a combination of factors dictates the clinical use of a particular dressing. These include the availability of the dressing, the familiarity of the physician with the dressing, and the type of wound. For patients to achieve better wound care outcomes, independent studies assessing the effectiveness of different SCWDs are needed.

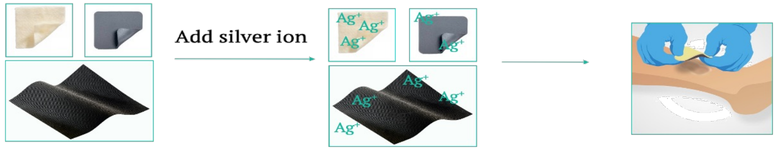

FIGURE 1: SCWD creation and utilization
The various dressings are created and then impregnated with silver ions. Ions are released after making contact with the biofilm developed on a wound. The silver disrupts the biofilm and aids in the healing process.

Materials and Methods

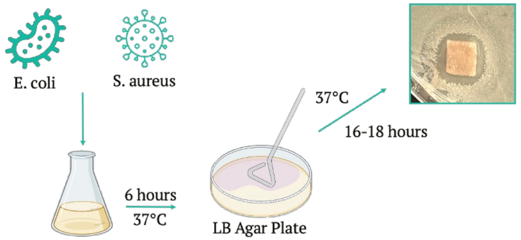

FIGURE 2: Preparation of in vitro wound model (modified Kirby-Bauer test)
Bacteria were grown for 6 hours and then applied to the surface of nutrient agar with the embedded SCWDs and incubated at 37°C overnight. After 18 hours we observed the zone of inhibition around each wound dressing and then compared them to one another through an ANOVA analysis.

Cell density measurements
Colonies of *E. coli* (ATCC25922 Seattle 1946) and *S. aureus* (HIP10787 mupA-positive QC strain methicillin-resistant) sourced from Thermo Scientific (LENEXA, KS 66215 USA) were independently inoculated into a 10-mL Luria Broth (LB) medium (Aldon Corporation, Rochester, NY). These were grown overnight to saturation in a 37°C incubator and shaken vigorously at 250 cycles per minute on a rotary shaker. About 10 µL of each saturated broth was then used to independently inoculate another 10 mL of an LB medium of *E. coli* and *S. aureus*. Thereafter, the broth cultures were grown until an optical density (OD) setting of 0.595 nm reached 0.6 as measured using a spectrophotometer (CGOLDENWALL 722N Visible Spectrophotometer) in accordance with National Committee for Clinical Laboratory Standards recommendations.

Results

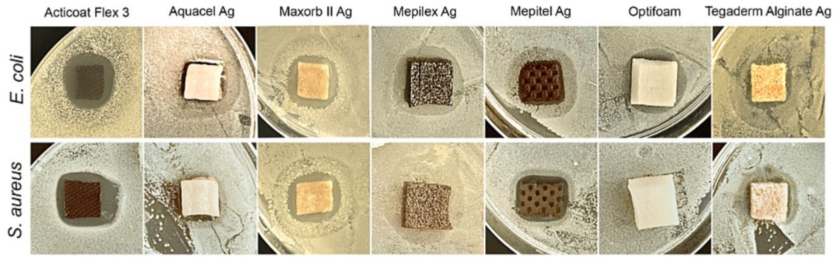

FIGURE 3: SCWDs demonstrate variable antimicrobial effects against *E. coli* and *S. aureus*.
Representative images of each SCWD for *E. coli* and *S. aureus*. The zone of inhibition is defined by clear zones adjacent to the SCWD.

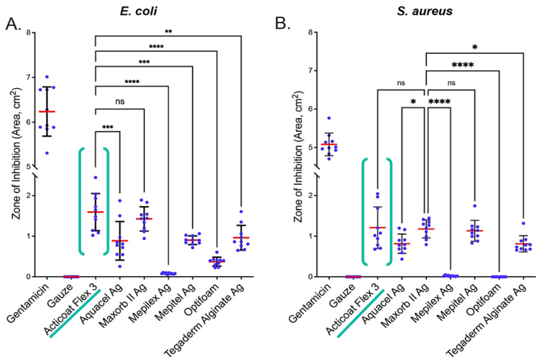

FIGURE 4: SCWDs differ in their antibacterial effect.
Antibacterial effect of SCWDs against (A) *E. coli* and (B) *S. aureus*. Gentamicin was used as a positive control, and gauze only was used as a negative control. Statistical analysis was performed using ordinary one-way ANOVA with Tukey's multiple comparisons test.

SCWD	E. coli	S. aureus	Score
Acticoat Flex-3	++++	++++	8
Aquacel Ag	+++	++	5
Maxorb II Ag	++++	+++	7
Mepilex Ag	+	+	2
Mepitel Ag	+++	+++	6
Optifoam	+	-	1
Tegaderm Alginate Ag	+++	++	5

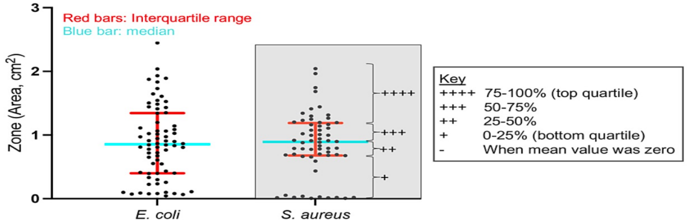

FIGURE 5: Defining the quartile ranges for semiquantitative analysis.
We defined quartile ranges for all data grouped by bacterial strain. Red bar represents the interquartile range of the center 50% of data. Blue bar represents the median.

Discussion

Wound infection is the most common postoperative complication, often causing debilitating pain that leads to significant suffering. In addition, this complication has been associated with negative economic impact, increased morbidity, extended postoperative hospital stay, readmission, sepsis, and death. SCWDs are an attractive and practical choice for wound treatment as silver has been shown to possess antimicrobial properties. Silver is detrimental to bacteria in part through its ability to damage the bacterial cell wall (resulting in increased membrane permeability), block enzyme and solute transport systems, prevent DNA and RNA replication, and block cellular respiration. Other studies have shown the effectiveness of different Acticoat-branded dressings; however, the relative effectiveness of Acticoat Flex-3 in an in vitro wound model, in particular, has not been investigated. Overall, the inhibitory effects of the selected SCWDs show that most silver-containing wound dressings can negatively impact bacterial growth. Taken together, we show through our comparative study that the antimicrobial effectiveness of SCWDs commonly used in current clinical settings varies significantly.

Conclusion

- The antibacterial properties of Acticoat Flex-3 outperformed those of selected SCWDs
- Maxorb II Ag and Mepitel Ag were generally effective across conditions but to a lesser extent than Acticoat Flex-3
- Mepilex Ag showed little to no inhibitory effects on the two strains
- Compared with the selected SCWDs Optifoam was not effective across any of the conditions tested