Suprathel-Acetic-Acid-Matrix Versus Acticoat and Aquacel As an Antiseptic Dressing

An In Vitro Study

Henning Ryssel, MD, Günter Germann, PhD, Katrin Riedel, MD, Matthias Reichenberger, MD, Susanne Hellmich, MD, and Oliver Kloeters, MD

Background: The treatment of burn wounds is still a challenge regarding the management of antiseptic wound conditioning. Especially, in the United States, silver-containing dressings, such as Acticoat and Aquacel are frequently used. Because silver-containing dressings have well-known drawbacks such as an antimicrobial lack against Pseudomonas aeruginosa, we sought to develop an alternative dressing method. In previous studies, we could demonstrate the excellent antimicrobial properties of acetic acid against common burn unit germs, and in another study, the feasibility and suitability of a Suprathel-Acetic-Acid-Matrix as an antiseptic dressing.

Materials and Methods: This study was designed to test the in vitro antimicrobial effect of a “Suprathel-Acetic-Acid-Matrix” versus Acticoat and Aquacel. To cover the typical bacterial spectrum of a burn unit, the following Gram-negative and Gram-positive bacteria strains were tested: Escherichia coli, extended-spectrum beta-lactamase-positive Klebsiella pneumoniae, P. aeruginosa, Acinetobacter baumannii, Enterococcus faecalis, and methicillin-resistant Staphylococcus aureus.

Results: The tests showed an excellent bactericidal effect of the “Suprathel-Acetic-Acid-Matrix” particularly with problematic Gram-negative bacteria such as Proteus vulgaris, P. aeruginosa, and Acinetobacter baumannii. The efficiency was superior to that of Acticoat and Aquacel.

Conclusions: Our results support the notion, that “Suprathel-Acetic-Acid-Matrix” has an excellent bactericidal effect and therefore seems to be suitable as a local antiseptic agent in the treatment of burn wounds.

Key Words: Suprathel, acetic acid, Acticoat, Aquacel, bacteria, burns, antiseptic dressing

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Deep partial-thickness and full-thickness burns often require temporary coverage with topical antimicrobial/antiseptic agents to prevent infections until the true depth of dermal tissue damage can be assessed. Furthermore, once the decision is made to treat superficial partial-thickness burns without surgery, antiseptic dressings are essential to prevent infections during the period of wound healing. Synthetic materials, known for their stimulatory effects on epidermal cell proliferation are often used in wound management but lack some antimicrobial activity and have an increased wound contamination rate, especially on necrotic and exsudative tissues. Setting of burn wound treatment, which stimulated the development of novel products synthesizing the benefits of silver ions and synthetic materials. The most commonly used types of antibacterial dressings and creams to treat deep partial-thickness and full-thickness wounds are silver sulfadiazine (Flammazine, Solvay Inc., Frankfurt, Germany), silver-containing hydrofiber (Aquacel, ConvaTec Inc., Princeton, NJ), and silver-coated high-density polyethylene mesh (Acticoat, Smith & Nephew). Intervals of dressing changes for these products vary substantially based on their specific silver ion release kinetics. According to the manufacturers’ guidelines, the following intervals are recommended: once a day for silver sulfadiazine, every 3 to 4 days for silver-containing hydrofiber, and every 5 to 7 days for silver-coated high-density polyethylene mesh. However, only a small number of studies addressed the efficiency as antimicrobial agents of these products in a comparative fashion. Castellano et al tested multiple commercially available silver-containing dressings such as Acticoat 7, Acticoat Moisture Control, Acticoat Absorbent, Silvercel, Aquacel Ag, Contreet F, Urgotol SSD, and Actisorb to compare their antimicrobial effectiveness in vitro against 3 commercially available topical antimicrobial creams, a nontreatment control and a topical silver-containing antimicrobial gel. Minimal inhibitory concentration and quantitative testing were performed to determine the antimicrobial power against Escherichia coli, Pseudomonas aeruginosa, Streptococcus faecalis, and Staphylococcus aureus. Their findings indicated that all silver-containing dressings and topical antimicrobials displayed antimicrobial activity. Moreover, there was a proportional relationship between silver concentration and bacterial growth inhibitory properties. Acticoat dressings tended to have increased antimicrobial activity than the other tested antiseptics. Topical antimicrobial creams, including silver sulfadiazine, sulfamylon and gentamicin sulfate, and the topical antimicrobial gel Silvasorb exhibited superior bacterial inhibition and bactericidal properties, essentially eliminating all bacterial growth at 24 hours. However, their bactericidal and bacteriostatic properties are inferior to those of commonly used topical antimicrobial agents, eg. frequently, there is a lack of effectiveness against P. aeruginosa in silver-containing dressings. In previous studies, we demonstrated the antiseptic properties of a Suprathel-Acetic-Acid-Matrix. In this study, we sought to investigate the synergistic effects of a novel antiseptic matrix combining the semicocclusive and regenerative properties of Suprathel along with the broad antiseptic spectrum of acetic acid, both of which are being demonstrated in previous investigations. In addition, we compared in vitro the antiseptic properties against typical burn unit bacteria, eg, P. aeruginosa of this novel matrix with established silver-containing dressings, Acticoat and Aquacel.

Materials and Methods

Acticoat

Acticoat (Smith & Nephew, Hull, U K) is a 3-ply gauze dressing that consists of an absorbent rayon and polyester core as...
well as upper and lower layers of silver-coated high-density polyethylene mesh. The silver coating consists of 0.2 to 0.3 mg silver per milligram of high-density polyethylene and is a binary alloy of silver (97%) and oxygen. It is <1 μm in thickness and engineered to change color in aqueous solutions. The coating film produced is abrasion-resistant, nonadherent to the wound, flexible, and it does not change the physical properties of the high-density polyethylene mesh.5

Aquacel
Aquacel (Aquacel Ag, ConvaTec Bristol-Myers Squibb Company, Skillman, NJ) was developed with the same technology as Aquacel-Hydrofiber. Sodium carboxymethyl cellulose is spun into absorbent hydrofibers, which immediately form a gel when in contact with wound exudates and maintains a moist environment. The dressing vertically wicks and entraps microorganisms within its fibers, reducing bio-burden and minimizing the risk of infection.5 The process of adding silver for the product Aquacel makes it unique when compared with other silver-containing dressings by both design and function. Rather than silver being applied as a coating on the wound contact surface, 1.2% weight to weight ionic silver is distributed throughout the entire hydrofiber material. Silver ions are released into the wound in a controlled fashion for ~14 days as opposed to other silver dressings with exhausting their silver ion after 3 to 7 days of storage already. Finally, in vitro studies have demonstrated that Aquacel has a broad range of effectiveness against both antibiotic sensitive and multiresistant wound pathogens such as methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant enterococcus.5

Acetic Acid
In this study, all experiments were carried out using a 3% acetic acid solution (Doktorenhof, Germany) as used in our previous studies.5,6

Suprathel
Suprathel is a newly developed wound dressing with permanent and degradable properties. It is produced from a synthetic copolymer consisting mainly of DL-lactic-acid, trimethylene carbonate and degradable properties. It is produced from a synthetic Acetic Acid Acetic Acid Acetic Acid Acetic Acid

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Suprathel
Suprathel is a newly developed wound dressing with permanent and degradable properties. It is produced from a synthetic copolymer consisting mainly of DL-lactic-acid, trimethylene carbonate, and caprolacton. It represents a synthetic dressing that imitates the epithelial properties and has semiocclusive properties. The membrane and the manufacturing process have been patented. During the production process, monomers are polymerized by melting procedure after the dissolution in inorganic solvents. Then, the material is processed by means of modified phase-inversion and freeze-drying techniques. The final product consists of a membrane with 80% porosity, resulting in symmetrical pore crosssections. Pore sizes vary between 2 and 50 μm. The membrane has an elongation capacity of ~250%, with a modulus of ~800 N/mm². This offers a large amount of plasticity, which allows instant adaptation to wound beds at body temperature. Its moisture permeability prevents accumulation of wound fluid, supporting wound healing, and reepithelialization. The membrane’s physicochemical properties and the scanning electron microscopical structure are shown in Figure 1 and Table 1.

As wound healing progresses, Suprathel detaches from the reepithelialized surface because of the molecular weight decrease of the material. Until then, Suprathel most likely serves as a semiocclusive dressing providing a moist environment and a temporary epidermal surrogate. When applied on burn injuries, it is recommended to cover Suprathel after debridement once directly to the wound surface with 1 layer of tailored paraffin gauze and an additional layer of regular paraffin gauze followed by compress dressing. This will protect the dressing and prevent material dislocation.

Experimental Settings
In a previous study, we showed the feasibility and suitability of Suprathel as a carrier for different antiseptic agents.5 After the protocol of this previous study, a Suprathel sheet in the size of 5 × 5 cm was placed in a 3% acetic acid solution for 10 minutes to allow for uptake of the agent. Standard 1-boullion-tubes were inoculated with the tested bacteria such as E. coli (Deutsche Sammlung Mikroorganismen Nr. 498, K12), Klebsiella pneumoniae (Hauser group 2), P. aeruginosa (Schroeter 1872, group 2), Actinobacter baumannii (Institute Limbach, Heidelberg, Germany), Enterococcus faecalis (Andrews and Horder 1906, group 2), and MRSA (Institute Limbach, Heidelberg, Germany) and incubated at 37°C for 24 hours according to a standard method based on a previously published protocol for incubation of bacteria.4 From the obtained bacterial cultures, 0.1 mL was dripped on standard agar plates. In the next step, the above mentioned Suprathel-Acetic-Acid-Matrix was put on top of the agar plate. Acticoat, Aquacel, and a sterile H₂O control group were treated in the same way. All investigated products were incubated for 60 minutes and 24 hours for each combination. After testing the antiseptic sheet/matrix for 60 minutes and 24 hours, Suprathel, Acticoat, Aquacel, Suprathel-Ag and the H₂O-control were removed and turned upside down on a new standard agar plate and doused with warm (47°C) standard I-agar. The tested products were then again incubated at 37°C for 48 hours followed by final

![FIGURE 1. Scanning electron microscopy showing the ultra structure of Suprathel and its membrane’s porosity.](image-url)

<table>
<thead>
<tr>
<th>TABLE 1. Technical Data of Suprathel (25 kGy Sterilized)</th>
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<tbody>
<tr>
<td>Membrane thickness*</td>
</tr>
<tr>
<td>Molecular weight†</td>
</tr>
<tr>
<td>Glass transition point, melting point‡</td>
</tr>
<tr>
<td>Load, strength§</td>
</tr>
<tr>
<td>Elongation break§</td>
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<tr>
<td>Modulus§</td>
</tr>
</tbody>
</table>

*SEM: Scanning electron microscopy.
†Capillary viscometry: 0.1% solution in chloroform, measurement of the inherent viscosity. Gel permeation chromatography (GPC): column Nucleogel M5, temperature 40°C, detection UV 225 nm, rate 1 mL/min, 1% of polymer solution.
‡Differential scanning calorimetry (DSC): 10 K/min heating rate.
§Instron stress/strain testing machine, measurement according to DIN53455, sample dimensions: 120 × 15 mm.
counting of colony forming units (CFU). Each combination of antiseptic dressing plus bacteria was tested 4 times. All experimental procedures of bacterial culture were based on the recommendations of the Robert Koch Institute and the German Institute of Hygiene.4,8

**TABLE 2. Pseudomonas Aeruginosa**

<table>
<thead>
<tr>
<th>Antiseptic Dressing</th>
<th>Initial Incubation (60 min) CFU/Agar Plate</th>
<th>Initial Incubation (24 h) CFU/Agar Plate</th>
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<tbody>
<tr>
<td>Supratheral acid</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Acticoat</td>
<td>++ +</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Aquacel</td>
<td>++ +</td>
<td>&lt;50</td>
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<tr>
<td>H2O</td>
<td>++ +</td>
<td>+ + +</td>
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Elimination of Pseudomonas aeruginosa, Acinetobacter baumannii, ESBL-positive Klebsiella Pneumoniae, Escherichia coli, Enterococcus faecalis, methicillin-resistant Staphylococcus aureus (MRSA) by 5 × 5 cm Supratheral sheet soaked with acetic acid, Acticoat, Aquacel, H2O control. CFU: colony-forming units. Standard 1-boullion-tubes were inoculated with these bacteria and incubated at 37°C for 24 h. From the obtained bacterial cultures, 0.1 mL was spread on standard agar plates. After incubation with an antiseptic dressing for 60 min and 24 h, a subsequent incubation at 37°C for 48 h followed and the CFU were counted. Each antiseptic dressing was treated in the same way. Each combination of antiseptic dressing and each germ were tested 4 times, and the average colony forming units were calculated.

—, no detectable bacterial growth; + + +, CFU > 10^3.

**TABLE 3. Acinetobacter baumannii**

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<th>Antiseptic Dressing</th>
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</tr>
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<td>Aquacel</td>
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</tr>
<tr>
<td>H2O</td>
<td>++ +</td>
<td>+ + +</td>
</tr>
</tbody>
</table>

—, no detectable bacterial growth; ++ +, CFU > 10^3.

**RESULTS**

Tables 2–7 summarize the results of the different antiseptic dressings with the different tested bacteria. All experiments were repeated 4 times for each bacteria/antiseptic combination because we have already used in our previous study.6

In the group with 60 minutes incubation, the Suprather-Alcetic-Acid-Matrix was the only antiseptic dressing, which eliminated *P. aeruginosa*, *A. baumannii*, and ESBL-positive *K. pneumoniae* completely. All other investigated antiseptic dressings showed >10^3 CFU after for these 3 bacteria. Regarding *E. coli* and MRSA, all dressings showed equal effectiveness.

In the group with 24 hours incubation, the Suprather-Alcetic-Acid-Matrix was the only antiseptic dressing to eliminate all investigated types of bacteria. On the contrary, Acticoat showed significant growth of *P. aeruginosa*, *A. baumannii*, and MRSA. Aquacel showed only minor antiseptic effects with significant growth of *P. aeruginosa*, *A. baumannii*, *E. coli*, *E. faecalis*, and MRSA. The overall effect of the Suprather-Alcetic-Acid-Matrix was higher than the other antiseptic dressings.

**DISCUSSION**

Despite major advances in the past decades, bacterial and fungal infections remain the main cause of death in burn patients. Besides early necrectomy, the mainstay for successful wound manag-
agrement and prevention of septic complications in patients sustaining severe burn injury is an adequate surface therapy with antiseptic dressings covering ideally all typical and multidrug-resistant bacteria on burn units. Nowadays, we are predominantly confronted with multidrug-resistant bacteria and are frequently resistant to common topical antiseptics as well.

We have already conducted trials for the in vitro antiseptical effects of acetic acid alone and the feasibility of a Suprathel-Acetic-Acid-Matrix and its antiseptic properties in vitro.4–6 Undoubtedly, Suprathel reduces the local wound pH because of its polyactic acid part (see manufacturers product information) and might therefore have some antiseptic effect. We have previously tested Suprathel in combination with water only to rule out the relevant antiseptic effects of Suprathel alone (unpublished data). In all investigated bacteria, we could not detect growth inhibition by Suprathel/water alone and after 60 minutes CFU >10^3 were observed. Therefore, we conclude that all observed antiseptic effects in this study can be attributed to acetic acid alone.

In this study, we investigated the antiseptic properties of a Suprathel-Acetic-Acid-Matrix compared with 2 standard dressings in vitro. Acticoat and Aqualuel are widespread antiseptic dressings containing nanocrystalline silver. A large body of studies exists investigating the mechanism of action and the effectiveness of silver-containing dressings whether as silver sulfadiazine or nanocrystalline silver formulations.9–15 Panacek et al16 demonstrated high antimicrobial and bactericidal activity of silver nanoparticles on Gram-positive and Gram-negative bacteria including multidrug-resistant bacteria such as MRSA. Furthermore, this study revealed a correlation between the size of nanoparticles and antibacterial activity, which was best at 25 nm. Pal et al15 added the relevant shape of nanoparticles for antimicrobial effectiveness with the lowest concentration at 1 μg of silver in truncated triangular shapes being inhibitory for bacterial growth. An in vitro comparison of 5 different commercially available silver-containing products by Ip et al17 showed a broad activity for Acticoat and Contreet against both Gram-positive and Gram-negative bacteria, whereas other products had a decreased range of bacterial spectrum.

Herein, we demonstrated that 60 minutes of incubation of Suprathel-Acetic-Acid-Matrix was sufficient to fully eliminate P. aeruginosa, A. baumannii, and extended-spectrum beta-lactamase-positive K. pneumoniae. The complete eradication of all investigated germs was only observed with Suprathel-Acetic-Acid-Matrix. On the contrary, Acticoat and Aqualuel showed >10^3 CFU after 60 minutes for these 3 bacteria. Against E. coli and MRSA, the 3 dressings showed the comparable effectiveness.

When Suprathel-Acetic-Acid-Matrix was incubated for 24 hours, it was the only dressing to eliminate all types of investigated bacteria. Acticoat exerted significant growth of P. aeruginosa, A. baumannii, and MRSA. Aqualuel had a quite poor antiseptic effect with significant growth of P. aeruginosa, A. baumannii, E. coli, E. faecalis, and MRSA. In summary, the overall antimicrobial effect of Suprathel-Acetic-Acid-Matrix was superior to other antiseptic dressings in this study.

This study elucidates the cytotoxic effect of 3% acetic acid on keratinocytes with pending results.

Lineaweaver et al15 investigated the cellular and bacterial toxicities of 4 different topical antiseptics (including 0.25% acetic acid) in vitro on human fibroblasts and S. aureus. At full strength, all 4 agents resulted in 100% fibroblast toxicity. Fibroblast toxicity still exceeded bacterial toxicity when S. aureus was incubated in serial dilutions of acetic acid. In another animal study, Lineaweaver et al19 concluded that acetic acid is not suitable for wound care. However, contaminated burn wounds have to be considered as a major lethal factor for the patient and contamination of burned surface tissue or even full blown septic patients might benefit from topical application of a Suprathel/3%-acetic-acid solution based on our in vitro findings. In such circumstances, fibroblast and keratinocyte toxicity, which can be observed at a varying range in all concurrently used topical antiseptic dressings are important, once the life-threatening stage of burn injury has been overcome. Further studies have to evaluate whether acetic acid in lower concentration might reveal a better keratinocyte/bacteria-toxicity-ratio.

In terms of cost efficiency, previous studies demonstrated a significant cost reduction in materials and labor, once the number of dressing changes can be reduced.20 Fong et al21 investigated this particular issue and compared silver sulfadiazine versus nanocrystalline-silver dressings. His results clearly indicate an average cost reduction of US$ 7613 per patient (US$ 27,339 vs. US$ 19,726), and a reduction of days in hospital when nanocrystalline-silver dressings are used. The costs per cm² of Suprathel/Acetic-Acid dressing is US$ 1,13. Although, it was not the focus of this study, we assume that Suprathel/Acetic-Acid dressing is a cost-efficient treatment option, and furthermore, clinical trials have to prove its cost efficiency.

We conclude that in an in vitro setting, the Suprathel-Acetic-Acid-Matrix is superior in its antiseptic spectrum and effectiveness when compared with the frequently used dressings Acticoat and Aqualuel, and might, therefore, be a valuable future alternative antiseptic dressing for burn units.

## Table 7. Methicillin-Resistant Staphylococcus aureus (MRSA)

<table>
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<tr>
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<tbody>
<tr>
<td>Suprathel acid</td>
<td>+++</td>
<td>—</td>
</tr>
<tr>
<td>Acticoat</td>
<td>&lt;50</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Aqualuel</td>
<td>+++</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Suprathel Ag</td>
<td>+++</td>
<td>+++</td>
</tr>
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### References


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