

An *in vitro* analysis of the antimicrobial properties of 10 silver-containing dressings

The variation in the structure and properties of the many silver dressings now on the market might be expected to affect their antimicrobial properties. This study, which follows up a paper published last March, compares their performance

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Silver-containing dressings, indicated primarily for the treatment or prevention of soft-tissue infections, depend on the ability of low concentrations of silver ions to kill a broad spectrum of microorganisms. Some of the new materials have been developed to carry and release silver in a controlled fashion. In others cases, a silver compound has been added to an existing product.

Given the considerable variation in the structure, composition and silver content of these new preparations, marked differences might also be anticipated in their ability to release silver in sufficiently high concentrations to exert a significant antimicrobial effect. This could have important implications for the dressings' clinical performance.

We have already described how the antimicrobial activity of four silver-containing dressings was compared in a laboratory-based study using three tests.¹ The dressings were: Acticoat (Smith and Nephew), Actisorb Silver 220 (Johnson and Johnson), Avance (SSL International) and Contreet-H (Coloplast).

This follow-up paper reports the results of further tests conducted in an identical manner on an additional six silver-containing dressings, together with a non-woven swab (negative control) and Acticoat (positive control).

Materials and methods

The six new dressings are described below, using the limited information provided by the manufacturers.

Arglaes (Medline)

Contains a mixture of an alginate powder and an inorganic polymer containing ionic silver. The alginate absorbs moisture to form a gel, and the silver complex breaks down in a controlled fashion to liberate ionic silver into the wound.

Aquacel Ag (ConvaTec)

Comprises a fleece of sodium carboxymethylcellulose (CMC) fibres containing 1.2% ionic silver. The

dressing absorbs moisture to form a gel, binding sodium ions and releasing silver ions.

Calgitrol (Magnus Bio-Medical Technologies)

A silver alginate dressing comprising an absorbent foam sheet, one surface of which is coated with an alginate matrix containing ionic silver, together with a 'cleanser, moisturiser and a superabsorbent starch co-polymer'.

Contreet Ag (Coloplast)

A polyurethane foam dressing containing silver in a so-called 'hydroactivated' form, which is released as the foam absorbs liquid.

Silverlon (Argentum Medical)

A knitted fabric dressing, silver-plated by means of a proprietary autocatalytic electroless chemical (reduction-oxidation) plating technique. This coats the entire surface of each individual fibre, resulting in a very large surface area for the release of ionic silver.

Silvasorb (Medline)

Composed of a synthetic, polyacrylate, hydrophilic matrix in which microscopic silver-containing particles are dispersed or suspended. On exposure to moisture, silver is released in a controlled fashion.

Test organisms

This study set out to compare the antimicrobial properties of the dressings rather than investigate the antimicrobial activity of silver itself.¹ Three standard organisms were therefore used:

- Gram-positive: *Staphylococcus aureus* (ATCC 6538P)
- Gram-negative: *Escherichia coli* (ATCC 8739)
- A yeast: *Candida albicans* (ATCC 2091).

Test methods

Three different methods were designed to compare various aspects of performance. Full details are given in the original article.¹

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Reference

1 Thomas, S., McCubbin, P.
A comparison of the
antimicrobial effects of four
silver-containing dressings
on three organisms. J
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Table 1. Summary of zone-of-inhibition data

	<i>S. aureus</i>	<i>E. coli</i>	<i>C. albicans</i>
Group A (score 3)			
Products that show evidence of sustained activity over two or more days	Acticoat Aquacel Ag Calgitrol Ag Contreet-H Silverlon	Acticoat Calgitrol Ag Contreet-H Hydrocolloid Silverlon	
Group B (score 2)			
Products that produce a well-defined zone of inhibition at one time interval	Arglaes Power Silvasorb	Aquacel Ag Arglaes Powder	Acticoat Arglaes Powder Calgitrol Ag Contreet-H Silvasorb Silverlon
Group C (score 0)			
Products that produce no well-defined zone of inhibition in this test	Actisorb Silver 220 Avance Contreet Ag	Actisorb Silver 220 Avance Contreet Ag Silvasorb	Actisorb Silver 220 Aquacel Ag Avance Contreet Ag

Table 2. Summary of microbial challenge test results

	<i>S. aureus</i>	<i>E. coli</i>	<i>C. albicans</i>
Group A (score 4)			
Products that demonstrate marked antibacterial activity after two hours' incubation	Acticoat Calgitrol Ag	Acticoat Calgitrol Ag Contreet Ag Silverlon	Acticoat Calgitrol Ag Contreet Ag Silverlon
Group B (score 3)			
Products that demonstrate marked antimicrobial activity after four hours' incubation	Silverlon	Contreet-H Aquacel Ag Silvasorb	
Group C (score 2)			
Products that demonstrate marked antimicrobial activity after 24 hours' incubation		Actisorb Silver 220	
Group D (score 1)			
Products that demonstrate limited evidence of antimicrobial activity after 24 hours' incubation	Aquacel Ag Contreet-H Contreet Ag Silvasorb		Contreet-H Aquacel Ag Silvasorb
Group E (score 0)			
Products that demonstrate no convincing evidence of antimicrobial activity even on prolonged incubation	Actisorb Silver 220 Avance	Avance	Actisorb Silver 220 Avance

• **Zone of inhibition** Samples of each dressing were placed on agar plates inoculated with 0.2ml of a log-phase broth culture of each test organism. After incubation, the plates were examined for the presence of a zone of inhibition. If one was detected, the width was measured and the dressing was removed from the agar, placed on another agar plate and seeded as before with the same microorganism. This process was repeated a maximum of seven times or until no further zone of inhibition was produced during the previous test.

• **Challenge testing** 0.2ml of a log-phase culture of each microorganism was added to portions of each dressing measuring 40x40mm. The inoculated dressings were incubated for two hours, then transferred into 10ml of 0.1% peptone water (Oxoid) and vortexed to remove any remaining viable organisms. Serial dilutions were performed in triplicate on each extract, and the number of viable organisms present determined using a standard surface counting technique.

If viable organisms were recovered, the test was repeated as before using a four-hour contact period, and then again with a 24-hour contact period.

If no organisms were detected on a particular dressing after two hours, the dressing was placed in 10ml of tryptone soya broth (TSB) to detect very low levels of residual contamination.

As no inactivator for silver was used during this test, it is possible that any remaining low concentrations of silver ions present could have prevented the recovery of these organisms, potentially resulting in a false negative result.

• **Microbial transmission test** Here, a strip of dressing forms a bridge between two separate agar blocks in a Petri dish, one of which is sterile and the other inoculated with the test organism. This test determines the bacteria's ability to survive on the dressing surface and migrate along it from the contaminated agar to the sterile agar. A positive result suggests that it is possible that microorganisms could be transported laterally out of a contaminated wound onto the surrounding skin, or potentially move in the opposite direction from the intact skin into the wound itself.

Silver content

Samples of each dressing were sent to Sheffield Analytical Services to determine the total extractable silver content of each dressing by inductively coupled plasma optical emission spectroscopy (ICP-OES).

Results

Zone of inhibition test

The results of this method for the three test organisms are summarised in Table 1, which also includes results from the original paper.¹ There was considerable variation in ability to inhibit growth of the

three test organisms. To further facilitate comparisons, a simple scoring system is also included. A dressing gets three points for each appearance in group A, two points for each appearance in group B and no points for each appearance in group C. The sum of these scores produces a very crude measure of the dressings' overall performance in this test.

Microbial challenge test

The results of this test are summarised according to the dressings' ability to produce a marked antimicrobial effect, arbitrarily defined as a 10^3 reduction in the number of viable organisms present at each time interval (Table 2). A similar scoring system to that outlined above has been devised to facilitate later comparisons. Due to the physical nature of the Arglaes material, it was not possible to include it in this series of tests.

Microbial transmission test

Results are summarised in Table 3. Again, both Tables 2 and 3 include results from the first paper.¹ Other than the control material, the only test samples to show any evidence of microbial transfer were Actisorb Silver 220 and Avance.

As previously discussed,¹ in the case of Actisorb Silver 220, microbiological migration occurred on only one sample, and probably took place across the nonwoven fabric outer sleeve of the dressing. No transfer occurred when only the inner core of the dressing was examined.

Evidence of transmission of bacteria was clearly visible on all three samples of Avance, as shown by prolific bacterial growth around the ends of the dressing on the surface of the sterile agar.

No transfer of *Candida albicans* took place on any of the sample tested including the control, which made the tests invalid.

Silver content of dressings

The total silver content of each dressing included in both papers is shown in Table 4 ranked by silver content, which indicates that major differences exist between these products, with values ranging from 546 to 1.6mg/100cm². Also included are the total scores achieved by each dressing in the various laboratory tests.

Discussion

The test methods were designed to compare the performance of the dressings under different simulated conditions of use.

The zone of inhibition method simulates the use of the products on moist or lightly exuding wounds and predicts the dressings' ability to kill or prevent bacterial growth in this situation.

In order to exert a significant antimicrobial effect in this test, a dressing must first absorb moisture

Table 3. Microbial transmission test

	<i>S. aureus</i>	<i>E. coli</i>	<i>C. albicans</i>
	Transfer ±	Transfer ±	Transfer ±
Acticoat	-	-	-
Actisorb Silver 220	+	+	-
Actisorb Silver 220*	-	-	-
Avance	+++	+++	-
Contreet-H	-	-	-
Control	+++	+++	-
Acticoat	-	-	-
Aquacel Ag	-	-	-
Calgitrol Ag	-	-	-
Contreet Ag	-	-	-
Silvasorb	-	-	-
Silverlon	-	-	-
Control	+++	+++	-

Each + indicates the results for a single test strip

*Only the inner core of Actisorb Silver 220 was used

Table 4. Silver content of the dressings

Product	Batch no.	Ag content (mg/100cm ²)	Total performance scores
Silverlon	102502-01	546	19
Calgitrol Ag	131-71	141	20
Acticoat	010814A-08 020214A	109 101	20
Contreet Ag	74853.01	47	9
Contreet-H	315768 267462 344046	31.2 32.4 31.4	13
Aquacel Ag	2H55863	8.3	10
Silvasorb	02082001	5.3	9
Actisorb Silver 220	0138-03 0135-04	2.9 2.4	2
Avance	01106947	1.6	0
Arglaes powder	527027	6.87mg/gram	

from the agar to activate or release the silver held within its structure. This silver, in the form of silver ions, must then diffuse back down into the agar to exert its antimicrobial action.

The microbiological challenge test provides an indication of each dressing's ability to kill or prevent growth of predetermined numbers of bacteria applied directly in the form of a suspension, and thus to some extent reflects what may occur within dressings applied to more heavily exuding wounds.

The third test determines the bacteria's ability to survive and be transmitted along the dressing surface.

It was anticipated from the outset that the ability to exert a significant antimicrobial effect would be directly related to the total amount of silver present. The very crude scoring system described above seems to support this view. There is clearly a very strong association between the dressings' measured silver content and the scores they achieved in the laboratory tests, although two results for Silverlon and Contreet Ag require further comment.

Although it scored highly overall, the somewhat poor performance of Silverlon against *Staphylococcus aureus* in the challenge test was surprising given that it contained by far the highest concentration of silver of any of the dressings examined (four to five times the amount of the next two highest products). Similarly, although Contreet Ag performed well in some tests, it was disappointing in others.

While total silver content is important, other factors also influence a dressing's ability to kill microorganisms. These include the distribution of the silver within the dressing (whether it is present as a surface coating or is dispersed through the structure), its chemical and physical form (whether it is present in a metallic, bound or ionic state) and the dressing's affinity for moisture — a prerequisite for the release of active agents in an aqueous environment. Products in which the silver content is concentrated on the dressing surface rather than 'locked up' within its structure performed well, as did those in which silver was present in the ionic form.

Calgitrol, which contains a high concentration of silver, performed very well in all tests. This is probably because the silver, already in the ionic form, is concentrated on the dressing surface in a hydrophilic coating, which facilitates its rapid release.

Contreet Ag and Contreet-H, although containing broadly similar concentrations of silver, performed very differently in the first two tests. In the zone of inhibition test the hydrocolloid performed well, unlike Contreet Ag. In contrast, in the challenge test the foam-based Contreet Ag markedly outperformed the hydrocolloid.

The reasons for this are not entirely clear but may be related partly to differences in the fluid-handling characteristics of the two dressings. Under the test conditions, absorbency of Contreet Ag may be such

Box 1. Summary of the main findings

An *in vitro* study published in *Journal of Wound Care* in March 2003 described the antimicrobial activity of four silver-containing dressings: Actisorb, Actisorb Silver 220, Avance and Contreet-H. This follows up on the results of the same tests conducted on six further silver dressings: Aquacel Ag, Calgitrol, Contreet Ag, Silverlon and Silvasorb.

The findings suggest that although the total amount of silver present in a dressing influenced its antimicrobial activity, the form and location of the silver could also have had a marked influence on its performance.

Great care must be taken when attempting to extrapolate the results of laboratory studies to the clinical situation.

that it created a suction gradient, continuously drawing fluid out of the agar and inhibiting the movement of solution containing silver ions in the reverse direction. Also, the foam had a tendency to curl away from the agar plate. In the challenge test, however, the organisms applied directly to the foam were destroyed by the silver ions released within its structure. This test probably more closely reflects the dressing's performance in the management of more heavily exuding wounds.

Aquacel contains ionic silver in a hydrophilic fibrous fleece. This material's fluid affinity is such that it was readily capable of drawing moisture out of the agar, which then released the silver ions. This enabled the dressing to exert significant antimicrobial activity on extended incubation, despite the relatively modest silver content.

Silvasorb, which also contains a relatively low concentration of ionic silver, showed broadly similar activity to Aquacel due to its hydrophilic structure.

Actisorb Silver 220, which contains low concentrations of metallic silver, showed evidence of only very limited antimicrobial activity.

Avance, which has the lowest silver content of the products examined, showed no evidence of any antimicrobial effect in any of the tests.

Considerable caution must be exercised when extrapolating the results of this or any laboratory-based study to the clinical situation as many factors determine a dressing's acceptability or clinical effectiveness, which may not become apparent in a laboratory model. For example, this study made no attempt to compare the fluid-handling properties of the various products or to determine their tissue compatibility or potential cytotoxic effects. All these issues were discussed at length.¹ Nevertheless, we believe our results may provide useful information to clinicians on one key aspect of the performance of this relatively new class of products. ■

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More detailed data on the results of the zone of inhibition and challenge tests are available from the author