Silver-containing foam dressings with Safetac:

a review of the scientific and clinical data

An educational supplement in association with

JWC journal of wound care

BJN British Journal of Nursing

Mölnlycke®

Declaration of interest
This supplement was written by Phil Davies, Sara McCarty and Kristina Hamberg, all of whom are employees of Mölnlycke Health Care. It has been subject to double-blind peer review.

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How to cite this document: Davies, P., McCarty, S., Hamberg, K. Silver-containing foam dressings with Safetac: a review of the scientific and clinical data. J Wound Care 2017; 26: 6 (Suppl. 1), S1–S32.

Background

Topical antimicrobials, such as silver dressings, are progressively being used alongside systemic antibiotics to provide adjunctive, antimicrobial therapy to wounds that are clinically infected or at risk of infection. To help improve wound management, dressings that use Safetac soft silicone technology in combination with a silver-impregnated foam dressing material were developed by Mölnlycke Health Care (Gothenburg, Sweden). The range comprises Mepilex Ag, Mepilex Border Ag and Mepilex Transfer Ag.

Aims

A literature review was undertaken to identify and summarise clinical data from the entire evidence hierarchy, as well as data from *in vitro* tests, which support the use of silver-containing foam dressings with Safetac.

Method

The MEDLINE (National Library of Medicine, Bethesda, US) and EMBASE (Elsevier BV, Amsterdam, Netherlands) bibliographic databases were searched. In addition, abstract books and proceedings documents relating to national and international conferences were scanned in order to identify presentations (oral, e-poster and poster) of relevance to the review.

Results

In vitro test results showed that the silver-containing foam dressings with Safetac have both rapid and sustained activity against a range of wound pathogens, reducing planktonic and established biofilm cultures, and preventing biofilm formation. In numerous clinical studies, silver-containing foam dressings with Safetac were used to manage wound bioburden effectively and resolve signs of localised infection in both acute wounds (such as surgical, traumatic and burn injuries) and chronic wounds (such as leg ulcers, pressure ulcers (PUs), diabetic foot ulcers (DFUs), and cancerous wounds). Studies reported that silver-containing foam dressings with Safetac are easy to use, provide an optimal environment for wound healing, and are associated with atraumatic and virtually pain-free removal. As well as being clinically effective, they are reported to be cost-effective when used on wounds that require topical antimicrobial therapy.

Conclusion

The findings of both scientific and clinical studies clearly indicate that clinical, patient-related and economic benefits are associated with the use of Mepilex Ag, Mepilex Border Ag and Mepilex Transfer Ag with Safetac in the treatment of wounds where antimicrobial activity is needed to help manage bioburden.

Keywords: bioburden ■ biofilm ■ dressing ■ antimicrobial ■ silver ■ soft silicone ■ Safetac

Introduction

Wound microbiology

Wounds provide an ideal environment for microbial growth.[1] Virtually all wounds, chronic and acute, become colonised by endogenous microbial flora, which may contain opportunistic pathogens.[2] In most wounds, colonisation does not affect the wound healing process because there is a balance between the microorganism's ability to invade the host tissue and the host's ability to prevent it. Usually, a healthy individual with an intact immune system will experience minimal effects from a contaminated wound and healing will take place within a normal timeframe.

In contrast, the wound of an immunocompromised patient, such as one with diabetes mellitus, may allow further colonisation from microbial communities, which may contribute to delayed healing or signs of overt clinical infection. Wounds are often colonised with planktonic (free-floating) microorganisms that divide rapidly, yet are vulnerable to antimicrobial agents. Some wounds, however, may lack these clinical signs of infection, despite the presence of high microbial loads.[3] While these wounds may appear healthy to the naked eye, they are colonised by a variety of sessile (slow-growing) microorganisms embedded in a matrix, which contribute to stalled healing.[4]

A biofilm is defined as an aggregate of sessile microorganisms, embedded in a matrix of either microbial or host origin, which is tolerant to both antimicrobial treatment and host defence.[5] The microorganisms in a biofilm have low metabolic activity, contributing in part to its inherent tolerance to antimicrobial treatment. Increasing evidence suggests a relationship between persistent chronic wound infection and the presence of a biofilm, with one study identifying its presence in 60% of chronic wounds, as opposed to 6% of acute wounds.[6]

More recently, a systematic review highlighted a 78% prevalence of biofilm in chronic wounds.[7] Based on these high prevalence rates, it should be assumed that biofilm is present in all non-healing chronic wounds that have failed to respond to standard care.[5]

Key points:

- Wounds provide an ideal environment for microbial growth
- Biofilm is present in many chronic wounds, contributing to delayed healing

Antimicrobial therapy

Acute wound infection is characterised by sudden onset of pain or increased pain, spreading erythema, swelling, cellulitis, appearance of purulent exudate, and malodour, posing significant clinical and economic challenges to healthcare providers. A wound care intervention must, therefore, be initiated at the earliest possible opportunity. Two main strategies are used to prevent and treat clinical infection: systemic antibiotics and topical antiseptics.[8] Traditionally, systemic antibiotics have played the principal role in the defence against bacterial infection but, as the incidence of antibiotic resistance increases, successful outcomes are becoming more difficult.

Consequently, topical antimicrobials are progressively being used alongside systemic antibiotics to provide adjunctive, antimicrobial therapy to wounds that are clinically infected or at risk of infection. Many topical antimicrobials, for example, antiseptics such as iodine,[9] zinc,[10] honey,[11] and silver-based preparations and dressings[12] exert a sustained broad-spectrum antimicrobial effect at the site of infection, but have a limited potential for systemic absorption and toxicity, thereby reducing the risk of antibiotic resistance.[13]

As well as impairing wound healing, clinical infection may increase the severity of wound-related pain[14,15] and have a direct effect on patient comfort. Indeed, Cutting et al.[16] reported on a multinational, multidisciplinary Delphi study that revealed a causal relationship between wound infection and the onset or change in the nature of pain: 15/21 respondents identified this as an issue in event-related pain and 19/21 cited this phenomenon in somatic-related pain, with 17/21 respondents citing that patients with wound infection generally experienced more pain than those who were free of infection. In addition, 20/21 clinicians thought that some types of dressing caused pain during dressing change. Therefore, when selecting appropriate products, the need to minimise trauma and pain at dressing change and avoid maceration of the periwound skin should be borne in mind. The design of antimicrobial dressings should, therefore, incorporate these features, as well as addressing wound bioburden.

Key points:

- Systemic antibiotics have been used as the primary defence against bacterial infection but, as the incidence of antibiotic resistance increases, successful outcomes are becoming more difficult to achieve
- Topical antimicrobials (for example, silver dressings) are being used increasingly alongside systemic antibiotics to provide adjunctive, antimicrobial therapy to wounds that are clinically infected or at risk of infection
- Clinical infection may increase the severity of wound-related pain
- Antimicrobial dressings should be designed to minimise trauma and pain at removal, avoid periwound maceration, and manage bioburden

Silver as an antimicrobial

The antimicrobial properties of silver have been recognised for many centuries. The metal itself is inactive, but when ionised it has broad-spectrum activity against microorganisms. The silver ions interact with the cell membrane, forming insoluble and therefore metabolically ineffective compounds, which disrupt cell replication by binding to bacterial DNA, and interfering with bacterial electron transport.[17] These antimicrobial properties have led to the inclusion of silver compounds in dressing products.[18-23] The efficacy and safety of silver dressings differ and depend on the material used, type of silver compound and its location in the dressing, and total silver content. As a result, not all silver dressings will perform in exactly the same way.

There is conflicting evidence about the therapeutic benefits of silver dressings in wound healing: while several systematic reviews have identified positive effects,[24-27] others have failed to establish any association.[12,28,29] Many studies analysed in these reviews included endpoints relating to healing. However, it has been suggested that endpoints relating to the measurement of microbial burden or the assessment of clinical indicators of infection would be more appropriate.[30,31]

One hotly debated clinical trial is the VULCAN study, in which patients with venous leg ulcers (VLUs) were randomised to receive one of a number of silver dressings or a clinician-selected, non-antimicrobial dressing.[32] The primary outcome measure was complete healing at 12 weeks. No statistically significant difference was observed in terms of the proportion of ulcers that healed, healing times or recurrence rates. This led the researchers to question the routine use of silver dressings on VLUs.

Numerous researchers pointed out that these conclusions were potentially misleading. First, even though silver dressings are indicated for the management of wound bioburden or to prevent infection in high-risk wounds, the study did not report on the risk of infection, or evaluate the wounds clinically or microbiologically for the presence of infection. Second, although silver dressings are not intended for use over extended periods (particularly if there is no infection), they were applied for up to 12 weeks in the study. Third, the researchers have questioned the use of wound healing as a primary outcome measure of efficacy on the basis that this is not the goal of care when using silver dressings.[31]

This controversy led to the circulation of several key documents that give clear guidance on how silver dressings can be used to produce effective clinical outcomes in wound management. Notable among these are the 2011 edition *Best Practice Statement: The use of topical antiseptic/antimicrobial agents in wound management*[33] and *Appropriate Use of Silver Dressings in Wound Management*.[31] Both documents highlight that, when used appropriately (for example, for managing wound bioburden) and for appropriate periods, silver dressings—in conjunction with systemic antibiotics—offer a safe, efficient and cost-effective treatment for wound colonisation and infection. Both documents state that the duration of treatment with silver dressings should be reassessed after two weeks and continued or discontinued, depending on the wound status.

Silver dressings are used on individuals at increased risk of infection, to treat localised wound infection and, in conjunction with systemic antibiotics, to treat local spreading or systemic wound infection.[4] The rationale for treatment should be documented and reviewed regularly.[31]

The cost-effectiveness of silver dressings is a complex multifactorial issue; however, studies have shown that they are associated with factors that contribute to cost savings. These include:

- Reduced healing times
- Shorter hospital stays
- Reduced dressing change frequency
- Reduced need for analgesia during dressing change
- Fewer meticillin-resistant *Staphylococcus aureus* (MRSA) bacteraemias resulting from MRSA-infected wounds.[31]

Key points:

- Silver dressings are used to prevent acute infection in individuals at increased risk, to treat localised wound infection and, in conjunction with systemic antibiotics, to treat local spreading or systemic wound infection
- Silver dressings differ in terms of the dressing material, type of silver compound used, location of the compound in the dressing, and total silver content. It cannot be assumed that all these dressings will perform in exactly the same way in the clinical setting
- Studies have shown that the use of silver dressings is associated with factors that contribute to cost-effectiveness

Silver-containing dressings with Safetac

Currently, the range of dressings with Safetac includes wound contact layers (with and without antimicrobial agents), film dressings (with and without antimicrobial agents), multilayer absorbent foam dressings (with and without antimicrobial agents), scar treatments and sealants.

Safetac involves the use of soft silicone. This material readily adheres to intact dry skin, but will remain *in situ* on the surface of a moist wound or damaged surrounding skin without adhering to fragile tissue.[34] Consequently, these dressings can be applied and reapplied without damaging the wound or stripping the epidermis in the periwound region (even in critical situations when exudate starts to dry out),[35] and will also minimise pain and psychological stress at dressing change.[36] The gentle but effective seal that forms between the intact skin and a dressing with Safetac inhibits the movement of exudate from the wound onto the periwound skin, helping to prevent moisture-related damage, such as maceration, to this region.[37]

This technology has been combined with silver-impregnated foam materials to create a range of wound dressings: Mepilex Ag, Mepilex Border Ag and Mepilex Transfer Ag (Table 1).

Key points:

- Dressings that combine Safetac with silver-impregnated foam materials have been developed for use on different types of wound where antimicrobial therapy is indicated
- Dressings with Safetac minimise trauma and pain at dressing change, and help prevent moisture-related damage to the periwound region

Aims

When making decisions about clinical interventions, it is common practice to consider the relative weight of the available data, according to the type and quality of studies from which they originate. In this so-called hierarchy of clinical evidence (Fig 1), randomised controlled trials (RCTs) and systematic reviews are considered to be the 'gold' standards for judging the benefits of interventions.[38,39]

Table 1. Characteristics of silver containing foam dressings with Safetac

Name	Description and composition	Mode of action	Intended uses
Mepilex Ag	■ Antimicrobial soft silicone foam dressing: consists of a Safetac wound-contact layer, a flexible absorbent polyurethane foam pad containing silver sulphate and activated carbon, and a vapour-permeable and waterproof outer film	■ Absorbs exudate and maintains a moist wound environment ■ In the presence of fluid, such as wound exudate, silver ions are released, inactivating wound-related pathogens (bacteria and fungi) for up to seven days, as shown *in vitro*[47] ■ By reducing the number of microorganisms, the dressing may also reduce malodour[86,92]	■ Low-to-moderately exuding wounds, such as leg and foot ulcers, pressure ulcers and partial-thickness burns[66*†]
Mepilex Border Ag	■ Self-adherent antimicrobial soft silicone foam dressing: consists of a Safetac wound-contact layer, an absorbent polyurethane foam pad containing silver sulphate and activated carbon, a layer with superabsorbent polyacrylate fibres, a non-woven layer, and a vapour-permeable and waterproof outer film		■ Moderately-to-highly exuding wounds, such as leg and foot ulcers, pressure ulcers, partial-thickness burns, traumatic and surgical wounds[*†]
Mepilex Transfer Ag	■ Antimicrobial soft silicone exudate transfer dressing: consists of a Safetac wound-contact layer, and a compressed polyurethane foam containing silver sulphate and activated carbon	■ Absorbs and transfers exudate, and maintains a moist wound environment ■ In the presence of fluid, such as exudate, silver ions are released, inactivating wound-related pathogens for up to 14 days, as shown *in vitro*[48] ■ By reducing the number of microorganisms, the dressing may also reduce malodour[55]	■ Low-to-highly exuding wounds such as leg and foot ulcers, pressure ulcers, partial-thickness burns, traumatic and surgical wounds[*†]

* Can be used under compression bandaging[82,96]
† Can be used on infected wounds as part of a treatment regimen under the supervision of a healthcare professional

While the conventional approach to evidence-based medicine is to use RCTs, many practitioners question their relevance. Practice-based medicine is favoured and allows flexibility as to the choice of wound dressings based on the individual patient.[40-44] While this does not mean that all research data are equally valid, it does signify that all available evidence should be considered and evaluated.

With this in mind, this review has considered clinical data from across the entire evidence hierarchy and includes *in vitro* data on the use of silver-containing foam dressings with Safetac. It is not a systematic review but aims, instead, to summarise the available evidence.

Key points:
- Evidence-based practice should reflect all types of evidence
- This review aims to summarise all the evidence generated from clinical and *in vitro* tests on the use of silver-containing foam dressings with Safetac

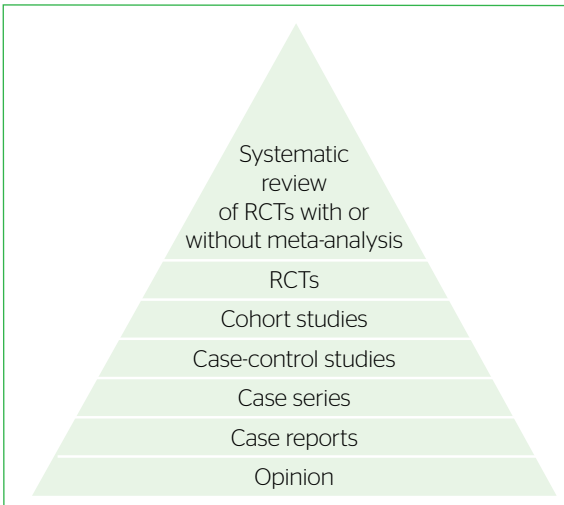


Figure 1. Hierarchy of clinical evidence (adapted from Akobeng, 2005)[39]

Method

An extensive literature search was undertaken to identify published articles citing scientific and clinical data on silver-containing foam dressings with Safetac. Electronic searches of bibliographic databases MEDLINE (National Library of Medicine, Bethesda, US) and EMBASE (Elsevier BV, Amsterdam, Netherlands), and specialist websites—Cochrane Library, World Wide Wounds—were performed to identify published articles for each dressing type. The search ranged from January 2005, when the first silver-containing foam dressing with Safetac was developed, to April 2017.

The following search terms were used: ['Mepilex Ag OR silver'] AND 'silicone' AND 'foam' and 'dressing'; ['Mepilex Border Ag OR silver'] AND 'silicone' AND 'foam' and 'dressing'; and ['Mepilex Transfer Ag OR silver'] AND 'silicone' AND 'foam' and 'dressing'.

In addition, abstract books and proceedings documents from national and international conferences of relevance to wound care held since 2005 were scanned to identify relevant presentations, namely:

- Symposium on Advanced Wound Care
- World Union of Wound Healing Societies' congress
- Wound Ostomy and Continence Nurses Society conference
- Wounds UK conference
- European Wound Management Association conference
- Conferénce Nationale des Plies et Cicatrisations
- Simposio Nacional Úlceras por Presión y Heridas Crónicas
- European Tissue Repair Society meeting
- European Burns Association congress
- Associazione Italiana Ulcere Cutanea conference
- Association of Perioperative Registered Nurses annual conference.

Research data from all levels of the clinical evidence hierarchy (Fig 1) and preclinical studies, such as *in vitro* tests, were included in the review.

Key points:

- Bibliographic databases were searched for relevant research articles
- Abstract books and proceedings documents from specialist conferences were scanned to identify relevant posters

Results

The literature search identified 18 peer-reviewed journal articles and 43 conference poster presentations (Table 2) that had specific references to evaluations of silver-containing foam dressing with Safetac. The findings of these articles and poster presentations are summarised in this supplement. Unless stated otherwise, the results are from published studies.

In vitro testing

There is no specific method for evaluating the antimicrobial effects of wound dressings. Consequently, the standardised *in vitro* approach for evaluating the effectiveness of antimicrobial agents has been used.[45,46] The studies reviewed used a variety of test methods to evaluate the antimicrobial properties of silver-containing foam dressings with Safetac *in vitro* (Table 3).

Planktonic microorganisms

In a series of logarithmic reduction assays reported by Chadwick et al.,[47] Mepilex Ag was found to reduce the number of viable cells (colony forming units (CFUs) of 18 wound-relevant pathogens (Tables 3 and 4) by more than 4.0 logarithmic units (log_{10}) after 24 hours' incubation. This was subsequently supported by Bibic and Hamberg,[48] who reported in a poster that Mepilex Transfer Ag reduced the number of viable cells by at least 4.0 log_{10} after 24 hours' incubation in the case of 15 tested microorganisms (Tables 3 and 4). A compound or product may be considered cidal if it reduces the test organism by at least 3.0 log_{10}.[49] These finding indicated that silver-containing foam dressings with Safetac are capable of controlling a variety of common wound pathogens, such as Gram-negative and Gram-positive bacteria and yeasts, as well as antibiotic-resistant strains.

A rapid effect of an antimicrobial dressing is clinically important since bacteria can adapt to an agent, which may result in the development of resistance to it.[50] If bacteria are

Table 2. Literature search results

Type	Number
Evidence pieces	
Peer-reviewed articles	18
Conference poster presentations	43
Evidence pieces relating to different wound types*	
Burns	14
Other acute wounds	20
Chronic wounds	28
Evidence pieces describing different study types*	
Randomised controlled trials	3
Cost-effectiveness analysis	1
Non-comparative study (prospective)	14
Non-comparative (retrospective)	1
Case study series	22
Case report	11
Audit	1
Expert opinion	1
In vivo tests	1
In vitro tests	8

*Some evidence pieces refer to more than one wound type and study type

Table 3. *In vitro* tests on the antimicrobial effects of silver containing foam dressings with Safetac

Reference	Design methodology	Main outcome measures
Halstead et al (2015)[61]	■ Biofilm formation assays ■ Test organisms: *Pseudomonas aeruginosa* and *Acinetobacter baumannii* isolates from burn wounds ■ Test dressings: Mepilex Ag, Aquacel Ag, Aquacel Ag Foam, Aquacel Ag Burn, UrgoTul Silver, Acticoat, PolyMem Silver, Inadine, L-Mesitran Net, L-Mesitran Hydro, Bactigras	■ Large variation in the ability of dressings to prevent isolates of test organisms forming biofilms, ranging from 33% increases with a honey-containing dressing (Mesitran) to 100% decreases with Mepilex Ag and Acticoat ■ After 72 hrs incubation with Mepilex Ag, all isolates exhibited a 95–100% ($p<0.05$) reduction in biofilm formation compared with the positive control

Bibic and Hamberg (2014)[48]	■ Modified ISO 20743:2013 Textile: determination of antibacterial activity of textile products
	■ Test organisms: eight species for evaluation of rapid/sustained activity; 15 species for evaluation of spectrum of activity (see Table 4 for details)
	■ Test dressings: Mepilex Transfer Ag
		■ Rapidity of action:
		  ■ Mepilex Transfer Ag reduced the number of CFUs of *Enterococcous faecalis* (VRE), meticillin-resistant *Staphyloccocus aureus* (MRSA), *A. baumannii*, *Enterobacter cloacae*, *P. aeruginosa, Candida albicans and Candida guillermondii by >4.0 log_{10} and ESBL-* producing *Klebsiella pneumoniae* by 3.6 log_{10} within 30 minutes
		■ Longevity of action:
		  ■ Mepilex Transfer Ag reduced the number of CFUs of *E. faecalis* (VRE), MRSA, *A. baumannii, E. cloacae*, *P. aeruginosa*, ESBL-producing *K. pneumonia, C. albicans* and *C. guillermondii* by ≥4.0 log_{10} after 15 days
		■ Broad-spectrum of action:
		  ■ Mepilex Transfer Ag reduced the number of CFUs of 15 wound-related pathogens by ≥4.0 log_{10} after 24 hrs

Bibic and Hamberg (2014)[55]	■ Logarithmic reduction assays (planktonic species): secondary dressing model
	■ Test organisms: *P. aeruginosa*, *S. aureus* and *C. albicans*
	■ Test dressings: Mepilex Transfer Ag, Restore Duo Ag, Therabond 3D, Acticoat 7, Aquacel Ag
		■ Without secondary dressing:
		  ■ Only Mepilex Transfer Ag and Acticoat 7 reduced the number of CFUs of all three test organisms by >4.0 log_{10}. Three other wound contact layers reduced *S. aureus* by approximately 2.0 log_{10}, whereas the viable counts of *P. aeruginosa* and *C. albicans* were not reduced at all
		■ With secondary dressing:
		  ■ The antimicrobial properties of the tested wound contact layers were not affected (Fig 3A)
		■ Mepilex Transfer Ag minimised the passage of all three microorganisms into the secondary dressing; the other wound contact layers allowed at least one of the test microorganisms to pass through (Fig 3B)

Hamberg et al, (2012)[53]	■ Logarithmic reduction assays (planktonic species): two-compartment model ■ Test organisms: *P. aeruginosa* and *S. aureus* ■ Test dressings: Mepilex Ag, Mepilex Border Ag, Acticoat 7, Allevyn Gentle Ag, Aquacel Ag, Cellosorb Ag (Urgocell Silver), Contreet (Biatain Ag), Melgisorb Ag	■ A relationship (positive) between the amount of silver released from the dressings and the antimicrobial effect was observed (Fig 2A) ■ Mepilex Border Ag and Mepilex Ag released the highest amount of silver and resulted in the highest log_{10} reduction of the test organisms (Fig 2B) ■ No correlation was observed between the total silver content in the dressings and the release of silver or the antimicrobial effect

Table 3. *In vitro* tests on the antimicrobial effects of silver containing foam dressings with Safetac (continued)

Werthen et al. (2012)[58]	■ Logarithmic reduction assays (planktonic cultures): Agar plate method and two-compartment model ■ Logarithmic reduction assays (biofilm cultures): 3D-model ■ Dressing adhesiveness (to 3D-fibroblast culture) [NB. Corresponding non-silver-dressings were used to prevent cytotoxic effects interfering with test results] ■ Test organism (all assays): *P. aeruginosa* ■ Test dressings: Mepilex Ag, Aquacel Ag	■ Planktonic assays: ■ Both Mepilex Ag and Aquacel Ag reduced the number of CFUs of the test organism in the region of 3.0 $\log_{10}$ after 24 hrs in the agar plate and two-compartment models ■ Biofilm assays: ■ Mepilex Ag reduced the number of CFUs of the test organism by 3.0 $\log_{10}$ whereas no reduction was observed with Aquacel Ag ■ Dressing adhesiveness assays: ■ Aquacel Ag reduced cell numbers in the culture by around 35% ($p<0.05$), whereas Mepilex Ag showed no reduction compared with the control
Werthen et al, (2012)[59]	■ Logarithmic reduction assays (planktonic cultures): Two-compartment model ■ Logarithmic reduction assays (biofilm cultures): 3D-model ■ Test organism (all assays): *P. aeruginosa* ■ Test dressings: Mepilex Ag and Acticoat 7	■ Both test dressings were associated with similar reductions in the number of CFUs of the test organism (in the region of 3.0 $\log_{10}$) in both planktonic and biofilm cultures
Werthen et al, (2010)[57]	■ Logarithmic reduction assays: planktonic species and 3D-biofilm model ■ Test organism: *P. aeruginosa* ■ Test dressings: Mepilex Ag, Allevyn Ag Gentle, Cellosorb Ag (Urgocell Silver), Aquacel Ag	■ Mepilex Ag outperformed Allevyn Ag Gentle, Cellosorb Ag and Aquacel Ag in terms of activity against planktonic and biofilm cultures of *P. aeruginosa* ■ Mepilex Ag was associated with >3.0 $\log_{10}$ reduction in the number of CFUs in biofilm (Fig 4) and planktonic cultures (Fig 5) after 24 hrs
Chadwick et al, (2009)[47]	■ Zone of inhibition measured following the addition of dressing eluates ■ SDS-PAGE and zymography ■ Test organism: *P. aeruginosa* ■ Test dressings: Mepilex Ag, Contreet, Acticoat Moisture Control (MC), Cellosorb Ag, Silvercel Ag, Acticoat 7, Tegaderm Ag	■ Growth of *P. aeruginosa* without serum: ■ Mepilex Ag: none (up to 48 hrs); Contreet: after 18 hrs; Acticoat MC: after 18 hrs; Cellosorb Ag: after 10 hrs; Silvercel Ag: after 10 hrs; Acticoat 7: after 10 hrs; Tegaderm Ag: after 6 hrs ■ Growth of *P. aeruginosa* with serum: Mepilex Ag: none (up to 48 hrs); Contreet: none (up to 48 hrs); Acticoat MC: after 24 hrs; Cellosorb Ag: after 10 hrs; Silvercel Ag: after 10 hrs; Acticoat 7: none (up to 48 hrs); Tegaderm Ag: after 10 hrs ■ Mepilex Ag and other silver dressings blocked the release of proteases (elastase), protecting from *P. aeruginosa*-mediated tissue degradation

Table 3. *In vitro* tests on the antimicrobial effects of silver foam dressings with Safetac (continued)

Chadwick et al. (2009)[47]	■ ASTM E2149 Standard test method for determining the antimicrobial activity of antimicrobial agents under dynamic contact conditions ■ Test organisms: five species for evaluation of rapid/sustained activity; 18 species for evaluation of spectrum of activity (see Table 4 for details) ■ Test dressings: Mepilex Ag	■ Rapidity of action: ■ Mepilex Ag reduced the number of CFUs of *C. albicans* by 3.8 $\log_{10}$ and *Enterococcus faecalis* (VRE), *P. aeruginosa,* MRSA and MSSA by >4.0 $\log_{10}$ within 3 hrs ■ Longevity of action: ■ Mepilex Ag reduced the number of CFUs of *C. albicans*, *E. faecalis* (VRE), *P. aeruginosa*, *Serratia marcescens*, MSSA/MRSA, and *A. baumannii* by >3.0 $\log_{10}$ every 24 hrs over a period of seven days ■ Broad-spectrum of action: ■ Mepilex Ag reduced the number of CFUs of 18 wound-relevant pathogens by >4.0 $\log_{10}$ after 24 hrs

ASTM – American Society for Testing and Materials; CFU – colony forming unit; ESBL = extended spectrum beta-lactamase; ISO – International Organisation for Standardization; MRSA – meticillin-resistant *Staphylococcus aureus*; MSSA – meticillin-sensitive *S. aureus*; SDS-PAGE – sodium dodecyl sulphate polyacrylamide gel electrophoresis; VRE – vancomycin-resistant enterococci

killed quickly, this possibility is substantially decreased. On the other hand, dressings that release low levels of silver ions are likely to be more problematic in terms of selection for resistance, especially if the silver ion concentration is sub-therapeutic.

Logarithmic reduction assays have shown that silver-containing foam dressings with Safetac have rapid antimicrobial effects against common wound pathogens. Mepilex Ag reduced the number of viable cells of *Candida albicans* by 3.8 $\log_{10}$ within three hours; the number of viable cells of four strains of bacteria (including meticillin-sensitive *Staphylococcus aureus* (MSSA) and meticillin-resistant *Staphylococcus aureus* (MRSA) strains) were reduced by more than 4.0 $\log_{10}$ within the same period (Table 3).[47] In similar tests, reported in a poster, Mepilex Transfer Ag reduced the number of viable cells of seven bacterial species by more than 4.0 $\log_{10}$ within 30 minutes (Table 3).[48] There was just one exception: the number of viable cells of the extended spectrum beta-lactamase-producing *Klebsiella pneumoniae* was reduced by 3.6 $\log_{10}$ within the same time frame. However, this remains above the range considered as cidal.[49]

Logarithmic reduction assays have also been used to evaluate the sustained antimicrobial effect of silver-containing foam dressings with Safetac. Mepilex Ag reduced the number of viable cells of six common wound pathogens by more than 3.0 $\log_{10}$ every 24 hours over a period of seven days (Table 4).[47] Similarly, Mepilex Transfer Ag, when exposed to microbial challenge at baseline and on day 7, reduced the number of viable cells of six bacterial and two fungal species by at least 4.0 $\log_{10}$ after 15 days, as reported in a poster (Table 4).[48]

A sustained antimicrobial effect makes it possible to avoid frequent and regular dressing changes (subject to variables such as exudate levels), minimising the risk of delayed healing due to wound bed disturbance. Because the antimicrobial effect of both dressings is maintained over time, this can also help minimise the risk of surviving microorganisms developing resistance to silver.

Theoretically, a higher release of silver will result in greater microbial inactivation. Studies, however, have failed to identify a correlation between the silver content of dressings and its antimicrobial effect,[51] or a correlation between silver release and antimicrobial effect.[52] However, the latter study[52] did not test both factors in the same test system and, because silver release depends on the test medium, this may account for the observed lack of correlation.

In contrast, as reported in a poster, the same *in vitro* test was used to study the relationship between silver release and the antimicrobial effect of Mepilex Ag, Mepilex Border Ag and seven other silver-containing dressings against *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Hamberg et al.[53] A relationship between silver release and antimicrobial effect was observed when the amount of silver from each dressing was plotted against $\log_{10}$ reductions of the test organisms (Fig 2). Of the dressings tested, Mepilex Border Ag and Mepilex Ag released the highest amount of silver and resulted in the highest $\log_{10}$ reduction of viable cells of both test organisms.

Silver dressings designed as wound contact layers allow the transfer of exudate into a secondary absorbent dressing. The latter can be changed independently of the WCL, leaving the wound bed undisturbed. The reduction of trauma to the wound and minimisation of dressing-related pain provides an optimal opportunity for the wound to progress and heal.[54] As reported in a poster, Bibic and Hamberg[55] determined the antimicrobial effect of five silver-containing wound contact layers, alone and in combination with a secondary dressing. When tested alone, only Mepilex Transfer Ag and a silver-coated barrier dressing were found to reduce the number of viable cells of all three test organisms by more than 4.0 $\log_{10}$. When

Table 4. List of microorganisms against which Mepilex Ag and Mepilex Transfer Ag have been shown to have antimicrobial activity[47,48]

	Mepilex Ag	Mepilex Transfer Ag
Type	**Species**	**Species**
Gram-positive	*Bacillus cereus* ATCC 14579 [B] *Enterococcus faecalis* ATCC 19433 [B] *Enterococcus faecium* ATCC 19434 [B] *E. faecalis* (VRE) ATCC 51575 [R,S] *E. faecalis* (VRE) CCUG 34289 [B] *E. faecium* (VRE) CCUG 36804 [B] *Staphylococcus aureus* ATCC 6538 [B,R,S] *S. aureus* (MRSA) ATCC 33591 [R,S] *S. aureus* (MRSA) ATCC 43300 [B] *S. aureus* (MRSA) CCUG 35571 [B]	*E. faecalis* (VRE) ATCC 51575 [B,R,S] *S. aureus* ATCC 6538 [B] *S. aureus* (MRSA) ATCC 43300 [B,R,S] *B. cereus* ATCC 14579 [B] *Staphylococcus epidermidis* ATCC 12228 [B]
Gram-negative	*Acinetobacter baumannii* ATCC 19606 [B,S] *Aeromonas hydrophila* ATCC 7966 [B] *Enterobacter cloacae* ATCC 13047 [B] *Klebsiella pneumoniae* ATCC 13883 [B] *Proteus vulgaris* ATCC 29905 [B] *Pseudomonas aeruginosa* ATCC 9027 [R,S] *P. aeruginosa* ATCC 15442 [B] *P. aeruginosa* multi-resistant CCUG 37385 [B] *Salmonella enterica* ATCC 25928 [B] *Serratia marcescens* ATCC 13880 [B,S]	*A. baumannii* ATCC 19606 [B,R,S] *E. cloacae* ATCC 13047 [B,R,S] *P. aeruginosa* ATCC 9027 [B,R,S] *K. pneumoniae* (ESBL-producing) CCUG 59349 [B] *Escherichia coli* ATCC 8739 [B] *Proteus vulgaris* ATCC 29905 [B] *S. marcescens* ATCC 13880 [B]
Fungi	*Candida albicans* ATCC 2091 [B] *C. albicans* ATCC 10231 [R,S]	*C. albicans* ATCC 10321 [R,S] *Candida guillermondii* ATCC 6260 [B,R,S] *Candida lusitaniae* ATCC 37495 [B]

ATCC – American type culture collection; B – used in spectrum of activity testing; CCUG – culture collection of the University of Gothenburg; ESBL – extended spectrum beta-lactamase; MRSA – meticillin-resistant *Staphylococcus aureus*; R – used in rapid activity testing; S – used in sustained activity testing; VRE – vancomycin-resistant enterococci

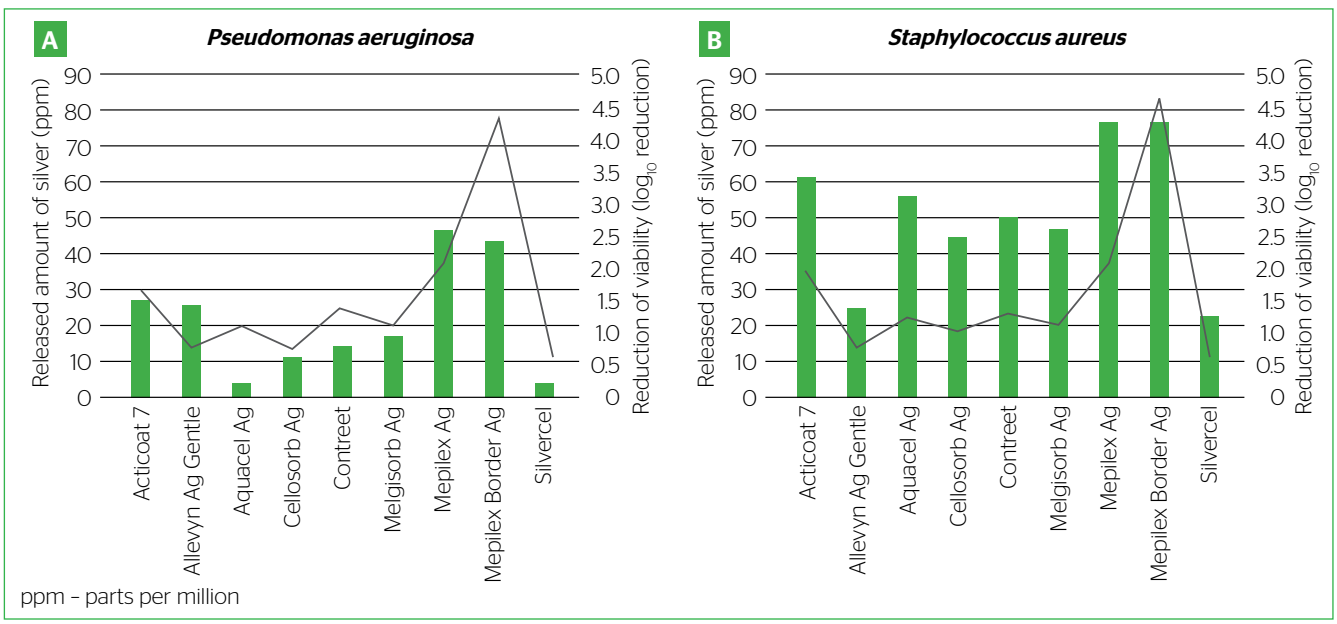
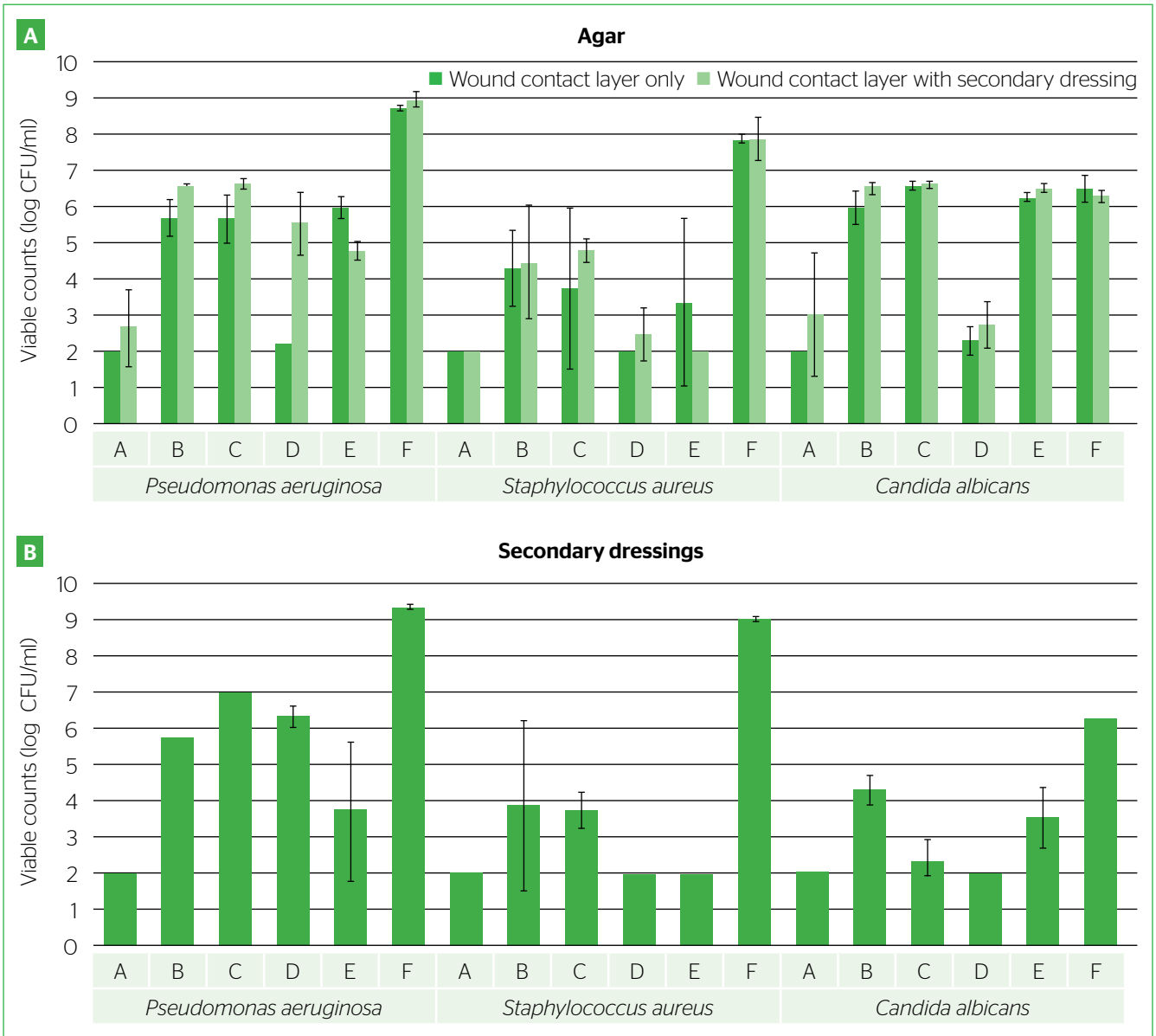


Figure 2. Silver release (grey line) versus antimicrobial effect at 24 hours (green bars) of different silver-containing dressings after 24 hours[53]

tested in combination with a secondary dressing, the antimicrobial properties of the tested wound contact layers were not affected (Fig 3a). However, of all the dressings tested, only Mepilex Transfer Ag minimised the passage of all three microorganisms into the secondary dressing; the other wound contact layers allowed at least one of the test microorganisms to pass through (Fig 3B). As the secondary dressing contained no antimicrobial substances, microorganisms that pass into it are free to multiply, and could therefore be a possible source of malodour or infection.[55]

Biofilms

From a clinician's viewpoint, it is important to establish whether an antimicrobial dressing can manage bioburden. Mepilex Ag and other silver-containing dressings were tested in an *in vitro* wound infection model in which biofilm bacteria aggregated in a collagen gel matrix with serum protein, mimicking the chronic wound bed.[56] Mepilex Ag outperformed the other silver dressings in terms of activity against planktonic and biofilm cultures of *P. aeruginosa*. A poster reported that it was associated with greater than



(A) Mepilex Transfer Ag, (B) Restore Duo Ag, (C) Therabond 3D, (D) Acticoat 7, (E) Aquacel Ag, (F) Soft silicone wound contact layer without silver (negative control)
NB. Initial microbial load was 6 $\log_{10}$ colony forming unit (CFU)/sample and detection limit was 2 $\log_{10}$ CFU/ml agar

Figure 3. Viable counts of microorganisms, when wound contact layers were tested alone or with a secondary dressing[55]

3.0 log_{10} reductions in the number of viable cells of test organisms after 24 hours' incubation in both the biofilm (Table 3; Fig 4) and planktonic cultures (Fig 5).[57]

Subsequently, in another poster, Werthén et al.[58] demonstrated that Mepilex Ag not only exhibited antimicrobial action but also did not stick to and damage to the culture substrate (Table 3). In agar plate and two-compartment models, Mepilex Ag and Aquacel Ag were associated with similar reductions in viable cells of planktonic species (compared with the original inoculation concentration) and considerable reductions compared with the cultured control.

In a biofilm model, Mepilex Ag reduced the number of viable cells by 3 log_{10} (from 10^9 to 10^6 CFU/ml), while no reduction was observed with the silver Hydrofiber dressing. The test for dressing adhesiveness demonstrated that the Hydrofiber dressing reduced the cell numbers in the culture by around 35% ($p<0.05$), whereas Mepilex Ag showed no reduction compared with the control. These reductions are consistent with those observed in another series of *in vitro* tests in which Mepilex Ag, Mepilex Border Ag and a nanocrystalline-silver dressing (Acticoat 7) were compared (Table 3).[58]

Due to the protection against antimicrobial agents and immune response afforded by the matrix of extracellular polymeric substances (EPS),[60] biofilms are associated with persistent wound colonisation and an increased risk of systemic infection, a complication that may delay healing. Consequently, it is important to determine the effectiveness of antimicrobial dressings against bacteria growing as biofilms.

In a series of *in vitro* tests, Halstead et al.[61] determined the ability of antimicrobial dressings (including Mepilex Ag), two non-antimicrobial dressings and acetic acid (AA) (used successfully to treat burn wounds infected or heavily colonised with *P. aeruginosa*) to prevent isolates of *P. aeruginosa* (PS_PA01 and PS_1586) and *Acinetobacter baumannii* (ACI_AYE and ACI_721) forming biofilms. A crystal violet biofilm formation assay was used to assess the test agents' ability to prevent biofilm formation. There was a large variation in their ability to reduce biofilm formation, ranging from an increase of 33% for a honey-containing dressing to a decrease of 100% with Mepilex Ag for PS_PA01 and ACI_721. After a 72-hour incubation with Mepilex Ag, all four isolates exhibited a 95–100% reduction in biofilm formation ($p<0.05$) compared with the positive control.

Wounds, particularly those of a chronic nature, are commonly colonised by a variety of microbial species, either as planktonic bacteria or a biofilm phenotype. There are suggestions that microbial interaction between different bacterial species may result in an enhanced pathogenic effect, which can be detrimental to the wound healing process, depending on the total number of microorganisms and their virulence. Studies of bacterial profiles in chronic wounds have identified the most frequently isolated planktonic bacteria as *S. aureus*, *Enterococcus faecalis*, *P. aeruginosa* and coagulase-negative staphylococci.[62]

Consequently, mixed infections may require antimicrobial agents that are effective against all planktonic bacterial components. It would therefore seem prudent to use silver-containing dressings that are effective against both Gram-positive and Gram-negative bacteria, with a proven high degree of silver release and rapid bactericidal activity. Based on the results of the *in vitro* testing mentioned above, silver-containing foam dressings with Safetac would appear to fulfil these criteria.

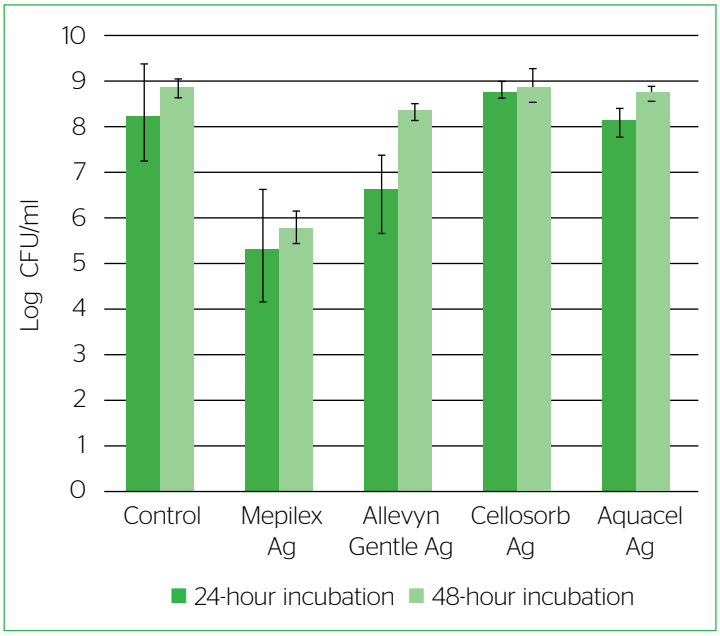
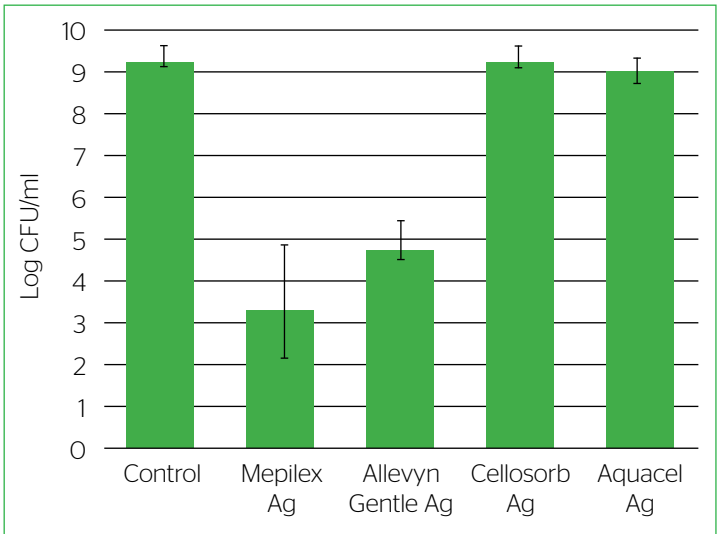


Figure 4. Effect of silver dressings on established *Pseudomonas aeruginosa* biofilms in collagen/serum matrices[57]



CFU = colony forming units
NB. Growth in medium supplemented with 50% serum incubated for 24 hours (CFUs at start, 10^6/ml)

Figure 5. Effect of silver dressings on a planktonic growing culture of *Pseudomonas aeruginosa*[57]

Key points:

- Ideally, antimicrobial dressings should provide rapid, sustained and broad-spectrum activity against wound-relevant pathogens
- Results of *in vitro* testing demonstrate that silver-containing foam dressings with Safetac have both rapid and sustained activity against a range of wound-relevant pathogens

Clinical research

In addition to the *in vitro* testing, the efficacy of silver-containing foam dressings with Safetac has been evaluated in the clinical setting. The methodologies and findings of the clinical studies on these dressings are summarised below and in Tables 5–15.

Mepilex Ag

As highlighted in Table 1, Mepilex Ag is intended for use on low-to-moderately exuding wounds of various aetiologies, when topical antimicrobial therapy is needed. A substantial amount of clinical research has been undertaken to evaluate the efficacy of Mepilex Ag in the treatment of partial-thickness burns (Table 5–9).

Burn injuries

Burn injuries comprise a challenging spectrum of acute, chronic, traumatic and surgical wounds with a wide range of anatomical locations and depth.[63] Topical management is based on the amount, depth and severity of the burn injury and, to a lesser degree, the body area affected. Burn depth is frequently classified as epidermal, superficial partial-thickness, deep dermal and full-thickness.[64] The main objectives of a topical treatment are to remove devitalised tissue, promote healing, prevent infection, maintain the function of the affected body part, and achieve closure as soon as possible.[65]

Dressings provide a protective barrier until tissue integrity is re-established or, if this is not possible, until reconstruction can be undertaken. Following reconstruction, dressings provide further protection and an optimal environment in which stabilisation and healing of the skin graft can take place.[66] Issues such as wound desiccation, infection, poor patient management and inappropriate wound care can lead to partial-thickness wounds developing into full-thickness skin loss. Appropriate care and management, particularly dressing choice, is therefore essential.[67] Clinicians must carefully consider the challenges posed by the injury, as well as the dressing functionality and design.

Burn injuries are associated with four factors:

- High exudate production (at least initially)[66]
- Susceptibility to infection[68,69]
- Wound pain (particularly at dressing change), distress and reduced quality of life (QoL)[70-72]
- Predisposition to wound bed trauma and disruption.[66]

These characteristics were taken into consideration in the design of three RCTs (Table 5) undertaken to investigate the efficacy of silver-containing foam dressings with Safetac. In the first of these trials,[73] children with partial-thickness burns were randomised to one of three treatment regimens: Acticoat (n=31), Acticoat combined with Mepitel (n=32) or Mepilex Ag (n=33). When adjusted for burn depth, the expected number of days to full re-epithelialisation increased by 40% (95% confidence interval (CI): 1.14–1.73, p<0.01) in the Acticoat group and by 33% (95% CI: 1.08–1.63, p=0.01) in the Acticoat combined with Mepitel group, compared with the Mepilex Ag group. Dressings with silicone interfaces were associated with significantly lower pain scores after removal and reapplication compared with Acticoat alone (p≤0.04) (Table 5). At the initial dressing change, the cumulative dressing removal and reapplication was significantly faster in the Mepilex Ag group (5:03 min, interquartile range (IQR) 2:48–7:53 min) compared with the groups treated with Acticoat (10:17 min ; IQR 7:38–21:58 min, p<0.01) and Acticoat combined with Mepitel (10:03 min, IQR 6:21–16:47 min ; p<0.01). In addition, Acticoat was rated by the nurses as significantly more difficult to remove than Mepilex Ag (p<0.01) and Acticoat with Mepitel (p<0.01).[73]

The other two trials were multicentre studies that compared treatment of partial-thickness burn injuries with Mepilex Ag and silver sulphadiazine (SSD). In the RCT reported by Tang et al.,[74] data from 153 patients were included in the analysis (Mepilex Ag, n=71; SSD, n=82). Although there was no significant difference in the healing rates of burns between the two groups, more burns healed in the Mepilex Ag group (n=13, 18%) compared with the SSD group (n=4, 5%; p=0.016). A significantly greater percentage of study burns healed in the Mepilex Ag group (mean, 44.3%) compared with the SSD group (mean, 27.0%; p=0.0092).

However, the difference between the treatments with respect to these two variables was not significant at weeks 2, 3 and 4. At week 4, 87.1% of burns in patients treated with Mepilex Ag healed, compared with 85.2% of burns treated with SSD.

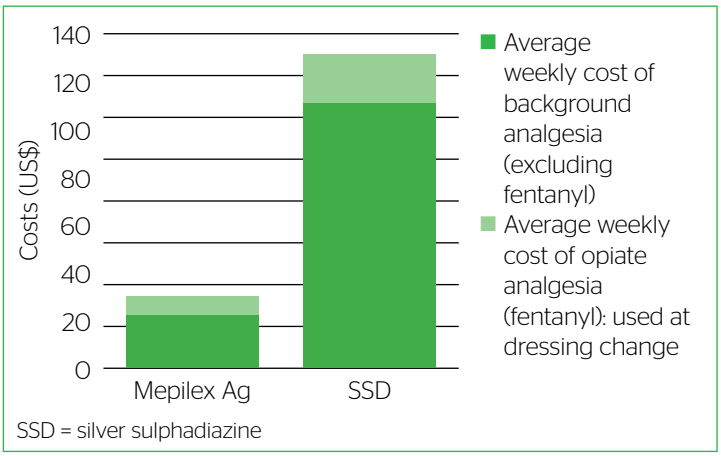
Significantly fewer dressings were required for the Mepilex Ag treatment arm (p<0.0001): the mean total number of dressing changes for Mepilex Ag was 3.06 compared with 14.0 for the SSD group, and the mean total number of dressing changes per week was 1.36 for the Mepilex Ag group compared with 5.67 for the SSD group. The researchers commented that the longer wear time of the silver-containing foam dressing promoted undisturbed healing and made it easier for patients to resume normal life sooner, as well as having cost benefits. At the baseline burn assessment, there was no significant difference between the two groups in pain experienced by subjects aged 13 years or older (Mepilex Ag group mean, 35.3; SSD group mean, 42.9 (p=0.071)). However, during the 4-week study period, the mean pain scores—recorded using a visual analogue scale (VAS)—before, during and after dressing removal at each scheduled visit were significantly lower in the group treated with Mepilex Ag, compared with the SSD group (p≤0.0254).

The clinicians' ratings for 'ease of application', 'lack of dressing adherence', 'ease of removal' and the 'overall experience of using the dressing' significantly favoured Mepilex Ag (p<0.0001 for all responses). In addition, patient evaluations of the dressings, in terms of 'good' or 'very good' responses, for 'experience of anxiety during dressing

Table 5. Randomised controlled trials of Mepilex Ag

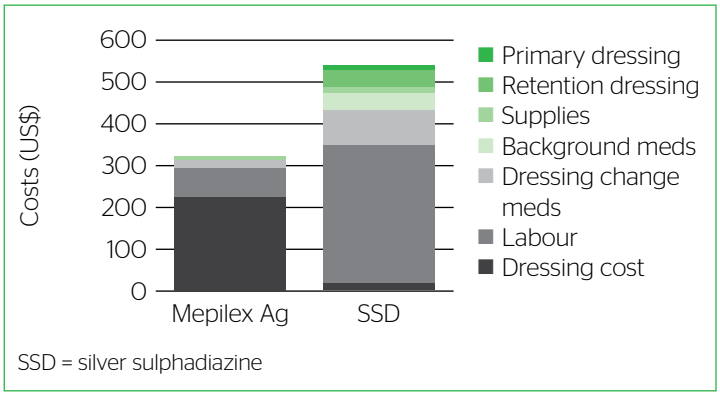
Reference	Design methodology	Main outcome measures	Main results
Gee Kee et al. (2015)[73]	■ Randomised controlled trial ■ Paediatric partial-thickness injuries <72 hours post burn (TBSA <10%) (n=96) ■ Treatment randomisation: ■ Acticoat (n=31) or ■ Acticoat combined with Mepitel (n=32) or ■ Mepilex Ag (n=33) ■ Treatment duration: up to 14 days	■ Time to healing (≥95% epithelialisation) ■ Pain severity (scored using FPS-R, FLACC pain scale, VAS, pulse rate and respiratory rate) ■ In-use characteristics	■ Median healing time (days): ■ Acticoat: 9.5 ■ Acticoat with Mepitel: 10.0 ■ Mepilex Ag: 7.0 After adjusting for burn depth, healing times (days) were 40% and 33% longer in patients treated with Acticoat or Acticoat with Mepitel, respectively, compared with Mepilex Ag (p≤0.01) ■ FLACC scores in the Mepilex Ag group were 32% lower at dressing removal (p=0.01) and 37% lower at dressing re-application (p=0.04), compared with those in the Acticoat group ■ VAS scores in the Mepilex Ag group were 25% lower at dressing removal (p=0.04) than those in the Acticoat group ■ Mepilex Ag was easier to apply (p=0.03) and remove (p<0.01) than Acticoat
Tang et al. (2015)[74]	■ Randomised controlled trial ■ Deep partial-thickness thermal burn injuries (TBSA 2.5–25%) (n=153) ■ Treatment randomisation: Mepilex Ag (n=71); or SSD (n=82) ■ Treatment duration: up to 28 days	■ Time to healing (>95% epithelialisation) ■ Number of dressing changes ■ Pain severity (scored using VAS) ■ In-use characteristics	■ No significant difference in healing rates between treatment groups: ■ Mepilex Ag: n=56 healed (79%); median healing time (days) = 15 ■ SSD: n=65, 79%; median healing time (days) = 16 ■ Mean total number of dressings used was greater in the SSD group than in the Mepilex Ag group (14.0 v 3.06, p<0.0001) ■ Pain at dressing change (before, during and after dressing removal) was lower in the Mepilex Ag group than the SSD group (p≤0.0254) ■ Mepilex Ag was rated higher than SSD by clinicians in terms of ease of application, lack of dressing adherence, ease of removal and overall experience (p<0.0001) ■ Mepilex Ag was rated higher than SSD by patients in terms of experience of anxiety during dressing change, ease of movement while wearing it, the dressing remaining in place, and lack of stinging or burning while wearing it (p<0.0001)
Silverstein et al. (2011)[34]	■ Randomised controlled trial ■ Partial-thickness injuries <36 hours post-burn (TBSA: 2.5–20%) (n=100) ■ Treatment randomisation: Mepilex Ag (n=49); or SSD (n=51) ■ Treatment duration: up to 21 days	■ Time to discharge from inpatient hospital care ■ Healing time ■ Pain severity (scored using VAS) ■ In-use characteristics ■ Total cost of therapy per patient	■ Mean time to hospital discharge (days) was shorter in the Mepilex Ag group than the SSD group (5.62 vs 8.31, p=0.034) ■ There was no significant difference in mean healing times (days) between the treatment groups: ■ Mepilex Ag: 13.44 ■ SSD: 17.11 ■ Pain intensity was lower in the Mepilex Ag group than the SSD group at dressing application (p=0.018), during wear (p=0.048) and on removal (p=0.097) ■ Mepilex Ag was rated higher than SSD in terms of ease of use (p=0.028) and flexibility (p=0.038) ■ Total cost of therapy per patient: ■ Mepilex Ag: US$309 ■ SSD: US$514

FPS-R – Faces Pain Scale - Revised; FLACC – Face, Legs, Activity, Cry, Consolability; TBSA – total body surface area; VAS – visual analogue scale



SSD = silver sulphadiazine

Figure 6. Cost comparison of pain medication for patients with partial-thickness burns treated with Mepilex Ag or silver sulphadiazine[34]



SSD = silver sulphadiazine

Figure 7. Breakdown of average cost per patient with partial-thickness burns treated with Mepilex Ag or SSD[34]

change', 'ease of movement while wearing the dressing', 'dressing remained in place while wearing it' and 'lack of stinging or burning while wearing the dressing' were all significantly in favour of Mepilex Ag compared with SSD ($p<0.0001$ for all responses).[74]

Mepilex Ag and SSD were also compared in a multicentre trial by Silverstein et al.[34] The American Burn Association/ children burn outcomes questionnaire, the short form (36) health survey and the EuroQol 5D health questionnaires were used to assess the consequences of burns, QoL and quality-adjusted life year (QALY) analysis. A total of 100 patients entered the study (Mepilex Ag, n=49; SSD, n=51).

The mean time to discharge from inpatient care was 5.62 days (median 3.0, range 1.0–30.0) in the Mepilex Ag-treated group, and 8.31 days (median 5.0, range 1.0–35.0) in the SSD group ($p=0.034$). Of these, 97.6% of the Mepilex Ag subjects required no nursing or skilled nursing interventions in the community, with 7.2% of SSD subjects requiring further input. At visit 2 (one week post-burn), 34.8% of the subjects treated with Mepilex Ag had achieved complete healing, while only 20% had complete healing in the SSD group . The average healing time for the Mepilex Ag group was 13.44 days, compared with 17.11 days for the SSD group. Although not statistically significant, this favoured Mepilex Ag ($p=0.097$).

A significant difference in mean pain scores, in favour of Mepilex Ag, was noted at the end of the first week of treatment at dressing application ($p=0.018$) and during dressing wear ($p=0.048$). Pain scores recorded at dressing removal also favoured Mepilex Ag ($p=0.097$). The trend in pain reduction at dressing change was also accompanied by a significant difference in average weekly costs of pain medication ($p=0.031$). The need for background pain analgesia was also lower ($p=0.078$) in the Mepilex Ag group (Fig 6).

Clinicians considered Mepilex Ag to be superior ($p=0.038$) to SSD in terms of ease of use and flexibility. In terms of ease of use, Mepilex Ag was rated by 95.6% as 'extremely well'/'very well' compared with 78.4% for SSD. Regarding flexibility, Mepilex Ag was rated by 97.8% as 'extremely well'/'very well' compared with 78.4% for SSD. The mean number of dressing applications undertaken in the first week following injury was 1.54 in the Mepilex Ag group versus 6.82 in the SSD group. During this period, no participant treated with Mepilex Ag required more than four dressing changes, with most (54.3%) requiring only one change.

Most (52.9%) of the SSD patients required daily dressing changes. By week 2, 94.7% of patients in the Mepilex Ag population required dressings once a week, with none requiring more than two per week. In the SSD group, 48.6% required daily dressing changes. By week 3, only seven required dressings once a week in the Mepilex Ag group compared with 17 in those treated with SSD. The total mean number of dressing applications per subject during the study was 2.24 (median 2.0, range 1.0–5.0) in the Mepilex Ag group and 12.4 (median 13.0, range 1.0–29.0) in the SSD group.

The mean total cost of wound management per patient was calculated at US$309 for the Mepilex Ag-treated group and US$514 for the SSD group ($p=0.000$) (Fig 7). The average cost-effectiveness of the two dressings was calculated by determining total cost of in-clinic treatment and dividing this by the rate of full re-epithelialisation at 20 days. The average cost-effectiveness per burn healed was US$395 for Mepilex Ag group compared with US$776 for the SSD group. Therefore, net saving per burn healed was US$381, with a protocol of care using Mepilex Ag instead of SSD. The incremental cost-effectiveness ratio was calculated to be –US$1688 in favour of the Mepilex Ag protocol.[34]

Although SSD has been the standard treatment for partial-thickness burns for decades, the often painful, labour-intensive daily dressing changes can have a negative effect on patient concordance, thereby delaying wound healing. Silver-containing dressings with Safetac offer an alternative to SSD; therapeutic silver is delivered to the burn via a dressing that can remain *in situ* for several days.

In a decision analysis with an incremental cost-utility ratio, Sheckter et al.[75] compared silver-containing dressings (Mepilex Ag and Aquacel Ag) with SSD in partial-thickness burn patients affecting less than 20% of total body surface area (TBSA). A literature review determined clinically relevant health states (healing, infection, and non-infected delayed healing requiring surgery or conservative management)

in partial-thickness burn patients. The probabilities of these health states occurring were combined with Centers for Medicare and Medicaid Services' Current Procedural Terminology reimbursement codes (cost) and patient-derived utilities (relative quality-of-life preference).

The incremental cost-utility ratio for silver dressings relative to SSD was about US$40K/QALY. One-way sensitivity analysis of complication rates confirmed the robustness of the model. Assuming a maximum willingness to pay of about US$50K/QALY the complication rate for SSD must be 22% or higher for silver dressings to be cost-effective. By varying complication rates for SSD and silver dressings, the two-way sensitivity analysis demonstrated the cost-effectiveness of using silver dressings at the majority of complication rates for both treatment modalities. These findings led the researcher to conclude that silver dressings are a cost-effective means of treating partial-thickness burns (Table 6).[75]

Other studies have reported on the successful use of Mepilex Ag in the management of partial-thickness burns (Tables 7–9). For example, in an observational study on 18 patients with partial-thickness burns reported in a poster,[76] the population mean TBSA was 7.28% (range 1–18%). In 11 patients, at least one joint was affected. Mepilex Ag was applied to the site of injury within 72 hours post-burn and removed at days 6/7 for evaluation.

The results showed that Mepilex Ag provided antimicrobial protection that left the burn injuries with a clean appearance. In addition, Mepilex Ag could be removed from the wound site without adherence, giving clinicians the opportunity to either examine the wound or leave the dressing *in situ* for up to seven days, at their discretion. Since it was possible to examine the injuries, the physician considered that Mepilex Ag did not delay the decision to graft burns that required surgical intervention.

A case series was presented in a poster by Sivertsen[77] on the use of Mepilex Ag on hand burns. A total of 10 patients (three adults and seven children) were treated with Mepilex Ag dressings stapled together over the dorsal and palmar surfaces, then divided between the fingers to construct bespoke dressing 'gloves'. The three adult patients (superficial partial-thickness burns) healed completely within two weeks. The seven children (superficial partial-thickness and deep dermal burns) healed completely in 2–8 weeks without surgical intervention. During treatment, mobility, exercise and hand function were maintained. The author concluded that the product and method of application was easy to use, enabled patients to carry out exercises and was comfortable.

Finally, Helle et al.[78] reported on a case study that demonstrated the use of Mepilex Ag on a 3-year-old child with a 6% partial-thickness scald injury. The authors found that the dressing was easy to apply and remove, and coped well with exudate management. Analgesia was limited and anaesthesia was required only in the first few dressing changes. The dressing was very conformable and patient mobility was maintained.

Complete healing occurred in 20 days. At five months, skin assessment demonstrated that the healed area was smooth and soft with no residual discomfort. Based on this finding, Kassira and Namias[79] indicated that Mepilex Ag may also be a suitable dressing for paediatric burns.

Acute wounds

Acute wounds, such as surgical wounds, generally heal by primary or secondary intention. If the patients are relatively healthy, with no comorbidities, the wounds tend to follow a normal healing process. However, this is not always the case. For example, in postoperative wound care, a number of surgical site complications have been reported, including infection, dehiscence, seroma, haematoma, local skin ischaemia and necrosis, and delayed healing.[80] In the case of infection, appropriate treatment is likely to be systemic antibiotic therapy, with or without the use of topical antimicrobial therapy.[33]

A number of clinical studies have evaluated the use of Mepilex Ag in the treatment of acute wounds showing signs of localised infection; these are summarised in Tables 7–10.

The results obtained from two studies in particular (Tables 7 and 8)[81,82] highlight the benefits of using Mepilex Ag on acute wounds. In the most recent of the studies (Table 8),[82] the use of Mepilex Ag as part of a defined protocol for treating a variety of acute (and chronic) wounds was evaluated in a case study series. The primary objective of the treatment regimen was to control the levels of bioburden in order to avoid infection. The regimen was observed to decrease symptoms of bioburden, promote moist wound healing, prevent trauma to the wound and surrounding skin, and minimise dressing-related pain.

Table 6. Health economic study of Mepilex Ag

Reference	Design methodology	Main outcome measures	Main results
Sheckter et al, 2014[75]	■ Cost-effectiveness analysis ■ Partial-thickness burn injuries (TBSA <20%) ■ Comparator groups: Mepilex Ag/Aquacel Ag vs. SSD ■ Treatment duration: 21 days	■ Incremental cost-utility ratio comparing silver dressings with SSD ■ Patient-derived utilities to assess quality-of-life evaluations (VAS assessments during patient interviews) ■ QALY calculations	■ Incremental cost-utility ratio for Mepilex Ag/Aquacel Ag relative to SSD was about US$40K/QALY ■ Mepilex Ag and Aquacel Ag have a higher cost utility than SSD, which offers patients a better quality of life

QALY – quality-adjusted life year; SSD – silver sulphadiazine; TBSA – total body surface area; VAS = visual analogue scale

Table 7. Non-comparative studies of Mepilex Ag

Reference	Design methodology	Main outcome measures	Main results
Glat et al. (2015)[110]	■ Non-comparative study (prospective) ■ Paediatric (age 1–4 years) partial-thickness injuries <12 hours post-burn (n=20) ■ Treatment duration: not stated	■ Length of hospital stay ■ Pain severity (scored using Wong-Baker faces scale) ■ In-use characteristics	■ Shorter hospital stays in patients treated with Mepilex Ag compared with historical controls ■ Occurrence of 'stinging' or 'burning' was reported as 'never', 'rarely' and 'sometimes' in 13 (65%), 8 (40%) and 1 (5%) patients, respectively ■ Mepilex Ag was easy to apply
	■ Non-comparative study (retrospective) (inpatient, n=60; outpatient, n=43) ■ Paediatric (<18 years old) partial-thickness burn injuries <24 hours post-burn (TBSA : 1–40%) ■ Treatment duration: not stated	■ Length of hospital stay ■ Pain assessment (narcotic administration)	■ Shorter hospital stays in patients treated with Mepilex Ag, compared to historical controls ■ Less pain medication was required in patients treated with Mepilex Ag, compared with historical controls
Kuo et al. (2013)[90]	■ Non-randomised comparative study (prospective) ■ Prevention of PUs around tracheostomy wounds ■ Tracheostomy with no dressing applied after procedure (n=93); Mepilex Ag applied under newly inserted tracheostomy tube (n=41) ■ Treatment duration: not stated	■ Peristomal skin breakdown	■ 11.8% patients who did not have Mepilex Ag developed skin breakdown complications; no patients with Mepilex Ag developed wound complications (p=0.02)
Ruben and Armstead (2010)[91]	■ Audit of newly introduced care protocol ■ Obese patients with low Braden scores and tracheostomy wounds ■ Treatment duration: not stated	■ Clinical signs of infection/skin maceration/peristomal ulceration ■ In-use characteristics	■ The number of skin complications reduced from 45% (baseline) to 25% within one month of protocol implementation ■ This reduction was sustained: 0% after 3 months following initiation of the new regimen) ■ Reduced frequency of dressing changes ■ Reduced costs/nursing time
Durante, (2008)[89]	■ Non-comparative study (prospective) ■ Chronic wounds (n=24) including leg, foot and pressure ulcers ■ Treatment duration: up to 4 weeks	■ Microbiological analysis of swab cultures taken at first visit, and after 2 weeks and 4 weeks of treatment ■ Healing response ■ Exudate levels ■ Wound-related pain	■ Reduced levels of common wound pathogens ■ 50% mean reduction in the wound area from baseline to day 30 (two wounds healed and eight showed signs of improvement at the end of the treatment period) ■ Number of patients with highly exuding wounds decreased from 13 at baseline to 7 at the end of treatment period ■ Reduced number of patients experiencing pain (50% had no pain or low levels of pain at end of the treatment period)

An additional benefit highlighted by the study was the low frequency of dressing changes; it was possible to leave Mepilex Ag in place for up to seven days, depending on wound exudate levels. Importantly, this dressing protocol contributed to positive clinical and financial outcomes for the healthcare provider.

Table 7. Non-comparative studies of Mepilex Ag (continued)

Meites et al. (2008)[76]	■ Non-comparative study (prospective) ■ Partial-thickness injuries <72 hours post-burn (mean TBSA: 7.28%) (n=18) ■ Treatment duration: not stated	■ Antimicrobial protection ■ In-use characteristics	■ Mepilex Ag provided antimicrobial protection, leaving the burns with clean appearances ■ No dressing adherence reported ■ Clinicians had the opportunity to either examine the wounds or leave the dressings *in situ* for up to 7 days ■ All patients were able to perform a range of motion exercises throughout the treatment period
Meuleneire, (2008)[81]	■ Non-comparative study (prospective) ■ Acute/chronic wounds, including burns, surgical wounds, traumatic wounds and skin grafts, with signs of localised infection requiring topical antimicrobial therapy (but not antibiotics) (n=30) ■ Treatment duration: up to 28 days	■ Clinical signs of localised infection ■ Healing response (qualitative visual assessment) ■ Pain severity (scored using VAS) ■ Qualitative rating of dressing by patients and investigator	■ Clinical signs of localised infection eradicated in 90% of wounds ■ The proportion of wounds that healed or had almost healed at the end of the treatment period was 53% and 27%, respectively ■ Pain severity (ongoing and at dressing change) was significantly lower at the first and final dressing changes ($p<0.0001$) than at baseline ■ The dressing was rated as 'excellent/very good' in 77% of investigator's evaluations and 82% of patients' evaluations
Schumann et al. (2007)[88]	■ Non-comparative study (prospective) ■ Chronic wounds (duration ≥ 6 weeks) (n=18) including VLUs, mixed arterial/venous leg ulcers and DFUs ■ Treatment duration: up to 28 days	■ Clinical signs of localised infection ■ Healing response ■ Exudate levels ■ Wound-related pain (scored using VAS)	■ Reduced number of wounds exhibiting signs of inflammation ■ Increase in viable tissue from 75% (baseline) to 85% (final visit) About 30% reduction in mean wound area from baseline to final visit ■ Reduced number of highly exuding wounds ■ Degree of pain was low at baseline and did not change at or after dressing changes or between visits

DFU – diabetic foot ulcer; PU – pressure ulcer; TBSA – total body surface area; VAS – visual analogue scale; VLU – venous leg ulcer

In an open non-randomised study by Meuleneire[81] different types of acute and chronic wounds with clinical signs of localised infection and requiring topical antimicrobial therapy (but not antibiotics) were treated with Mepilex Ag for four weeks, or until complete healing took place. Clinical signs of localised infection, ongoing/persistent pain in the wound and at dressing change, and healing response were measured at baseline and subsequent dressing changes. At the final dressing change, the patient and investigator rated the overall dressing performance. In total, 30 patients were included in the study.

The results demonstrated that, by the end of the study period, clinical signs of localised infection had been eradicated in 90% of wounds, while 53% had healed and 27% had almost healed. Importantly, the severity of ongoing pain and pain during dressing changes was significantly lower at the first and final dressing changes ($p<0.0001$) compared with baseline. The dressings were rated as 'excellent' or 'very good' in 77% of the investigators' evaluations and in 82% of the patients' evaluations.

The results of these studies, together with the findings of other evaluations undertaken to assess the performance of Mepilex Ag in treating acute wounds (Tables 7–10), indicate that the silver-containing foam dressing with Safetac is capable of:

- Resolving signs of localised infection[81,83-85]
- Significantly reducing ongoing pain and pain at dressing changes[81,83-85]
- Evoking a good healing response[81,83-85]
- Effectively managing wound exudate[86,87]
- Preventing maceration.[83,85]

Some of the studies and evaluations referred to above were presented as posters.

Table 8. Case study series involving Mepilex Ag

Reference	Wound type	Treatment duration	Observations								
			Dressing easy to apply/remove/use	Dressing effectively handled exudate	Dressing maintained mobility during wear	Reduced dressing-related pain	Reduced need for analgesia	Reduced signs of localised infection	Healthy periwound skin	Wound healed/ reduced in size	Dressing reported to be cost-effective
Obregón et al. (2012)[111]	Second-degree burns (n=39)	Not stated	•			•					
Richards and Chadwick (2011)[87]	DFUs (n=15)	Up to 28 days				•		•		•	
Sivertsen (2011)[77]	Superficial partial-thickness and deep partial-thickness hand burns (n=10)	Up to 56 days	•		•	•					
De Coster and Meuleneire (2010)[112]	Second-degree burns (n=15)	Not stated				•		•		•	
Barrett (2009)[86]	Chronic leg ulcers (n=2)	Up to 77 days	•	•		•		•		•	
Barrows (2009)[82]	Acute/chronic wounds (n=3)	Up to 42 days	•			•	•	•	•		•
Cuvelier (2009)[113]	Chronic wounds (n=10)	Not stated	•			•		•	•	•	
Tong (2009)[105]	DFUs (n=4)	Up to 112 days		•				•	•	•	
Beer (2008)[114]	Acute/chronic wounds (n=5) colonised by PVL	Up to 56 days				•		•		•	
Gomez et al. (2008)[115]	DFUs (n=3)	Not stated	•	•		•		•	•	•	
Gomez et al. (2008)[116]	Chronic wounds (n=24)	Not stated		•		•		•		•	
Hernandez et al. (2008)[117]	Chronic wounds (n=7)	Not stated		•		•		•	•	•	
Kheng (2008)[104]	VLUs (n=5)	Up to 28 days						•	•	•	
Laverda et al. (2008)[118]	Chronic painful leg ulcers (n=2)	20 days	•			•			•	•	
Nisbet (2008)[84]	Acute/chronic wounds (n=6)	Not stated		•		•		•		•	
Blakely and Weir (2007)[119]	Acute/chronic wounds (n=3) (with NPWT)	Not stated							•	•	

DFU – diabetic foot ulcer; NPWT – negative pressure wound therapy; PVL – Panton-Valentine Leukocidin

Chronic wounds

Chronic wounds are more difficult to treat than acute wounds, and can be colonised by a variety of pathogens, leading to infections.[15] This is, in the main, because patients with chronic wounds may be immunocompromised as a result of comorbidities, age, and/or treatment regimens.

Table 9. Case studies involving Mepilex Ag

Reference	Wound type	Treatment duration	Observations								
			Dressing easy to apply/remove/use	Dressing effectively handled exudate	Dressing maintained mobility during wear	Improved patient comfort/QoL	Reduced dressing-related pain	Reduced need for analgesia	Reduced signs of localised infection	Wound healed/reduced in size	Dressing reported to be cost-effective
Hernandez et al. (2014)[120]	PU	Not stated	•	•					•	•	
Mir (2013)[106]	DFU	49 days	•	•					•	•	
Helle et al. (2011)[78]	Paediatric partial-thickness burn	Not stated			•		•	•		•	
Hernandez et al. (2008)[121]	Leg ulcer	84 days					•	•	•	•	
Meuleneire (2008)[122]	DFU	10 days	•				•		•	•	
Rivas (2008)[123]	Infected toe wound	11 days		•		•				•	
Rojas et al. (2008)[124]	DFU	56 days							•	•	
Timmins, (2008)[85]	Haematoma	Not stated				•	•				
Davoudi et al. (2007)[125]	VLU	28 days		•					•	•	

DFU – diabetic foot ulcer; PU – pressure ulcer; VLU – venous leg ulcer

Table 10. Expert opinion on Mepilex Ag

Reference	Design methodology	Overview
Bevilacqua and Rogers (2008)[126]	■ Expert opinion ■ Surgical pin sites (post-Charcot midfoot deformity surgery) ■ Treatment duration: not stated	The authors refer to the ease of using MepilexAg in dressing surgical pin sites. They state that the dressing 'sticks' to the skin, absorbs drainage, neutralises bacteria and provides some compression

The management of chronic, colonised leg ulcers that are at high risk of infection, for example, may pose major management challenges.

A number of clinical studies have been undertaken to evaluate the use of Mepilex Ag (Tables 7–9) in the treatment of chronic wounds with signs of infection. For example, in a prospective, observational study, Truchetet et al.[83] investigated the nature and aspects of wounds treated with Mepilex Ag in a community setting. Both acute and chronic wounds (>6 weeks duration) were eligible for inclusion. Of the 2191 clinicians invited to participate, 242 accepted. These included 128 GPs, 63 vascular medicine specialists, and 51 dermatologists. Each participant reported on the first two consecutive adult patients for whom they prescribed Mepilex Ag, describing patient and wound characteristics, as well as the presence of 10 local signs compatible with wound infection. In addition, the clinicians' rationale for prescribing the silver dressing for each patient was recorded.

In total, 794 wounds were included in the study. Of these, 584 were chronic and categorised as follows: 534 (67%) VLUs, 32 (4%) PUs, 14 (1.8%) DFUs and four (0.5%) oncology wounds. In addition, there were 210 (26%) acute wounds, 120 (15%) post-traumatic, 19 (2.4%) surgical, 60 (7.6%) partial-thickness burns wounds, and 11 (1.4%) animal bites.

On average, 3.7 ± 1.5 local signs of infection were present and mean pain intensity (on a VAS) was 50 ± 24mm. In 82% of cases, the main rationales clinicians gave for prescribing Mepilex Ag were infection and delayed healing; oral antibiotics

Table 11. Non-comparative studies of Mepilex Border Ag

Reference	Design methodology	Main outcome measures	Main results
Kles et al. (2015)[94]	■ Non-comparative study (prospective) (QIP) ■ Surgical wounds (CABG surgery with donor site procedures) (n=262) ■ Treatment duration: not stated	■ DSWI incidence ■ Treatment costs	■ DSWI incidence reduced from 3.74 per 100 procedures to 0.7 and ultimately 0 ■ After completion of the QIP, no patients who had CABG surgery with donor site procedures developed a DSWI in over 30 months and 590 procedures, resulting in estimated cost savings of more than US$600K and avoiding 377 excess hospital days
McCarty et al. (2013)[92]	■ Non-comparative study (prospective) ■ Chronic (n=215) and acute wounds (n=84) ■ Treatment duration: median 22 days; range 3–182 days	■ Clinical signs of localised infection ■ Periwound region condition ■ Pain severity (scored using VAS) ■ Wound size ■ Overall performance	■ Number of wounds that exhibited signs of localised infection reduced progressively throughout the study ■ Periwound skin disturbance at the final visit was less than at baseline ■ Pain severity during and after dressing removal and during wear was significantly lower at the final dressing change ($p<0.0001$ for each parameter) than at baseline ■ Wounds showed statistically significant ($p<0.05$) reductions in wound surface area and depth from baseline to final visit (28.5% and 35%, respectively) ■ 55.8% of investigators rated the overall assessment of Mepilex Border Ag as 'very good' and 34.4% rated it as 'good'
Zurcher et al. (2013)[93]	■ Non-comparative study (prospective) ■ Surgical wounds (CABG surgery) (n=61) ■ Treatment duration: not stated	■ SSI occurrence ■ Treatment costs	■ Significant reduction (71.4%) in SSI incidence – 2/61 developed SSI (incidence 3.27%) in patients treated with Mepilex Border Ag; 7/64 developed SSI (incidence 10.94% in patients not treated with Mepilex Border Ag (historical control) ■ Estimated cost avoidance equated to about US$313K a year
Meek and Downs (2012)[108]	■ Non-comparative study (prospective) ■ Surgical wounds (knee or hip surgeries) (number of subjects not stated) ■ Treatment duration: 14 days	■ Superficial SSI occurrence ■ Healing response ■ Exudate management ■ Pain severity ■ In-use characteristics	■ Reduced occurrence of SSI ■ Dressing remained in place for 7 days, permitting undisturbed wound healing ■ Exudate effectively managed ■ Reduced pain at dressing application and removal ■ Improved patient concordance. The dressing was easy to apply, patients were able to shower with dressing in situ, and its excellent conformability provided comfort and facilitated patient mobility

CABG – coronary artery bypass graft; DSWI – deep sternal wound infection; QIP – quality improvement process; SSI – surgical site infection; VAS – visual analogue scale

were started concurrently in 19% of wounds. At follow-up visits (median of 19 days post-inclusion, range 7–97 days), all wound parameters were documented as significantly improved, with 17% of wounds healed and 73% showing signs of improvement. Tolerability and efficiency of the silver dressing was considered 'good'/'very good' in more than 97% of cases.[83]

Schumann et al.[88] undertook a study, presented in a poster, to investigate the tolerability of Mepilex Ag in patients with chronic wounds, dressing performance, and healing progress. The study was designed as a multicentre, prospective, open, non-comparative investigation of four weeks' duration. Adult patients (n=18) with VLUs (n=11), ulcers of mixed arterial/venous

aetiology (n=4) and DFUs (n=3) (maximum ulcer size 200cm^2, ulcer age of at least six weeks, and an ankle brachial index of greater than 0.5) were enrolled. Only three non-serious adverse events (ulcer deterioration, eczema, and vasculitis) were considered to be dressing-related.

With regards to healing, Mepilex Ag was associated with an increase in the number of healthy wounds, an increase in viable tissue (from 75% to 85%), and a reduction in wound size by about 30%. In addition, fewer patients had wounds exhibiting signs of inflammation and fewer highly exuding wounds. From these findings, it was concluded that Mepilex Ag was well tolerated and effective in older patients.[88]

Durante[89] investigated how best practice could reduce healing times in infected, aged and inadequately treated wounds. The results were presented in a poster. The patient population (n=24) had different types of wounds (Table 7). The study was designed as a non-comparative open regimen evaluation over four weeks. Most ulcers had been previously treated, locally and systemically, in other hospitals or at home, with little/no improvement or had become worse, and most had showed signs of long-term bacterial colonisation. Mepilex Ag was applied after wound disinfection and skin cleansing. Microbiological cultural swabs were conducted at the first visit and repeated after 15 and 30 treatment days.

Three of the wounds completely healed and eight improved greatly (that is, demonstrated a reduction in wound size, by almost 40% and 50%, after 15 and 30 days, respectively). In addition, there was a reduction in the number of patients with highly exuding wounds and those exhibiting pain (at the final visit, more than 60% of patients had low or no pain). Importantly, the analysis of the microbiological cultural swabs showed efficacy against MSSA, MRSA, *Acinetobacter baumanii*, *Morganella morganii* and *E. faecalis*.

More recently, Richards and Chadwick[87] (Table 8)reported on a case study series that evaluated the effects of Mepilex Ag on the signs and symptoms of local infection in DFUs. A total of 15 ulcers were treated with the dressing for up to four weeks. Pain at dressing changes, wound size, the performance characteristics of the dressing and adverse events were also monitored. Ulcers treated with the dressing were associated with reductions in pain, erythema, oedema, heat and exudate levels. Decreases in pain associated with dressing changes and wound size were also observed. The dressing performance was rated very highly by the investigators and was extremely well tolerated. The findings of this small study indicated that the dressing simultaneously resolved localised infection and addressed the issues of pain and trauma in the treatment of DFUs (Table 7).[87]

Two studies highlighted the use of Mepilex Ag in preventing complications of tracheostomy care in vulnerable populations, paediatric patients[90] and (in a poster) obese individuals in intensive care.[91] In a retrospective case study review, Kuo et al.[90] identified 134 paediatric patients who underwent a tracheostomy between June 2005 and June 2011. Before February 2010, dressings were not applied at the end of the tracheostomy procedure in almost 70% patients (n=93); the remainder (n=41) had Mepilex Ag applied under newly applied tracheostomy tubes. The rates of wound breakdown before and after the introduction of Mepilex Ag were compared. In the cohort without Mepilex Ag there was evidence of skin breakdown by the time of the first tracheostomy tube change in 11.8% of patients. When Mepilex Ag was used to pad the tracheostomy site, there was no peristomal skin breakdown (p=0.02). No comorbidities were associated with postoperative ulcer formation in either cohort.

Second, Ruben and Armstead[91] studied the use of Mepilex Ag in the management of tracheostomy complications in obese individuals in an intensive care environment. They presented the results in a poster. Traditionally, fenestrated gauze had been used under the tracheostomy flange to prevent skin erosion caused by moisture, device movement and secondary infection. However, this had been unsuccessful and, despite changing the gauze several times a day, tissue breakdown had become a regular problem (reported incidence of 45%). The authors implemented a new regimen incorporating Mepilex Ag, which was fenestrated to accommodate the tracheostomy tube placement and changed every three days. Within one month of introduction, the incidence of tracheostomy skin breakdown had fallen to 25% and continued to fall.

The protocol was considered inexpensive, and reduced the impact on nursing time. It was also regarded as highly effective in reducing tissue damage. The authors considered the technique of using Mepilex Ag important to wound specialists, respiratory specialists and those caring for patients with tracheostomies in improving patient outcomes.

Key points:

- In a randomised controlled trial (RCT) that evaluated different silver dressings, partial-thickness burns treated with Mepilex Ag healed significantly faster than those treated with Acticoat. They were also associated with less pain at dressing change
- In RCTs that compared treatment of partial-thickness burns with Mepilex Ag and silver sulphadiazine, Mepilex Ag was associated with significantly less pain at dressing change and lower costs
- Numerous studies recorded reductions in clinical signs of localised infection, positive healing responses, improvements to the periwound region, and minimal dressing-related trauma and ongoing pain in a variety of wound types treated with Mepilex Ag. The dressing was repeatedly described as being easy to apply and remove

Mepilex Border Ag

Mepilex Border Ag is intended for use on moderately-to-highly exuding wounds of various aetiologies, when there is a requirement for topical antimicrobial therapy. The dressing can be expected to achieve similar clinical outcomes to Mepilex Ag, but has the advantage of being self-adherent (Table 1). Clinical research has been undertaken to evaluate the efficacy of Mepilex Border Ag (Tables 11–13).

McCarty et al.[92] in a poster, described the results of an observational study involving a variety of different wound types (Table 11). The study assessed the effectiveness of Mepilex Border Ag in terms of reducing signs of localised

Table 12. Non-randomised, comparative study of Mepilex Border Ag

Reference	Design methodology	Main outcome measures	Main results
Warner and Zinko (2015)[95]	■ Non-randomised comparative study (prospective) ■ Surgical wounds (primary unilateral total knee replacement) ■ Treatment: Mepilex Border Ag or a non-stick pad with adhesive tabs (number of subjects not stated) ■ Treatment duration: 7 days	■ Adherence and flexibility of the dressings during physical therapy ■ Cost-effectiveness	■ Physical therapists rated Mepilex Border Ag as 63% more adherent during physical therapy than the non-stick pad with adhesive tabs, and they had to think about it less ■ Decreased requirement for dressing changes, and fewer interruptions in staff work flow

Table 13. Case study series involving Mepilex Border Ag

Reference	Wound type	Treatment duration	Observations					
			Dressing easy to apply/re-move/use	Dressing effec-tively handled exudate	Reduced dress-ing-related pain	Reduced signs of localised infection	Reduced wound malo-dour	Wound healed/ reduced in size
Davis (2012)[107]	DFUs (n=8)	18–78 days	•	•	•			•
Krasner and McKinney (2012)[127]	Acute/chronic wounds (n=5)	Not stated	•	•	•	•		•
Philbin (2012)[109]	Acute/chronic wounds (n=7)	Up to 14 days	•	•	•	•	•	•

DFU – diabetic foot ulcer

Table 14. Case study/case study series involving Mepilex Transfer Ag

Reference	Wound type	Treatment duration	Observations					
			Dressing easy to apply/re-move/use	Dressing effec-tively handled exudate	Improved pa-tient comfort/ QoL	Reduced dress-ing-related pain	Healthy peri-wound skin	Wound healed/ reduced in size
Arnold-Long (2015)[98]	Acute wounds (n=3)	Not stated		•		•		
Koerner and Adams (2015)[97]	Traumatic wounds (n=3)	Not stated			•	•	•	•
Marshall-Hanson (2015)[99]	Erythroderma reaction to chemotherapy regime (n=1)	15 days	•	•	•			•
Quimby (2015)[100]	Acute and chronic wounds (n=3)	Not stated			•	•	•	
Quimby (2015)[101]	TEN (n=1)	6 days	•	•				

TEN – toxic epidermal necrolysis

infection, managing the periwound skin, minimising dressing-related trauma and pain, and reducing wound size. The findings highlighted the positive effect of Mepilex Border Ag in terms of preventing dressing-related trauma, reducing signs of infection and improving the condition of the periwound region. Use of the dressing was also associated with statistically significant reductions in dressing-related pain and wound size.[92]

Postoperative wound infections following coronary artery bypass graft (CABG) surgery are one of the most costly and dangerous complications that can occur. A non-comparative clinical investigation, presented in a poster, was initiated to determine if the use of Mepilex Border Ag alongside a standard protocol for incision care would have a positive effect on the incidence of postoperative surgical site infection (SSI) in patients undergoing CABG surgery (Table 11).[93] Over a 12-month period, 61 patients were enrolled on the study. Mepilex Border Ag was applied to the sternum and leg incision in the operating room using sterile technique and left in place for more than 48 hours. Following dressing removal, the incision was cleaned daily with a chlorhexidine gluconate product for either the duration of the hospital stay or one week postoperatively. After discharge, the patient cleaned the incisions daily with soap and water. If Mepilex Border Ag was removed within the 48-hour period, a silicone dressing without silver was reapplied, which was changed every three days or as required.

Based on the data collected, the incidence of SSI following CABG surgery was 3.27% (two out of 61 patients) compared with an incidence of 10.94% (seven out of 64 patients) in the preceding 12 months. This correlated to a 71.4% reduction in postoperative SSI incidence in patients and was closer to the previously published Iowa Average Benchmark of 2.24%. As well as the patient-related quality outcomes, the estimated cost savings for the hospital equated to about US$313K per calendar year.[93]

Kles et al.[94] described a quality improvement process (QIP) at a regional medical centre initiated after the incidence of deep sternal wound infection (DSWI) after CABG was found to be higher than the national benchmark: 3.74 per 100 procedures versus 2.55 per 100. Post-CABG DSWI further complicates patient recovery due to the need for additional surgery, advanced wound care, and long-term medication (antibiotics).

As part of the QIP, gauze dressings were replaced with Mepilex Border Ag for sternal incision care. The rationale for the new strategy was based on the lack of evidence to support the efficacy of gauze dressing and its inability to provide an antibacterial barrier. In contrast, the placement of the silver dressings over incision sites at the time of primary closure was associated with a reduction in SSI rates. Mepilex Border Ag was applied over the incision site for up to seven days or for the duration of hospitalisation, whereas previously the gauze dressing had been changed every two days.

During the study period, 262 CABG surgeries with saphenous vein donor-site procedures were performed. Two patients developed DSWI within the first two months of initiating the QIP (incidence rate of 0.7 per 100 procedures, surpassing the target of 1.61 per 100 patients). After the completion of the QIP, no patients who underwent CABG surgery with donor site procedures developed a DSWI in more than 30 months and 590 procedures, equating to cost savings in excess of US$600K and 377 excess hospital days avoided over 32 months.[94]

Further patient-related and economic benefits of using Mepilex Border Ag were highlighted in a non-randomised comparative clinical trial, reported in a poster, where the adherence and flexibility of Mepilex Border Ag was compared with a non-stick pad with adhesive tabs from a physical therapist's point of view (Table 12).[95] Over one week, eight physical therapists working with patients following total knee replacement surgery evaluated the two dressings using a Likert-type survey (scale 1–5, where 1=never and 5=always).

The therapists evaluated Mepilex Border Ag as being 63% more adherent during physical therapy compared with the non-stick pad with adhesive tabs (Likert scale: Mepilex Border Ag, 4.75; non-adherent pad, 1.75). During therapy sessions, the therapists had to think about the dressing 70% less with Mepilex Border Ag compared with the non-stick pad with adhesive tabs (Likert scale: Mepilex Border Ag, 1.3; non-adherent pad, 4.5).

In addition, a poster presentation showed that Mepilex Border Ag proved to be a cost-effective alternative, reducing unneeded and labour-intensive dressing changes—only one Mepilex Border Ag dressing (US$4.03 per dressing—was required per week compared with 42 (six per day) pads (US$1 per dressing), and decreasing interruptions to the physical therapy regimen.[95]

Key points:

- Mepilex Border Ag can achieve similar clinical outcomes to Mepilex Ag, but has the advantage of being self-adherent
- In three studies, surgical wounds treated with Mepilex Border Ag were found to have less surgical site infection
- The studies observed reductions in clinical signs of localised infection, positive healing responses, improvements in the periwound region, and minimal dressing-related trauma and pain with Mepilex Border Ag on a variety of wound types. The self-adherent properties of the dressing contribute to its 'stay-on-ability', which can potentially cut treatment costs by reducing the need for frequent dressing changes

Mepilex Transfer Ag

As highlighted in Table 1, Mepilex Transfer Ag is intended for use on low-to-highly exuding wounds of various aetiologies, when there is a requirement for topical antimicrobial therapy. The dressing is designed to absorb and transfer excess exudate from the wound to a secondary dressing, while maintaining a moist wound healing environment. A number of clinical studies have been undertaken to evaluate the efficacy of Mepilex Transfer Ag in treating burns, acute and chronic wounds (Tables 14 and 15).

Table 15. Non-comparative studies of Mepilex Transfer Ag

Reference	Design methodology	Main outcome measures	Main results
Dhatariya et al. (2016)[102]	■ Non-comparative clinical evaluation ■ DFU (median duration 4 weeks (range 1–208 weeks) (n=24) ■ Mepilex Transfer Ag used in conjunction with a suitable secondary dressing ■ Treatment duration: up to 28 days (with further 12-week follow-up period)	■ Clinical signs of localised wound infection ■ Healing response (PictZar digital planimetry program) ■ Condition of periwound skin ■ In-use characteristics	■ Significant reduction in signs/symptoms of local wound infection ■ 50% reduction in mean wound size; continued reduction in wound size during follow-up ■ Significant improvement in periwound area ■ Overall satisfaction: dressing rated as 'very good' by clinicians. ■ Dressing reported to be comfortable to wear and remained in place
Schweiger et al. (2013)[96]	■ Non-comparative study (prospective) ■ Superficial partial-thickness or superficial deep partial-thickness burn injury (TBSA: 1–25%) (n=10) ■ Treatment duration: up to 21 days	■ Time to healing (>95% epithelialisation) (PictZar Photo Analysis System) ■ Inflammation/infection management	■ Median wound healing rate was 8.0 days, range 5.0–14.0 ■ Median percentage change in surface area at the last subject visit was -95.8, range -100; -70) ■ Inflammation and infection were successfully managed

DFU – diabetic foot ulcer; TBSA – total body surface area

In an open, single centre, non-comparative clinical study, reported in a poster, 10 patients with second-degree partial-thickness (superficial, deep or mixed depth) burns injuries (1–25% TBSA), were treated with Mepilex Transfer Ag.[96] Secondary dressings used were gauze rolls and compression bandaging. The burns treated with Mepilex Transfer Ag exhibited an acceptable rate of healing: seven subjects (70%) were healed at week 1 and the remainder healed by week 2 (median: 8.0 days, range: 5.0–14.0). The dressing's antimicrobial coverage was considered adequate and, despite a small number of positive swabs at baseline, infection did not proliferate. The researchers concluded that Mepilex Transfer Ag showed acceptable performance in terms of healing rate and exudate management in the treatment of second-degree partial-thickness burns.[96]

The results of a number of case studies, all presented as posters, (Table 14) highlight the clinical benefits of using Mepilex Transfer Ag in managing acute wounds—namely, improvements in the condition of the wound bed and periwound skin, good exudate management, and minimal pain and trauma at dressing change.[97-101]

Poster citations

■ The poster presentations cited in the reference list are available on request from Mölnlycke at: gems@molnlycke.com

A non-comparative clinical evaluation assessed the performance and safety of Mepilex Transfer Ag in treating infected DFUs (Table 15).[102] It was used for up to four weeks and additional treatment was provided at the clinicians' discretion. After a maximum of four weeks' treatment with Mepilex Transfer Ag, the signs/symptoms of localised wound infection had improved in 23 out of 24 DFUs (95.8%). By the end of the post-study period, 16 DFUs were free of infection (76.2%). At the point Mepilex Transfer Ag treatment was stopped, the mean total wound area had reduced by 44%, and five wounds had healed. During the 12-week post-treatment period a further six wounds healed and another six improved. At baseline, 75% of the DFUs had unhealthy periwound skin; however, post-treatment, 71% had healthy and intact surrounding skin. At 12 weeks post-treatment, 85.7% had healthy periwound skin. All the wounds were exuding at baseline assessment but, after treatment, the type and level of exudate had improved in 62.5% of wounds.

On average, the investigators rated overall satisfaction with Mepilex Transfer Ag as 'very good'. They scored it on a range of parameters—ease of application and removal, flexibility, lack of adherence to the wound bed on removal, ability to adhere to healthy intact skin and conformability—and rated it as 'very good'. The likelihood of changing only the secondary dressing was rated as 'good/very good'. Patients rated the dressing as 'very good' in terms of anxiety experienced during dressing change, ease of movement while wearing the test product, dressing comfort, its ability to remain in place, and lack of stinging/burning experienced during wear.[102]

Key points:

- Mepilex Transfer Ag can be used to manage low-to-high levels of wound exudate effectively by absorbing and transferring it to a secondary dressing
- Reductions in clinical signs of localised infection, positive healing responses, improvements in the periwound skin, and minimal dressing-related trauma and pain have been observed in studies on the use of Mepilex Border Ag with different wound types

Conclusion

Wounds that are infected, or at risk of infection, generally pose a greater clinical challenge than those free of infection. This means that, in addition to addressing the bioburden, wound management must take into account the fact that infected wounds are associated with higher than normal levels of, and heightened sensitivity to, pain.[15] Infected wounds are also generally associated with higher levels of exudate than non-infected wounds, and so contain more serous proteins, which affect viscosity and uptake into the dressing.[103]

Clinical studies have shown that moderate levels of wound exudate are absorbed effectively by the silver-containing foam dressings, Mepilex Ag[34,82,85,88,89,104-106] and Mepilex Border Ag.[107-109] In addition, it has been demonstrated that Mepilex Transfer Ag can manage wound exudate effectively by transferring it to a secondary dressing.[96]

In vitro tests have shown that silver-containing foam dressings with Safetac have both rapid and sustained activity against a range of wound-relevant pathogens. An antimicrobial environment is provided by all three dressings: Mepilex Ag,[47,53,58,59] Mepilex Border Ag[53,59] and Mepilex Transfer Ag.[48,55]

The silver-containing foam dressings with Safetac reviewed here, due to their Safetac wound contact surfaces, are associated with atraumatic and virtually pain-free removal (Mepilex Ag;[86] Mepilex Border Ag;[92] Mepilex Transfer Ag[97]). These dressings are well tolerated and comfortable, while being easy to use, to the point where patients have been able to do their own dressing changes. Ease of use, low frequency of dressing changes, and clinical efficacy all contribute to the cost-effectiveness of the dressings.

In summary, silver-containing foam dressings with Safetac provide dressing options that fulfil the needs of both clinicians and patients when it comes to producing an optimal environment for wound healing and addressing patient-centred outcomes that can enhance quality of life.

Key points:

- Mepilex Ag, Mepilex Border Ag and Mepilex Transfer Ag are successful in managing bioburden
- In addition, these dressings manage exudate effectively, reducing the need for frequent dressing changes
- The Safetac wound contact layer of these silver-containing foam dressings minimises trauma and pain on removal, offering undisturbed healing and improved patient comfort

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Published on behalf of Mölnlycke Health Care by MA Healthcare Ltd

Managing director: Anthony Kerr
Associate Publisher, Medical Education: Tracy Cowan
Project Manager: Camila Fronzo
Sub-editor: Janet Perham
Designer: Lindsey Butlin
Published by: MA Healthcare Ltd, St Jude's Church, Dulwich Road, London SE24 0PB, UK

Tel: +44 (0)20 7501 6726 Email: anthony.kerr@markallengroup.com Web: www.markallengroup.com

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