

# Skin adhesion properties of three dressings used for acute wounds

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## Abstract

**Background:** Considerable thought has been given to the development of dressings and adhesives for use on chronic wounds. Dressings and adhesives used on acute (surgical/traumatic) wounds, however, have not had the same level of scrutiny regarding the skin damage that may be incurred on removal, particularly as the dressings are often removed after short application periods. **Aims:** To compare the skin adhesive properties of three dressings used for acute wounds in terms of their peel adhesion, pain on removal and their effect on skin post removal. **Results:** The study shows that dressing A displayed a lower level of adhesion (thus potentially less skin damage), and yet remained in place after 96 hours application. Baseline levels of pain on removal were low, which might account for the fact that no significant differences were observed between the three dressings in respect of this measurement. Application of dressing B showed an increased level of hydration in the skin, which may have clinical implications in terms of maceration. **Conclusions:** The study demonstrates that the same level of care is required when selecting dressings for acute wounds to ensure that minimal damage is caused to skin which may be as fragile as that close to chronic wounds. **Conflict of interest:** The study was sponsored by Mölnlycke Health Care.

## KEY WORDS

Acute wounds  
Skin adhesion properties  
Peel adhesion force  
Skin hydration  
Infection

Acute wounds occur as a result of accidental injury or predetermined surgical procedures, which may be fairly minor in the form of simple incisions or major where the operative procedure causes considerable damage to the tissue(s). Under ideal conditions, acute wounds will follow the normal wound healing pathway (Stojadinovic et al, 2008) and, as such, require different interventions and perhaps less complicated treatments and/or dressings than chronic wounds (Vaneau et al, 2007).

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Such wounds, however, do present clinical challenges that need to be addressed. A significant factor with these wounds, as with any wound, is the propensity for infection. Damage to the skin allows ingress of foreign matter, including potential pathogens. An open wound is an ideal environment for the growth of pathogens, being moist, warm, and providing nutrients.

In hospitals, the incidence of surgical and other hospital-acquired infections (HAIs) is clinically significant, adding an extra burden on the resources of the health service. For example, a prospective study of 20,822 operations reported that the overall infection rate for clean general surgery (class 'A' operations) was 4.5%; for potentially infected surgery (class 'B' operations) 9.5%; and for clean orthopaedic surgery 3% (Davis et al, 1973). An additional complication is the emergence of resistant strains of bacteria, such as meticillin-resistant *Staphylococcus aureus* (MRSA). This is now thought to colonise about 10% of the world's population. Resistant strains represent a real problem in relation to colonisation and infection of wounds in general (Anderson and Kaye, 2009).

A requirement in the treatment of wounds (even those healing by primary intention) is to use a dressing that will provide some form of protection to the wounded tissue. It is recognised that dressings in general should meet the following criteria (Thomas, 2008):

- ▶▶ High moisture vapour permeability (MVP)
- ▶▶ Low adherence to wound surface
- ▶▶ Absorbent
- ▶▶ Waterproof, or washproof for minor surgery
- ▶▶ Bacterial barrier
- ▶▶ Conformable
- ▶▶ Non-sensitising
- ▶▶ Good adhesion to skin
- ▶▶ Sterile
- ▶▶ Low cost
- ▶▶ Non-flammable and non-toxic.

For acute/surgical wounds the following properties may be added to the list of characteristics required to achieve the 'ideal' surgical dressing:

- ▶▶ No risk of maceration of intact tissue
- ▶▶ Easy to use
- ▶▶ Removable without disturbing the sutures or clips
- ▶▶ Allows inspection of wound site without disturbance.

These criteria highlight the clinical challenge in the acute/surgical wound environment of maintaining the dressing in place while allowing the wound to be evaluated at frequent intervals. Thus, the dressing needs to be adherent, but not to the extent that it will cause damage to the surrounding skin or wound upon repeated application and removal of dressings.

Another problem that has been identified in the treatment of acute/surgical wounds relates to how the healthcare worker uses the dressing. It is unfortunate, but the adhesion of wound dressings to the skin in the acute wound setting receives less attention than for those dressings used on chronic wounds. This is probably due to the greater likelihood of chronic wounds being managed by one and the same healthcare professional, who is likely to ensure that damage to fragile skin is minimised on dressing removal by selection of an appropriate dressing throughout the course of treatment (Watret and White, 2001). Conversely, because it is often different carers who apply and remove dressings in the acute setting, it is important that the adhesion of the dressing to skin is optimised in order to avoid damage to viable tissue and infliction of pain when the dressing is removed.

In addressing the clinical challenges surrounding the treatment of acute/surgical wounds, the following points should be considered with respect to dressing attributes. The dressing should:

- ▶ Provide protection and prevent pathogenic ingress
- ▶ Have adhesive properties that are not so great as to cause damage to the wound/skin and yet be able to stay in place for short or extended periods
- ▶ Be able to accommodate the wide levels of adhesion resulting from the many different skin types in the population
- ▶ Be removable after a short period to allow the wound to be viewed, typically after 24 or 48 hours.

To show how dressings can overcome the clinical challenges that have been identified, a volunteer

**Table 1**

**Types of dressings examined in the study**

| Product code | Product name       | Manufacturer             | Lot number |
|--------------|--------------------|--------------------------|------------|
| A            | Mepore®            | Mölnlycke Health Care AB | 0825-1433  |
| B            | Cosmopor® E Steril | Hartmann AG              | 81902309   |
| C            | Cosmopor® Steril   | Hartmann AG              | 709302B    |

study was undertaken to evaluate the adhesive properties of three dressings used for the treatment of acute wounds. Hydration and sebum levels were also measured on the dressing sites on the volunteers to examine the influence of skin type on adhesion.

**Materials and methods**

Three dressings were examined in the study (Table 1). All the dressings are CE marked, currently on the market, and indicated for use on acute wounds. The study examined two parameters to evaluate the performance of the adhesive: (1) the peel adhesion force, and (2) the pain associated with complete removal of a dressing. Additionally, in order to characterise the different types of skin and to establish the influence of skin type on the adhesion of the dressing, skin dryness and sebum levels were measured.

The study was carried out at proDERM Institute for Applied Dermatological Research, Hamburg, Germany. A total of 18 healthy volunteers were entered into the study, none of whom were excluded from the data analysis. The age of the volunteers, who were all female, was  $47.6 \pm 14.3$  years (mean  $\pm$  standard deviation). The inclusion/exclusion criteria for the volunteers are shown in Table 2.

**Peel adhesion force**

Two samples, 15x80mm, of each test product per time point were applied to the back of each volunteer. Following application of the dressing strips, a 1kg roller was applied five times along the length of the strip to ensure a constant application pressure. The dressing strips were removed after 24 hours and 96

hours using a Zwicky Universal Testing Machine (UTM) (Zwick GmbH Ulm). The samples were peeled at an angle of 135° at a rate of 300mm/minute.

**Pain on removal**

Dressings were applied to the upper and lower volar forearm of the volunteers; they were randomised to each forearm to enable a direct comparison of each dressing against each of the other two dressings. After application, the dressings were rolled with a 1kg roller to ensure even application pressure of the adhesive to the skin. The dressings were removed by a trained technician after 24 and 96 hours. The sensation of pain was recorded by the volunteer on a visual analogue scale (VAS). Application and removal of the dressings was carried out in a controlled environment,  $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$  and  $50\% \pm 5\%$  relative humidity. The volunteers also acclimatised in a controlled environment 30 minutes before the application of the dressings and 10 minutes before removal of the dressings.

Additionally, dressings from the pain study were photographed using a scanning electron microscope to investigate the quantity of skin attached to them after removal. Electron microscopy was carried out at Intertek Ltd NWTC, Bebington, Wirral.

**Skin characterisation**

Stratum corneum hydration was measured using the electronic capacitance method with a Corneometer CM 825, (Courage and Khazaka, Cologne, Germany). Skin hydration was measured before application of the dressings and after the dressings had been removed from the skin. Hydration was measured

from a site under the dressing and a control site close to the peeled site. Skin sebum measurements were taken using a Sebumeter SM 810PC (Courage and Khazaka, Cologne, Germany). Skin sebum values were recorded before application of the dressings on both the forearms and the back.

**Results**

**Peel adhesion force**

The mean peel adhesion forces are shown in *Figure 1*. Statistical analysis was undertaken of these data. For the peel adhesion results, analysis of variance (ANOVA) was performed on the mean values, examining the factors of dressing type and wear time. Additionally, interaction of these two factors was also evaluated. Statistical significance was found for the factor of dressing type and the interaction of dressing and wear time. No significant effect was recorded for the factor of wear time. Given the outcome of ANOVA, and the nature of the data sets, an F-test is justified thus:

$$F = \frac{\text{between-group variability}}{\text{within-group variability}}$$

As the p-value of an F-Test for interaction between dressing and wear time was lower than 0.05, pairwise comparisons of dressings with t-tests of wear time were performed. Test product A (Mepore®) showed significantly lower values on day two and day five compared with test products B (Cosmopor® E Steril) and C (Cosmopor® Steril). Furthermore, significantly lower values were detected for test product C in comparison with test product B on day two (*Table 3*).

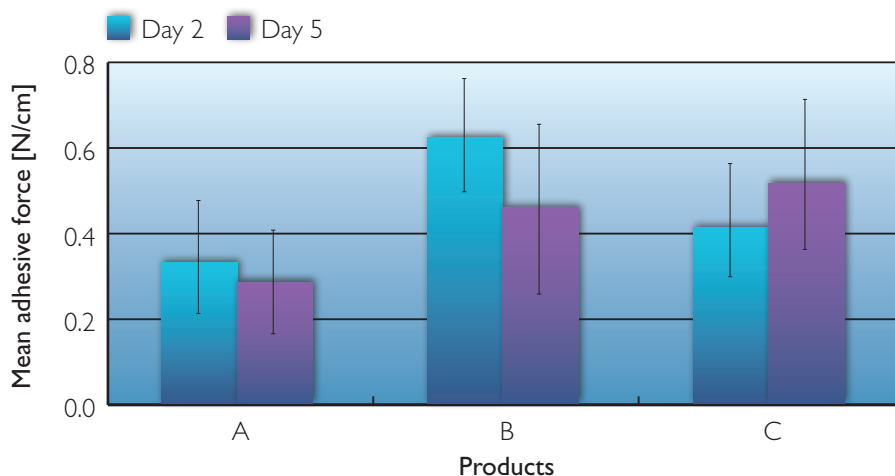
**Pain on removal**

The levels of pain subjectively assessed by the volunteers as the dressing was removed by the trained technician are shown in *Figure 2* and *Table 4*. For pain assessment an ANOVA model corresponding to the balanced incomplete block design (BIBD), with factors 'volunteer', 'product' and 'time' as variables, was performed. The factor volunteer showed significant effects (p<0.001). No significant effects for product (p=0.696) and time (p=0.983) were found. Regarding the interactions between day and product (p=0.864)

**Table 2**

**Inclusion and exclusion criteria for study volunteers**

| Inclusion criteria  | Exclusion criteria   |
|---|--|
| <ul style="list-style-type: none"> <li>▶▶ Male or female</li> <li>▶▶ Between 18 and 65 years of age</li> <li>▶▶ Signed informed consent form to participate in the study</li> <li>▶▶ Willingness to actively participate in the study and to come to the scheduled visits</li> <li>▶▶ Willingness to discontinue the use of detergents and/or cosmetic products (e.g. creams, moisturisers) in the treatment areas throughout the course of the study</li> <li>▶▶ Willingness not to bring the test area into contact with water (e.g. showering, bathing) during the application period</li> </ul> | <ul style="list-style-type: none"> <li>▶▶ Pregnancy or lactation</li> <li>▶▶ Drug addiction; alcoholism</li> <li>▶▶ Acquired immune deficiency syndrome (AIDS) or infectious hepatitis if known to the panellist</li> <li>▶▶ Serious illness that might require systemic medication (e.g. insulin-dependent diabetes, cancer), or conditions which exclude participation or might influence the test reaction/evaluation</li> <li>▶▶ Active skin disease at test area</li> <li>▶▶ Documented allergies to patch systems</li> <li>▶▶ Moles, tattoos, scars, irritated skin, hairs, etc at the test area that could influence the investigation</li> <li>▶▶ Application of cosmetic products within the 24 hours before the start of the study</li> <li>▶▶ Participation or being in the waiting period after participation in similar cosmetic and/or pharmaceutical studies</li> </ul> |



**Figure 1. Mean adhesion forces (showing standard deviation).**

and panellist and day (p=0.739), no significant effects were found. Hence, according to protocol, no further comparisons by assessment times had to be undertaken. No complete dressings were prematurely lost before the specified removal time. Skin damage was assessed on these samples to avoid the problem observed by Murahata et al (2008), who showed that higher peel forces are not always associated with more skin damage.

**Skin characterisation**

Levels of skin hydration compared with adjacent control sites are shown in *Table 5* and *Figure 3*. ANOVA was performed on the differences to control on the back with the factors 'dressing' and 'wear time' and their interaction. The factors dressing and wear time showed significant effects. No significant effect was documented for the interaction of dressing and wear time. The hypothesis that there is no difference between the products and

wear times cannot be rejected. Due to the explorative character of this study, pairwise comparisons of test products with t-test by assessment time were performed and are shown in Table 6.

Test products A and C showed significantly lower skin hydration differences between treated and untreated areas on day two compared with test product B. No further significant differences were documented. The same differentiation was found on day five.

### Discussion

Striking a balance between effective levels of adhesion that will maintain dressing security and yet result in minimal skin damage on removal is a significant challenge for the dressing designer. Ultimately, this is also a challenge for the healthcare worker in that they need to choose appropriate dressings that will fulfil the needs of the patient but not cause damage to the wound site or surrounding skin. This is perhaps more important for dressings used for acute wounds that may need to be removed after short periods, which is often the time that maximum skin adhesion is attained.

### Peel adhesion force

The measurement of peel force of dressings/adhesive tape as an indicator of skin damage and discomfort has been used frequently (Dykes et al, 2001; Karwoski and Plaut, 2004). The results of this study show that in terms of adhesive removal force, dressing A (Mepore) was associated with a lower force than dressings B and C (Figure 1 — mean adhesive forces 0.34, 0.63 and 0.42 N/cm, respectively). A statistical comparison of the results has shown that the difference between Mepore and the other two dressings was significant (Table 3). The adhesive was shown to be effective as none of the Mepore dressings or, indeed, any of those dressings tested, were lost before day two or five in the study assessing pain at dressing removal. Clinically, therefore, this implies that less trauma will be inflicted on either the wound site or adjacent periwound skin of patients treated with dressing A. Similar studies have been undertaken by Dykes et al (2001) and it has been shown that the less aggressive the adhesive, the

**Table 3**

Results of statistical comparison of products by assessment times by paired t-test on mean adhesive forces (n=10–18)

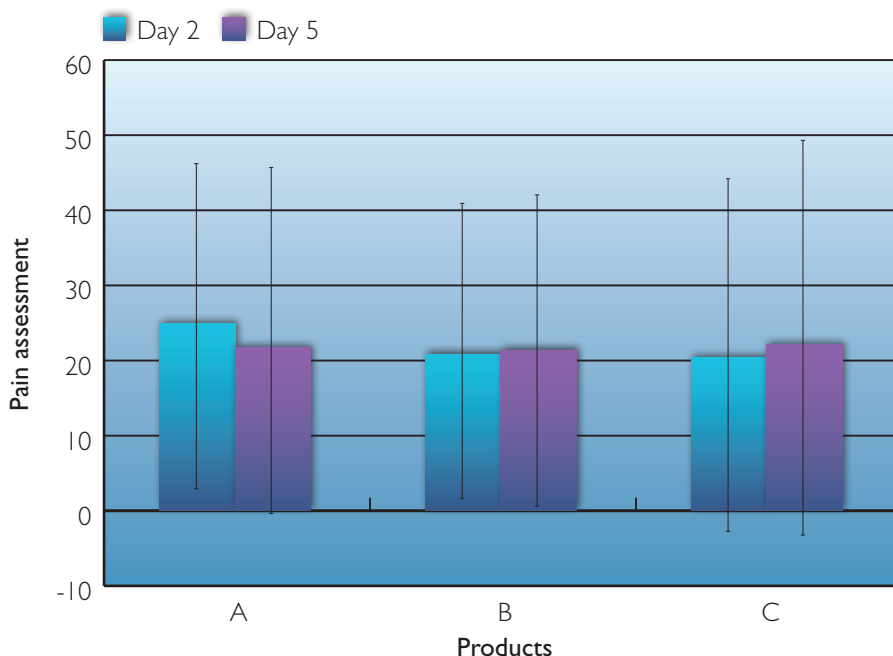
| Product code | Levels of significance of the mean adhesive forces [N/cm] |            |
|--------------|---|------------|
|              | Day 2   | Day 5      |
| A vs B       | <0.001*   | <0.001*    |
| A vs C       | 0.004*  | 0.008*     |
| B vs C       | <0.001*   | 0.994 n.s. |

n.s.: not significant; \*: significant for local alpha = 0.05

**Table 4**

Mean values of subjective pain assessment (n=12)

| Product code | Pain assessment |       |
|--------------|-----------------|-------|
|              | Day 2           | Day 5 |
| A            | 24.42           | 22.42 |
| B            | 21.42           | 21.83 |
| C            | 20.58           | 22.42 |



**Figure 2.** Levels of pain subjectively assessed by volunteers at dressing removal.

less damage is inflicted on the stratum corneum. Damage to the stratum corneum can ultimately cause significant problems in terms of infection, in that the barrier to pathogens is compromised.

These points are also supported by the data related to the subjective assessment of skin reddening. The results show that after removal of the dressings, the lower level of adhesion for dressing A also

resulted in a lower incidence of reddening on day two and day five, whereas dressing B demonstrated consistently higher scores and dressing C was higher at day five (Table 7).

Examination of the wound contact layers of the dressings by scanning electron microscopy did not show the marked differences seen with silicone and acrylic adhesives (Waring et al, 2008), however, less skin appeared to be removed by dressing A compared with dressings B and C (Box 1).

**Pain on removal**

In patients with chronic wounds, pain related to the wound and treatment, for example, removal of aggressively adhesive dressings at dressing changes, has been identified as a significant problem (Cutting, 2008). In acute wounds, post-surgical pain can become chronic (Katz and Seltzer, 2009) and the healthcare worker needs to be aware of the implications that an inappropriate dressing may have on such a transition.

In this study using healthy volunteers, the results relating to the evaluation of pain upon removal of the dressing did not differentiate between any of the dressings in terms of the level of pain at dressing removal (Table 4). This is probably because the level of pain on the VAS scale recorded in the volunteers was very low (only 20–30), equating to the descriptors ‘tingling to a little sore’. The only variable to show significance was the volunteer indicating that the sensation of pain is quite different from one individual to another. On reflection, these results are not surprising as healthy volunteers will not have the heightened sensitivity to pain as do patients who have undergone surgery and, as the data show, there is considerable variation between the volunteers. The low scores indicate that the dressings may be comparable with respect to the degree of pain caused to volunteers, but it may be that an evaluation on patients who have actually sustained surgical wounds will be more clinically relevant.

**Skin characterisation**

The level of skin hydration under dressing B was shown to be significantly raised after dressing removal, as a

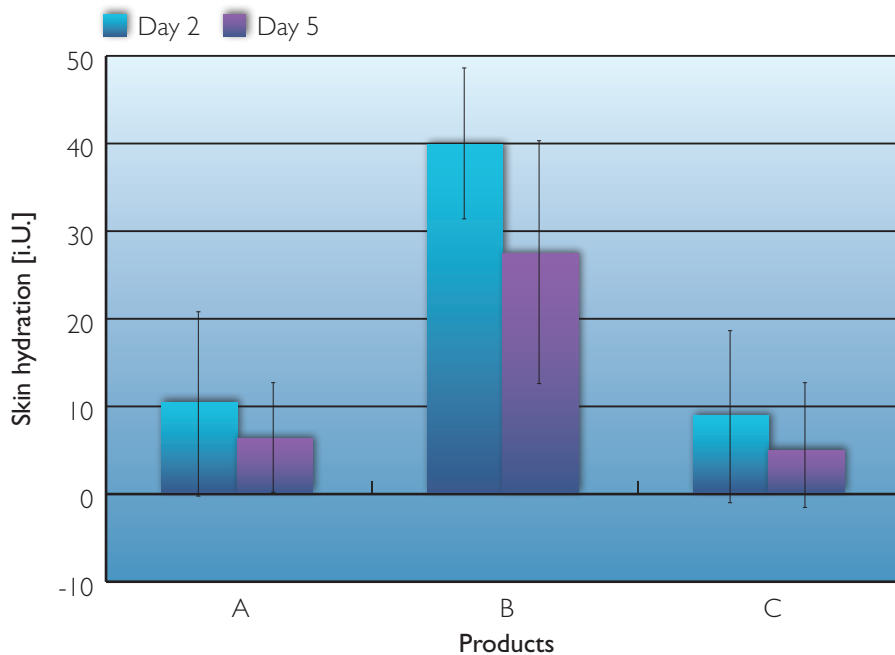


Figure 3. Levels of skin hydration compared with adjacent control sites.

**Table 5**

Mean values by products — skin hydration on back (n=11–18)

| Product code | Skin hydration [I.U.] |         |                       |           |         |                       |
|--------------|-----------------------|---------|-----------------------|-----------|---------|-----------------------|
|              | Day 2                 |         |                       | Day 5     |         |                       |
|              | Treatment             | Control | Difference to control | Treatment | Control | Difference to control |
| A            | 53.58                 | 43.31   | 10.28                 | 49.64     | 43.32   | 6.32                  |
| B            | 83.50                 | 43.39   | 40.11                 | 70.38     | 43.38   | 27.00                 |
| C            | 51.89                 | 43.33   | 8.56                  | 48.13     | 42.78   | 5.34                  |

result of the non-permeable backing for this waterproof dressing. Dressings A and C appeared to raise the level of skin hydration only slightly compared with the control site. This increase was lower after day five compared with day two, suggesting increased permeability through the dressings after day five. Skin hydration levels for the control sites were reproducible for both test days. These data are important in relation to the fact that numerous articles have highlighted the fact that damage to the surrounding skin (maceration) can exacerbate and delay healing (Walker et al, 2008), increase associated pain, increase the propensity for infection, and potentially increase the cost of treatment (Thomas, 2008).

Maceration, in particular, has the propensity to cause infection and it has been demonstrated that dressings with aggressive adhesives may also contribute to skin breakdown and allow infection to begin. Shannon and Chakravarthy (2009) and Cutting (2008) both showed impaired barrier function with increases in transepidermal water loss as a result of aggressive skin adhesives. It is therefore essential that the healthcare worker understands the importance of these parameters when choosing an appropriate dressing for treating such wounds so that treatment is optimised.

It was envisaged that characterising the skin by measuring hydration and sebum

levels would give some indication as to the variability in levels of skin adhesion for the volunteers and in clinical use generally; however, this was not seen to be the case. Higher sebum levels were not linked to lower adhesion as may have been predicted, although the number of volunteers and limited measurements may have prevented this link being established.

Overall, these results compare well with a recent randomised controlled, trial comparing Mepore with Aquacel® (ConvaTec) in primary closed wounds after vascular surgery. The results showed that there was no significant difference in patient comfort between the two groups, but costs were higher in the Aquacel group despite significantly fewer changes of dressings in these patients. No differences in the infection rate (13% vs 11%;  $p=0.73$ ), length of hospital stay, or wound complications were noted between the two groups (Vogt et al, 2007).

**Conclusion**

Dressings used for the treatment of acute, postoperative wounds are required to

have levels of adhesion that accommodate trauma-free removal after short periods of application and yet maintain security and protection for the wound for up to five days. All three dressings examined in this study were shown to be trauma free on removal and provided secure adhesion for up to five days application. Dressing A was shown to have lower skin adhesion and to produce less skin reddening after removal. In addition, dressings A and C controlled moisture to a greater degree than dressing B, which may have implications for preventing maceration and associated problems such as infection. **WUK**

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**Key points**

- ▶▶ Three dressings (Mepore®, Cosmopor® E Steril, and Cosmopor® Steril) used for acute wounds were evaluated for adhesive properties in a study using healthy volunteers.
- ▶▶ Peel adhesion force studies revealed that the adhesive removal force associated with Mepore (0.34 N/cm) was significantly lower than that for Cosmopor E Steril (0.63 N/cm) and Cosmopor Steril (0.42 N/cm).
- ▶▶ Clinically the findings imply that less trauma will be inflicted on either the wound site or adjacent periwound skin of patients treated with Mepore.
- ▶▶ After removal of dressings the lower level of adhesion for Mepore resulted in lower incidence of reddening on day two and day five compared with the other dressings tested.
- ▶▶ Low pain scores on the VAS scale indicated that the three dressings used in the study may be at least comparable with respect to the degree of pain caused to the healthy volunteers, but it may be that an evaluation of patients who have actually sustained wounds may be more clinically relevant, since healthy volunteers will not have the heightened sensitivity to pain as do patients who have undergone surgery.
- ▶▶ Mepore controlled moisture to a greater degree than Cosmopor E Steril; this may have implications for preventing maceration and associated problems such as infection.

**Table 6**

Results of statistical comparison of products by assessment times by paired t-test on skin hydration values (n=10–18)

| Product code | Levels of significance for skin hydration [I.U.] |            |
|--------------|--|------------|
|              | Day 2  | Day 5      |
| A vs B       | <0.001*  | <0.001*    |
| A vs C       | 0.359 n.s.                                       | 0.451 n.s. |
| B vs C       | <0.001*  | <0.001*    |

n.s.: not significant; \*: significant for local alpha = 0.05

**Table 7**

Subjective assessment of skin reddening post-dressing removal

| Product code | Recognisable skin reddening |                 |               |                 |
|--------------|-----------------------------|-----------------|---------------|-----------------|
|              | Day 2, slight               | Day 2, moderate | Day 5, slight | Day 5, moderate |
| Dressing A   | 2                           | 2               | 2             | 0               |
| Dressing B   | 4                           | 10              | 2             | 12              |
| Dressing C   | 4                           | 2               | 10            | 2               |

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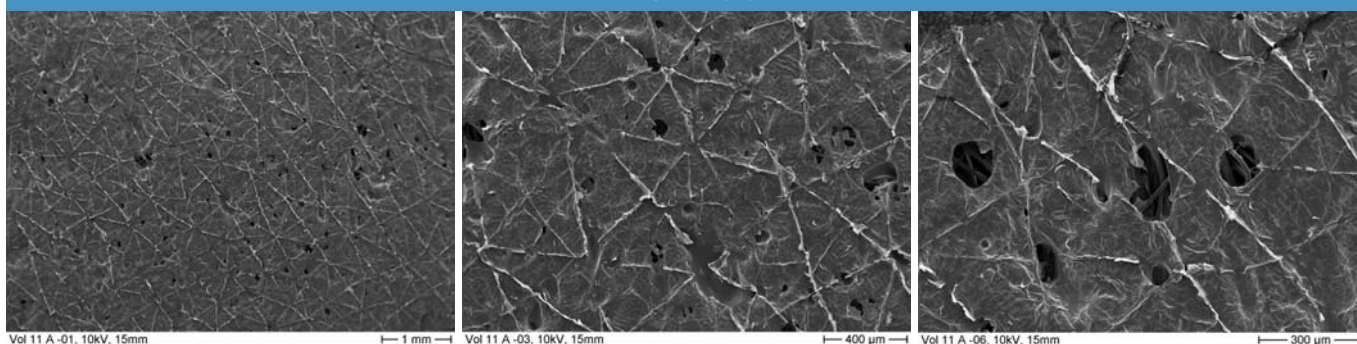
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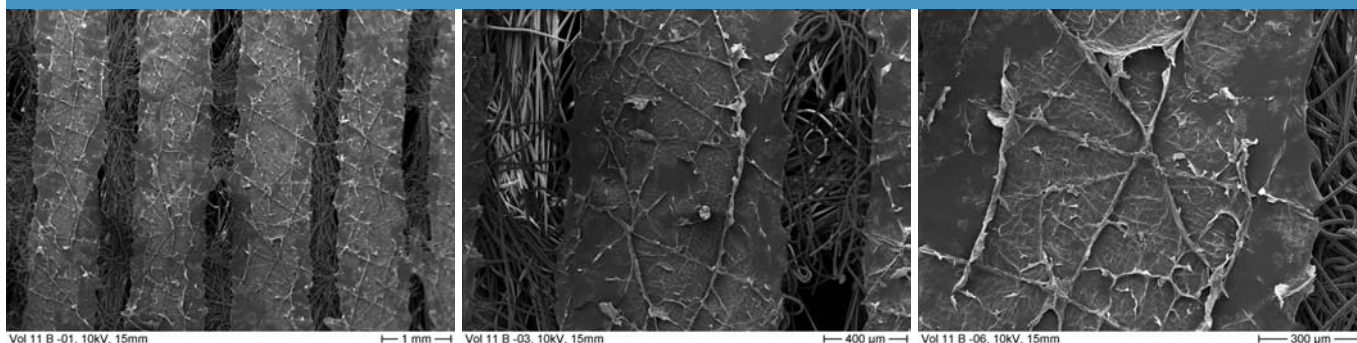
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**Box I. Samples of the scanning electron micrographs of the skin contact side of the dressings after removal from the volunteers.**

**Mepore (A)**



**Cosmopor E (B)**



**Cosmopor (C)**

