Original article

Comparing fluid handling and microclimate conditions under superabsorbent polymer and superabsorbent foam dressings over an artificial wound

ABSTRACT

Introduction Superabsorbent foam (SAF) and superabsorbent polymer (SAP) dressings are compared on their abilities to handle moisture exuding from an artificial wound and to affect the microclimate beneath the dressings by measuring: the amount of moisture absorbed; the amount of moisture evaporated through the outer layer; the humidity, both beneath and outside the dressing and the difference between the two; and the temperature, both beneath and outside the dressing and the difference between the two.

Method A thermodynamic indenter was used in a laboratory setting to deliver a steady flow of moisture vapour across a standard wound size to each dressing under the weight of the indenter. Sensors recorded the humidity and temperature inside and outside each dressing over 3 hours and 16 minutes with a 45-second complete unweighting of the dressing at the 3- hour mark to simulate a patient weight shift. Dressings were weighed at test end to determine moisture absorbed and moisture evaporated.

Results There were no significant differences between the SAF and the SAP dressing groups in moisture absorption nor evaporation, nor in humidity nor temperature inside versus outside the dressings.

Conclusion It can therefore be determined that SAF and SAP dressings appear to be equally competent in maintaining a warm and moist microclimate in the wound bed. It should also be noted that these dressings do not dry the wound bed as the term superabsorbent may imply.

Keywords Exudate, microclimate, wound, superabsorbent, dressing

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INTRODUCTION

Wound dressings are selected to manage moisture during wound healing for three reasons: to absorb exudate; to maintain an appropriate microclimate in the wound bed; and to protect the periwound from damage due to maceration from excessive moisture. Broad categories of absorptive technologies are foams, hydrocolloids, calcium alginates, hydrofibres, and moisture-binding polymers[1,2]. More complex superabsorbent foam (SAF) and superabsorbent polymer (SAP) dressings have been developed recently that claim to go beyond earlier dressings in managing wound moisture; however, these have been untested in comparison to each other. In addition, the term superabsorbent raises questions as to the possibility of over-absorption and therefore drying of the wound bed and inhibition of wound healing.

Exudate management

Since Winters published his pivotal work in 1963, moist wound healing has become accepted as best practice[2,3]. Cytokines

and growth factors require moisture to diffuse throughout the wound bed to stimulate healing via wound closure and re-epithelialisation[4]. Maintaining the proper moisture level in a wound bed prevents desiccation which allows epithelial cells to migrate freely across the wound surface. Moist wounds granulate, epithelialise and heal two to three times faster than dry wounds[5].

Exudate occurs naturally as a part of the wound healing process and keeps the wound bed moist to stimulate closure in most wounds. Some types of wounds are naturally more exudative than others, especially venous wounds, large pressure ulcers, and burns. Chronic wounds are highly exudative due to a sustained state of inflammation and disruption of normal cellular activity. Chronic wound exudate differs markedly from acute wound exudate, consisting of high levels of protein-degrading enzymes, matrix metalloproteases (MMPs), neutrophils and pro-inflammatory cytokines. Exuding wounds therefore require absorptive dressings whose capabilities match the flow of exudate to maintain an optimum moisture level at the wound bed. As these wounds begin to granulate, exudate decreases and dressing needs move from absorption to protection as a primary characteristic[2].

The amount of exudate or moisture coming from a wound is commonly documented in a patient's records with subjective descriptors such mild, moderate, severe and excessive rather than objective measurements. Several validated scales have been proposed for documenting exudate amount, including the Wound Exudate Score, the Bates-Jensen Wound Assessment Tool and the Pressure Ulcer Scale for Healing (PUSH) tool. Each scale provides a descriptor for each level on that scale. A summary and comparison of the available tools and their descriptors can be found in *Wound exudate: effective assessment and management*, a consensus document on exudate published by the World Union of Wound Healing Societies in 2019[5].

Wound microclimate

The microclimate has been identified as a key factor in both wound prevention and healing. The microclimate is the combination of temperature and humidity, and sometimes airflow, in a local region as compared to the ambient or surrounding area[6]. A warm moist environment is conducive to wound healing. Dini et al.[7] show wound healing is impaired at <33°C by a decrease in neutrophil, fibroblast and epithelial cell activity. This same study shows a correlation between improvements in the wound bed and wound bed temperatures between 33–35°C. In addition, Salvo et al.[8] report two studies showing that temperatures in the range of 36–38°C appear to promote wound healing.

Dressings, however, resist moisture escape, increasing heat and humidity levels beneath them. Advanced absorptive dressings can therefore affect the microclimate of the wound bed by drawing excessive moisture off the wound surface and maintaining warmth and humidity while dissipating excess heat and moisture through a vapour-permeable outer layer. Occlusive dressings do not have these functions.

Periwound skin

Excessive moisture on intact periwound skin weakens the dermis and epidermis by interrupting the arrangement of lipids in the stratum corneum (SC) and the linkages between epidermal cells[1]. The resulting increase in permeability makes the periwound more susceptible to invasion by contaminants and to the compounding effect of friction and shear. The term moisture-associated skin damage (MASD) refers globally to epidermal injuries resulting from exposure of the skin to moisture (for example perspiration) and irritants (for example urine, stool, ostomy effluent, wound exudate)[1]. One of the four clinical categories of MASD is periwound skin damage. Compounding the bond-weakening effects of moisture, enzymes in wound exudate that normally degrade contaminants in the wound also degrade proteins in intact skin. The resulting damage can cause pain, an increase in wound size, and decreased keratinocyte migration from the wound edges, therefore impairing wound closure[9]. As such, clinicians should choose dressings that prevent exudate from coming in contact with the periwound by locking in absorbed exudate. Ideally, the absorptive pad of a dressing should also be sized to that of the open wound bed rather than extending to the periwound.

Dressing constructions

Dressings are a dynamic primary method of either resisting moisture loss from a dry wound bed or absorbing excessive moisture from a wet wound bed while keeping the periwound free from excessive moisture.

Basic dressings such as pads made from cotton gauze or absorbents made from cellulose fibres or foams cover the wound bed and protect it from trauma and from the environment as well as simply absorbing moisture. Island dressings include an adherent border around the absorbent area. Dressings with increased capacities and enhanced features are used to treat highly exudative wounds that can overwhelm basic dressings.

SAP dressings are comprised of multiple layers in order to accommodate more highly exudative wounds by both absorption and evaporation of wound moisture. The superabsorbent core is often a mixture of cellulose and hydrophilic polymers wrapped in a cellulose tissue and/or a non-woven material. Most SAP dressings have an outer low-friction vapour-permeable polyurethane layer that allows moisture to transpire, thereby drawing more exudate from the wound and allowing a longer wear time. Polyurethane with a moisture vapour transmission rate of more than 35g/m^2/hr is correlated with faster wound healing under occlusive dressings[10]. The sum of the fluid absorbed into the dressing and the fluid transpired through the dressing is called the fluid-handling capacity of the dressing, as defined by the European Committee for Standardization[11].

Table 1. Size and construction of representative test dressings.

	Adhesive	Adhesive coverage	Backing film	Foam layer	Absorbent material – foam or non-woven	Outside border dimensions (cm)	Absorbent pad dimensions (cm) and (total area in cm^2)
SAF dressings							
Mepilex® Border (Mölnlycke Healthcare, Gothenburg, Sweden)	Silicone	Perforated 20% open over entire surface	Polyurethane	Yes	Cellulose and binding polymer	15 x 15	11 x 11 (121)
ALLEVYN Life (Smith and Nephew plc, Hertfordshire, UK)	Silicone	Perforated 20% open over entire surface	Polyurethane	Yes	Hyper-absorber lock-away core	12.9 x 12.9	7.6 x 7.6 (57.8)
Biatain® Silicone (Coloplast Corporate, Humlebæk, Denmark)	Silicone	Perforated 20% open over entire surface	Polyurethane	Yes	Lock-away layer	12.5 x 12.5	8.5 x 8.5 (72.2)
SAP dressings							
Vliwasorb® Adhesive (L&R International, Rengsdorf, Germany)	Polyacrylate	Border only	Non-woven polypropylene cloth	No	Polyethylene polypropylene cellulose sodium polyacrylate	12 x 12	8.2 x 8.1 (66.4)
Cutimed® Sorbion® Sachet Border (BSN Medical, Hamburg, Germany)	Polyacrylate	Border only	Polyester breathable outer cover	No	Cellulose fibres and gel-forming absorbent polymer in fibre layer	15 x 15	10 x 10 (100)
RespoSorb® Silicone (Hartmann AG, Heidenheim, Germany)	Silicone	Silicone mesh prevents sticking	Polypropylene fleece	No	Cellulose and superabsorbent polyacrylate	12.5 x 12.5	10.5 x 10.5 (110.25)
RespoSorb® Silicone Border (Hartmann AG, Heidenheim, Germany)	Silicone	Silicone mesh prevents sticking	Polypropylene fleece plus polyurethane backing	No	Cellulose and superabsorbent polyacrylate	12.5 x 12.5	7 x 7 (49)
Control / reference point							
Cosmopor® E Sterile (Hartmann AG, Heidenheim, Germany)	Acrylate (polyethylene contact layer)	Border only	Non-woven polyester	No	Viscose (treated cellulose)	15 x 8	11 x 3.8 (41.8)

Some SAP dressings have acrylic adhesive on a border around the absorbent island so no additional taping nor fixation of such dressing is required. Some of these dressings also feature a silicone layer across the wound surface of the dressing to minimise trauma to the wound bed – see Table 1 for an examination of the similarities and differences among a representative group of these dressings.

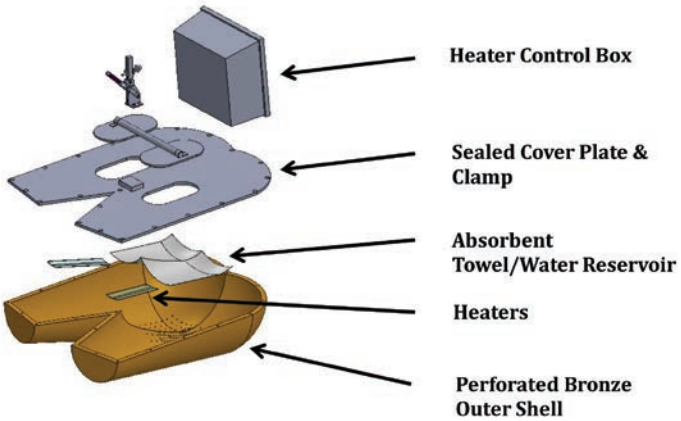
It should also be noted that the term superabsorbent can imply that a dressing can draw too much moisture from a wound and dry it out, thereby counteracting moist wound healing. One subgroup of SAP dressings – SAF dressings – are constructed in a manner similar to the SAP dressings and include an extra foam layer between the silicone and the polymer that is purported to prevent drying of the wound bed and to optimise the microenvironment of the wound bed (Table 1). Furthermore, removing pressure from a wound and dressing through a pressure release manoeuvre or a repositioning of the patient may affect moisture evaporation and heat dissipation and enhance the function of the dressing, increasing wear time.

There are few published studies comparing the effects of different dressings on similar wound types in patient use, nor ones examining the claims made by manufacturers in reference to benefits of their products in affecting the wound bed or the microclimate. Clinical research comparing dressings is very difficult to accomplish due to the many variables affecting wound healing and the impossible task of standardising patients. However, well-designed laboratory research can standardise the wound size and the exudate amount so that test dressings can be compared to each other. This standardisation limits applicability of results to the highly variable clinic population, but can provide some evidence to give guidance as to the effectiveness of a dressing in controlling the physical properties of a wound to optimise wound healing.

STUDY PURPOSE

This in vitro study compares dressings in the SAF and the SAP dressing categories described in Table 1. A basic non-polymer surgical dressing was included as a control or a reference point.

Figure 1. Thermodynamic rigid loading indenter.



The dressings were studied for their abilities to handle moisture exuding from an artificial wound by measuring the:

- Amount of moisture absorbed, reported as total grams per dressing and g/cm^2.
- Amount of moisture evaporated through the outer layer, reported as total grams per dressing and g/cm^2.
- Humidity, both inside the covered wound bed and at the outer layer and the difference between the two.
- Temperature, both inside the covered wound bed and at the outer layer and the difference between the two.

Additionally, the effect of a pressure release or patient repositioning on each of these parameters was measured.

It is important to note that previous work was reported as simply moisture per dressing[12]. For this study, due to the large variation in dressings mass and surface area, these values are reported in grams of moisture per cm^2.

METHOD

This study was conducted by an independent laboratory that is a contributor to the development of standards for support surfaces, wheelchair cushions, dressings and other wound-related medical equipment. The laboratory had an ambient temperature of 23°C ±2°C and a relative humidity of 50% ±5% as specified in ISO 554-1976(E)[13].

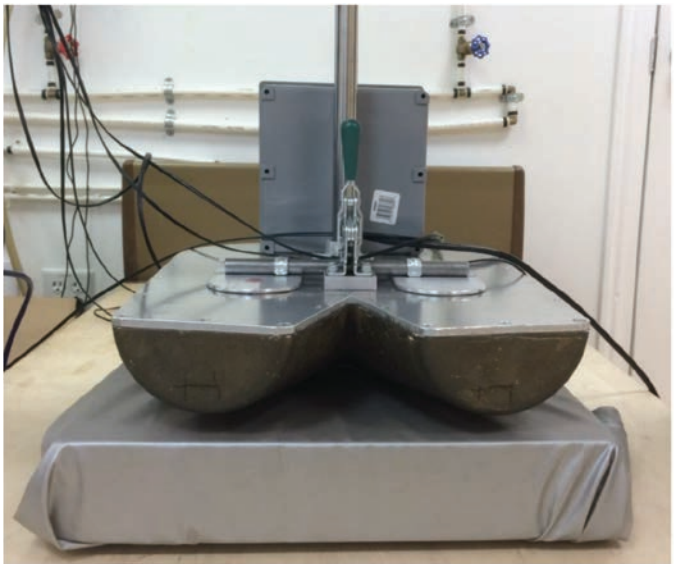
The human model was a bronze thermodynamic rigid cushion loading indenter first described by Ferguson-Pell et al.[14] for use in testing wheelchair cushions. The model was developed by a group of researchers from the United Kingdom, Japan and the United States. Since 2009 it has become a standard piece of testing equipment for studying support surfaces, dressings and wheelchair cushions in the international wound care market[15] (Figure 1).

The test indenter was compliant with the American National Standards for Support Surfaces[16]. The indenter is shaped according to the buttocks and upper thighs of a 50th percentile human male and has pre-drilled holes in the area of the sacrum and ischium. The indenter can be loaded with pre-measured amounts of water, heated and cooled, and weighted. Diffusion of the water through the pre-drilled holes simulates moisture loss through the skin. This indenter mimics the heating, cooling, sweating and drying, weighting and unweighting of the human sacral area. Resulting conditions at the indenter–surface interface are measured, and can be compared between products, as well as in steady-state and transient conditions.

For this study the indenter was weighted with 64lbs ± 2.25lbs (just over 29kgs ± just over 1kg) which is the weight of this segment of the body for a 50th percentile male lying in bed supine. An artificial wound was created by covering all sweating pore holes not covered by the dressing pad; aluminised tape ensured no moisture evaporated outside the artificial wound area (Figure 2). This left an area of 7x7cm holes for moisture vapour; this was used for all dressings tested.

Figure 2. Indenter showing 7x7cm perforated holes covered with aluminised tape.

Figure 3. Indenter placed on a cushion.



Challenging dressings under these conditions provides a scenario that is clinically relevant because foams and polymers are compressed and moisture vapour escape is reduced by the actual use conditions of the test[14,15]. For example, temperature and humidity sensors are high accuracy digital sensors manufactured by Sensirion AG (Staefa ZH, Switzerland) which are accurate to ±1.8% at 0–80% relative humidity and ±0.3°C at 20–50°C. The test support surface was an open-cell foam cushion 3x18x18" (7.6x45.7x45.7cm) covered with a breathable liquid moisture-resistant mattress cover by Dartex Coating US (Slaterville, RI) and positioned on a rigid mattress board.

Moisture and humidity were supplied by a weighed amount of distilled water soaked into Enduracool™ Microfiber Cooling towels. This towel was chosen because the microfibre is a thermo-regulating technology with a moisture release rate compatible with previous published studies on LAL support surfaces[17,18]. In a laboratory setting, wound exudate is represented by distilled water. While the properties of each fluid differ markedly, the study is designed to demonstrate performance differences and this can be accomplished with a standard fluid. Previous publications characterising the moisture-handling capacity of dressings using this method provide a comparative baseline[12].

The wound model used here is not a highly exudating model; it is a water vapour model. This model delivers a low level of moisture to the dressing surface over a period of time in a controlled manner so that a researcher can determine if the moisture is bound to the dressing or transpires through it. Test dressings were chosen from conveniently acquired and commonly utilised multilayer dressings in the European Union and in the United States. The representative dressings are listed in Table 1.

The indenter was suspended over the cushion by an H-frame which was positioned around the bed frame at about the midpoint of the bed frame. The cushion was centred under the indenter so that the ischial tuberosity area of the indenter was located 10–15cm from the rear edge of the cushion (Figure 3). The indenter was set to 37°C. The weights of two dry sets of Enduracool™ towels were recorded, then 100±1g of distilled water was added to each towel set providing a potential for 200g to be delivered to the dressing. Each towel was folded in thirds and placed inside the indenter so that the towels covered all of the sweating pore holes. Heated weights were placed on top of the towels to facilitate moisture delivery.

Three sensors were placed to sense moisture escaping from the artificial wound area (Figure 4). Sensor locations were modified to accommodate the size of each dressing. The dressing was centred over the open sweating pore holes and

Figure 4. Placement of dressing and sensors over dressing.

covered all three sensors. Sensors placed outside the dressing lined up with those under the dressing (Figure 4). The indenter was lowered so that it settled on the support surface and transferred the full load of 64lbs ± 2.25lbs (just over 29kgs ± just over 1kg) to the support surface. A seventh sensor was used to measure ambient temperature and humidity. An EK-H4 Viewer program was set to log data at 30-second intervals through the test period.

To simulate a pressure release or patient repositioning, the indenter was raised from the support surface for 45 seconds at 3 hours ± 6 minutes. Readings were taken five minutes before the lift, identified as 175 minutes in the results section, to provide an air gap between the indenter and the support surface. It was held fully suspended from the support surface for a total of 45 seconds ± 10 seconds, then lowered back onto the support surface fully loaded for an additional 15 minutes ± 1 minute. Final readings are reported as 196 minutes in results.

At the end of the test the indenter was raised and the towels were removed and weighed. The dressing was removed from the indenter and artificial wound, and its weight recorded. The weight of a dry paper towel was recorded, the towel was used to wipe all moisture remaining in the indenter, and the towel was weighed again.

Between trials the indenter was allowed to return to steady state before the next trial was initiated. Distilled water was added to return the towels and the water mass back to the total weight of the dry towels plus 200±1g of distilled water. Two cushions and two covers were used; these were switched between trials to allow full recovery. A total of three trials were done for each dressing. Three trials were also performed with the indenter hanging in the air for 3 hours and 16 minutes without a dressing applied to measure the moisture vapour output of the artificial wound.

The final weight of the towels plus the paper towel was subtracted from the starting weight of the towels to ascertain the total amount of distilled water delivered to the system. Moisture absorbed in the dressing pad was calculated by subtracting the dressing initial weight from the dressing's final weight. The amount of water vapour produced from the system was calculated by subtracting the starting weight of the towels from the end weight of the towels and adding the moisture recovered from inside the indenter using the paper towel. The amount of moisture that evaporated the dressing was calculated by subtracting the amount of moisture trapped in the dressings from the amount of water vapour produced by the system. The 95% CI was calculated.

While the artificial wound size was constant throughout the study, the absorbent pads for the dressings varied from 41.8cm^2 to 121cm^2 (Table 1). As such, the total moisture absorbed and evaporated per dressing was calculated. Calculations for moisture absorbed and moisture evaporated were done on a per cm^2 basis as well to account for the variability in dressing sizes and to more accurately compare dressing performance. The average difference in temperature and humidity between the outside or cushion surface of the dressing and the inside or patient side of the dressing at 175 minutes and over the full length of the test was calculated by averaging the difference between the value over the dressing and the value under the dressing for each data point.

RESULTS

The aim of the study was four-fold, namely to measure: the amount of moisture absorbed; the amount of moisture evaporated through the outer layer; the humidity, both beneath and outside the dressing and the difference between the two; and the temperature, both beneath and outside the dressing and the difference between the two.

The amount of moisture each dressing absorbed is shown in Table 2. This shows the total moisture and the moisture absorbed in g/cm^2 per dressing as well as showing the average. The range of the SAF dressing group was 0.22–0.34g. The range of the SAP dressing group was 0.24–0.39g if the one outlier at 0.56g is not considered. The reference dressing was the smallest in area and absorbed the least by far. The range for six of the seven study dressings was 0.22–0.39g.

The amount of moisture evaporated (transpired or evaporated) through the outer polyurethane layer is also shown in Table 2 and in Figure 5. The range of the SAF dressing group was 3.9–5.4g, a difference of 1.5g, whereas the range of the SAP dressing group was 3.4–4.1g, a difference of just 0.7g. Indeed, six of the seven test dressings were within 0.7g of each other (range 3.4–4.1g). There was no significant difference among the dressings at a 95% CI.

In Table 2 it should be noted that the total amount of moisture delivered by the indenter was 5.9g. Adding together moisture absorbed and moisture evaporated shows that none of the dressings removed all of the moisture.

Figure 5 graphs the total amount of moisture absorbed and moisture evaporated in gcm^2 for each dressing. Figures 6a and 6b graph the moisture absorbed and the moisture evaporated per cm^2 arranged in order of size of the absorbent pad, from smallest to largest. As the dressing size increased, the amount of moisture absorbed and escaping per cm^2 appears to decrease, making the larger pads appear to perform more poorly. However, larger dressings have more area over which to absorb and evaporate moisture, and this graph is not standardised for wound and dressing size.

Figure 7 graphs the moisture evaporated per cm^2 per wound area. That is, the dressings are compared by using both a standard wound size – the area of the exposed holes in the indenter – and a standard amount of vapour across a standard area. When compared in this way, all dressings manage approximately the same amount of moisture according to their absorbent area.

The humidity, both beneath and outside the dressing as well as the difference between the two, was also recorded. Table 3 shows the average percentage of relative humidity at 175

Table 2. Moisture absorbed in absorptive pad and moisture evaporated per dressing in total g and g/cm² and averages of SAF and SAP.

	Absorbed		Evaporated		Total
	Whole dressing (g)	g/cm²	Whole dressing (g)	g/cm²	(g)
SAF dressings					
Mepilex® Border	0.22	0.0018	4.0	0.0332	4.23
ALLEVYN Life	0.29	0.0050	5.4	0.0926	5.64
Biatain® Silicone	0.34	0.0047	3.9	0.0537	4.22
Average SAF	***0.28***	***0.0038***	***4.4***	***0.0598***	***4.70***
SAP dressings					
Vliwasorb® Adhesive	0.39	0.0058	3.7	0.0562	4.12
Cutimed® Sorbion® Sachet Border	0.56	0.0056	4.1	0.0410	4.66
RespoSorb® Silicone	0.31	0.0028	3.4	0.0307	3.70
RespoSorb® Silicone Border	0.24	0.0048	3.4	0.0697	3.64
Average SAP	***0.37***	***0.0048***	***3.7***	***0.0495***	***4.10***
Control / reference point					
Cosmopor® E Sterile	0.04	0.0009	4.3	0.1027	4.30

minutes (before pressure release) and at 196 minutes (after pressure had been reapplied for 15 minutes, at test end) inside and outside the dressings, and the difference between the inside and outside dressings, by dressing and by group. At 175 minutes all humidity readings outside the dressings were above ambient (50%), indicating active transpiration across the polyurethane backings. The SAF dressing group had a higher average humidity both inside and outside the dressing than the SAP dressing group, but the difference between the inside and the outside of the two groups was similar, 11.4 and 12.2% respectively. The reference dressing had much higher humidity both inside and outside the dressing, with a difference of only 3.8% (Table 3 and Figure 8). At 196 minutes the SAF dressing group had higher average humidities inside and outside the dressing than the SAP dressing group, but the differences between the inside and the outside were greater in the SAF dressing group. The reference dressing had a very small difference between the inside and the outside (Table 3). Looking at the error bars in Figure 8, there were no significant differences among the dressings at the 95% CI.

The temperature, both beneath and outside the dressing as well as the difference between the two, was also recorded. At 175 minutes, the average temperatures of the SAF dressing group, the SAP dressing group, and the reference dressing were within 0.9°C. The SAF and the SAP dressing groups had larger differences in temperature between the inside and the outside of the dressings than the reference dressing (Table 4 and Figure 9). At 196 minutes the average temperatures of the SAF and SAP dressings both inside and outside the dressings were within 0.2°C of each other. The reference dressing was only slightly below the two groups (Table 4 and Figure 10). The range of temperatures inside and outside the dressings at 196 minutes was 33.1–34.3°C. The range of temperature difference between the inside and the outside of the dressings was 0.4–0.8°C. The negative control had a temperature difference of only 0.2°C. There were no significant differences among the dressings at the 95% CI.

DISCUSSION

This study measures the relative performance of dressings in a laboratory setting by comparing results at specific time points and averaged across time. While the 3+ hour test period is a small segment of time compared to the length of time that a patient normally wears these types of dressings, the test gives an indication of how they may perform relative to each other over longer times.

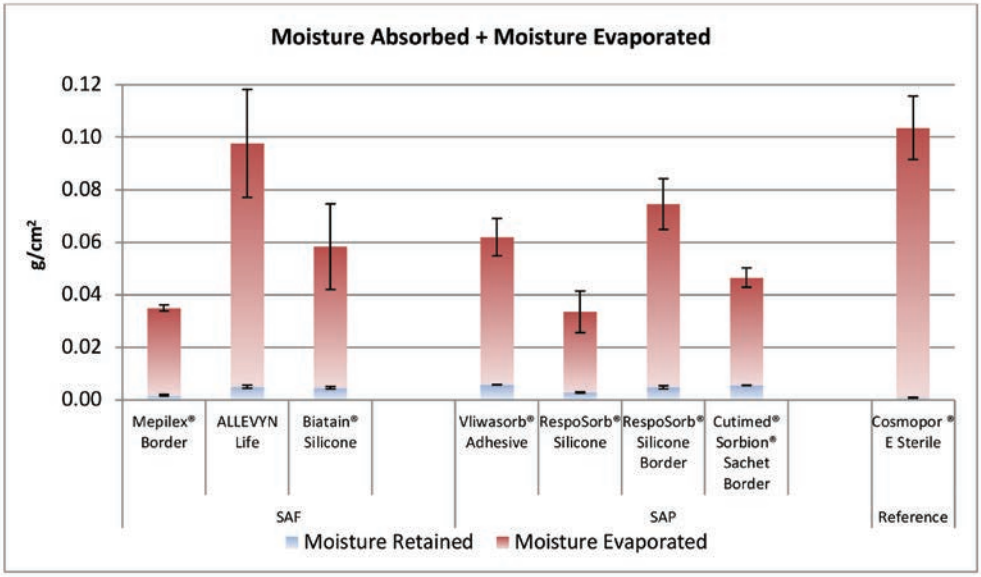
This method tested how dressings handle moisture from a low steady exuding of vapour. When the integument is compromised in a stage 2, 3 or 4 wound, the regulation of moisture vapour escape is compromised as well, adding to the moisture that a dressing must handle. Total vapour can compromise the integument and must therefore also be considered when evaluating dressings[6,19].

As expected, the more advanced SAF and SAP dressings outperformed the control/reference point basic island dressing in most categories.

Moisture absorbed and moisture evaporated

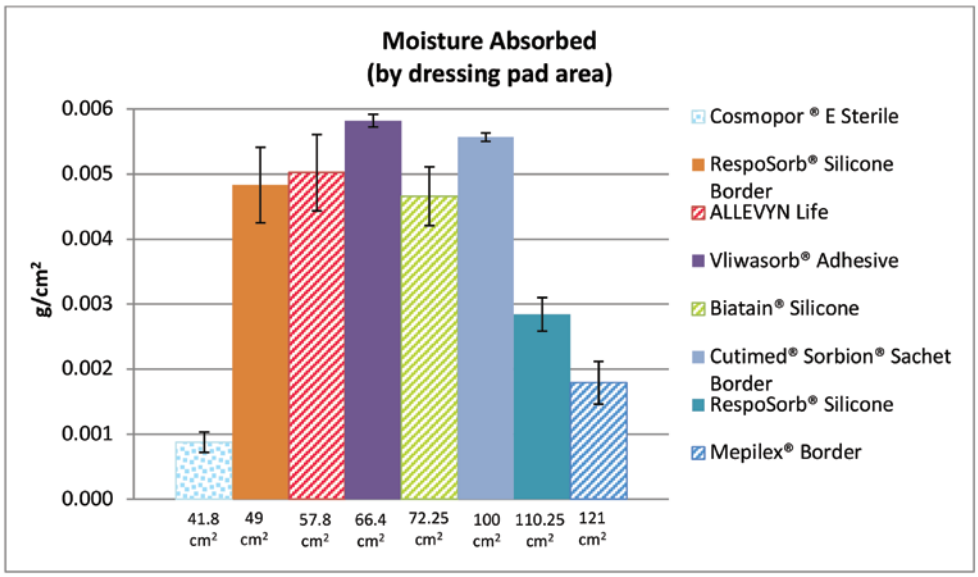
Both SAF and SAP dressing groups absorbed significantly more moisture in the pad than the reference dressing, indicating that their polymer materials absorb and lock in moisture and

Figure 5. Moisture absorbed and moisture evaporated per cm² added together showing 95% CI.



a) Moisture absorbed in g/cm².

Figure 6. Showing a) moisture absorbed and b) moisture evaporated by dressing pad area (shown on X axis in cm²). Results are arranged in ascending order of absorbent pad and dressing size.
SAF dressings are striped bars;
SAP dressings are solid bars;
Reference dressing is blue speckled.



b) Moisture evaporated in g/cm².

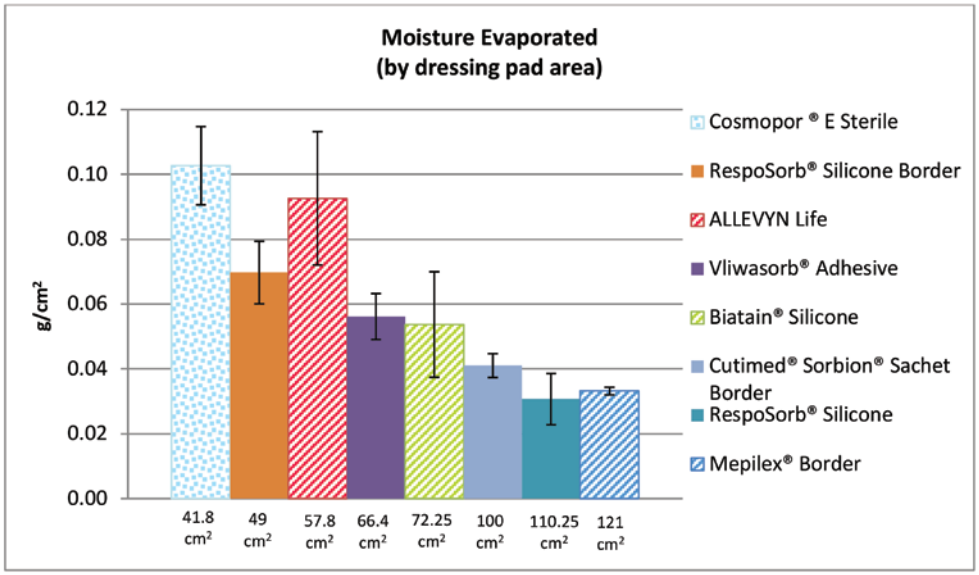
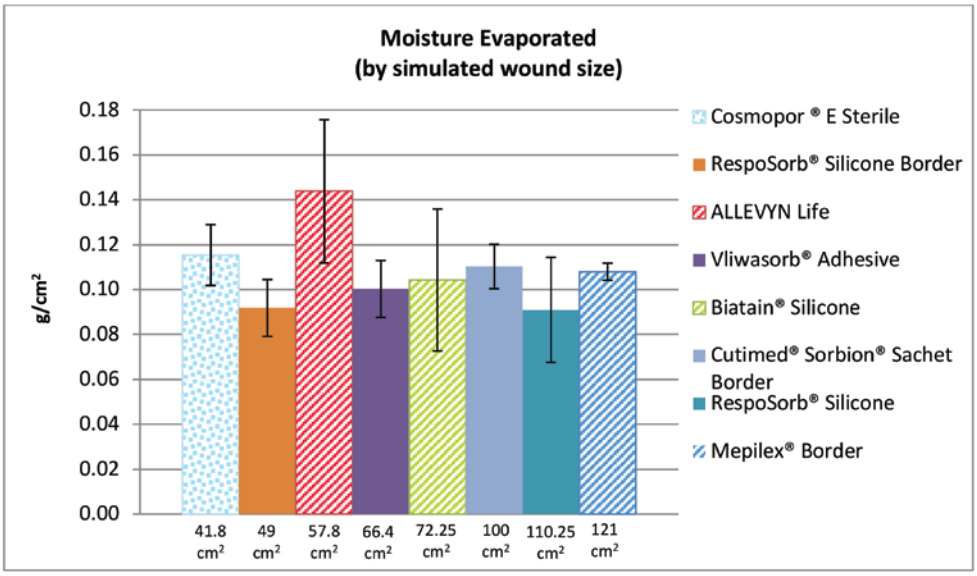


Figure 7. Moisture evaporated from each dressing in order of the size of the absorbent pad area.
SAF dressings are striped bars;
SAP dressings are solid bars;
Reference dressing is blue speckled.



prevent it from migrating to the periwound or the wound bed. Six of the seven advanced dressings absorbed between 0.24–0.39g, with one outlier absorbing 0.56g. Dressings are expected to absorb enough to prevent maceration of the wound bed but not so much as to dry it. In order to dry a wound, a dressing would have to absorb and transpire all of the moisture provided to it. None of these dressings did, therefore the total of the moisture for each dressing in Table 2 does not equal the total moisture delivered by the indenter, 5.9g. It appears from these results that the SAF and SAP dressings are adept at absorption and will not dry a wound that exudes at the moderate level of the test fixture. The ALLEVYN Life comes closest to absorbing and transpiring all of the fluid supplied.

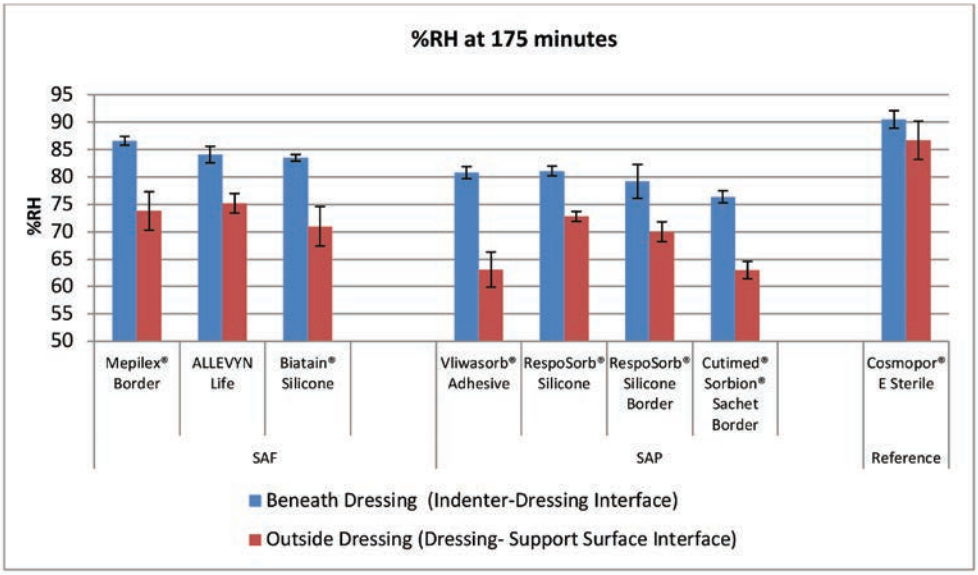
The same amount of moisture was delivered to all dressings. The smallest dressing had the least moisture absorbed and the most moisture which evaporated; this may be expected because the wound size was constant throughout, leaving the ratio of area of the artificial wound delivering the moisture to the area of the dressing that is available to transpire it dramatically greater for the larger dressings. Larger dressings are able to absorb and retain more, and the polymer locked in that moisture so that it could not – and did not – escape. Larger dressings can also spread and diffuse the moisture over a larger area.

The SAF dressing group, the SAP dressing group and the reference dressing were not significantly different in the amount of fluid that evaporated or transpired from the wound area at the 95% CI (Figure 6b). When moisture evaporated is graphed based on both moisture delivered and pad area in g/cm^2, the advanced dressings are very similar (Figure 7). Various sizes of dressing can affect results. However, when results are shown in g/cm^2 in order to compare various sized dressings, the differences are very small. This makes interpretation more difficult.

Table 3. Average percentage of relative humidity at 175 and 196 minutes.

	RH at 175 min			RH at 196 min		
	Beneath	**Outside**	**Difference**	**Beneath**	**Outside**	**Difference**
Mepilex Border	86.6	73.8	12.8	82.9	67.7	15.2
ALLEVYN Life	84.1	75.2	8.9	79.8	68.6	11.2
Biatain Silicone	83.5	71	12.5	79.2	66.2	14
Average SAF	***84.7***	***73.3***	***11.4***	***80.6***	***67.2***	***13.5***
Vliwasorb Adhesive	80.8	63.1	17.7	76	58.2	17.7
RespoSorb Silicone	81.1	72.8	8.3	77.7	69	8.7
RespoSorb Silicone Border	79.2	70	9.2	76.3	65.5	10.8
Cutimed	76.4	63	13.4	71.9	58.2	13.7
Average SAP	***79.4***	***67.2***	***12.2***	***75.5***	***62.7***	***11.7***
Cosmorpor (Reference)	***90.5***	***86.7***	***3.8***	***87.6***	***83.4***	***4.2***

Figure 8. Percentage of relative humidity at 175 minutes graphed with 95% CI bars.



This test was performed consistent with other testing – some published and some unpublished – where striking differences in moisture handling between advanced dressings were shown[6,12]. This has inspired manufacturers to improve their products and the polymers and vapour-permeable backings used in the dressings, possibly resulting in more uniformity in dressing structures and the similarity in apparent handling capacities among the tested dressings.

Humidity and temperature

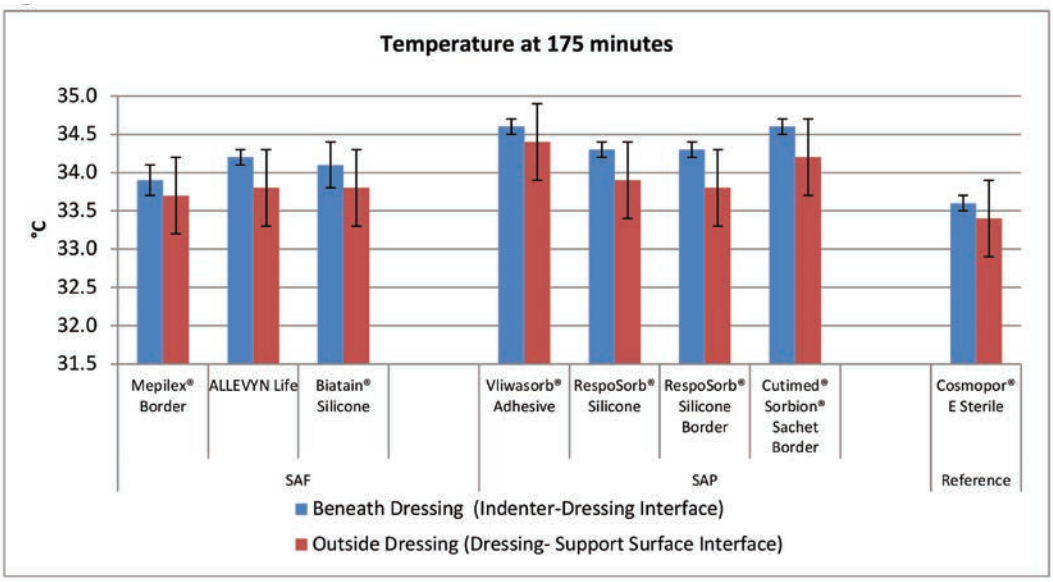
Specific temperature and humidity values defining the optimal microclimate conditions have not yet been determined by clinical nor laboratory research. Dressings are expected to keep the wound bed moderately warm and moist rather than too wet or too dry, too warm or too cool relative to the individual patient's normal subdermal or dermal body conditions and to the external atmosphere. Higher humidity and moisture levels may negatively impact the wound environment just as they weaken intact skin[1]. The SC is in equilibrium hydration at ambient humidity of 40–60% but absorbs water at disproportionately increasing rates above 60%[20–22]. Wildnauer's results show that relative humidity above 60% has the greatest influence in decreasing internal cohesive forces within the SC[23].

At 175 minutes, all dressings were above 75% relative humidity beneath the dressing with a range of 83.5–86.6% for SAF dressings and 76.4–81.1% for the SAP dressings. It is reasonable to consider these values as moist. Dressings with higher inside humidities – the SAF dressing group and the reference dressing at 90.5% – may be cause for concern in potentially over-hydrating the wound bed or periwound. At 175 minutes, all dressings also had lower humidity readings outside the dressing than inside, as would be expected. All of the humidity levels outside the dressings were higher

Table 4. Average temperature at 175 and 196 minutes.

	Temperature at 175 min			Temperature at 196 min		
	Beneath	**Outside**	**Difference**	**Beneath**	**Outside**	**Difference**
Mepilex Border	38.9	33.7	0.2	33.5	33.1	0.4
ALLEVYN Life	34.2	33.8	0.4	33.9	33.2	0.6
Biatain Silicone	34.1	33.8	0.4	33.9	33.4	0.6
Average SAF	***34.1***	***33.8***	***0.3***	***33.8***	***33.2***	***0.5***
Vliwasorb Adhesive	34.6	34.4	0.2	34.3	33.9	0.4
RespoSorb Silicone	34.3	33.9	0.3	33.7	33.1	0.6
RespoSorb Silicone Border	34.3	33.7	0.6	33.9	33.1	0.8
Cutimed	34.6	33.2	0.4	34.1	33.6	0.5
Average SAP	***34.5***	***34.1***	***0.4***	***34***	***33.4***	***0.6***
Cosmorpor (Reference)	***33.6***	***33.4***	***0.1***	***33***	***32.8***	***0.2***

Figure 9. Average temperature at 175 minutes graphed with 95% CI bars.



than ambient, indicating that the polyurethane backing does evaporate or transpire fluid. There was also a correlation between relative humidity beneath the dressing and moisture absorbed by the dressing pad. Lower moisture absorbed by the pad correlated with higher humidity beneath the dressing (Pearson's correlation coefficient = –0.83).

The complete release of pressure at 176 minutes suspended the indenter and the test dressing in air and allowed exchange of heat and moisture with the environment. Figure 11 shows the graphed results for one of the dressings, RespoSorb® Silicone, across the 196 minutes of the test. This is illustrative of a similar path seen for all dressings. Temperatures and humidities rose early in data collection, then temperatures eventually plateaued while humidities continued to rise. Both values dropped sharply when the indenter was lifted for the 45 second pressure release, then increased to or near pre-lift levels. It was impressive that a pressure release can have a rapid, measurable and significant affect on both heat and moisture which demonstrates the benefits of frequent position changes beyond addressing simply pressure and shear. Fifteen minutes after the pressure relief lift, at 196 minutes, all humidity levels were above 70%, with the reference dressing the highest at 87.6%. It appears that moisture vapour escapes more readily than it is trapped as, within 15 minutes of the lift, all values returned to the 175-minute levels.

Both dressing groups kept the wound bed relatively warm as indicated by lower temperatures outside the dressing than inside. This is conducive to wound healing as all were within the recommended 33–35°C range[7]. Yusuf et al.[24] reported that a skin temperature difference of only 0.3°C predicted pressure ulceration. While this measurement is not in a wound bed, it does indicate that small differences in skin temperature can relate to damage. The range of inside dressing temperatures among the dressings was 1°C at 175 minutes and 0.8°C at 196

Figure 10. Average temperature at 196 minutes graphed with 95% CI bars.

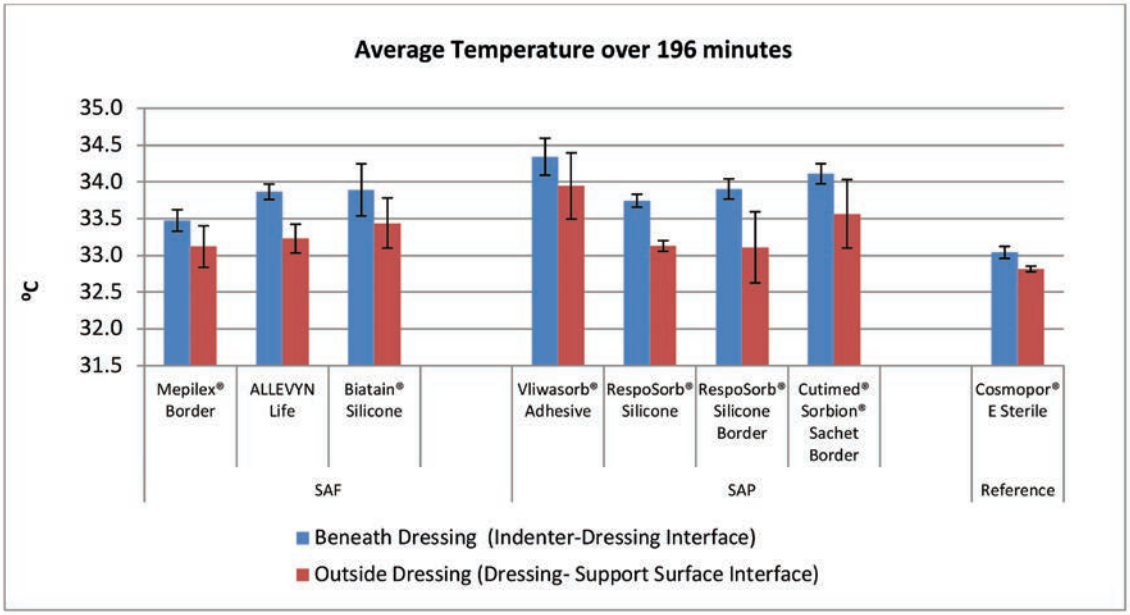
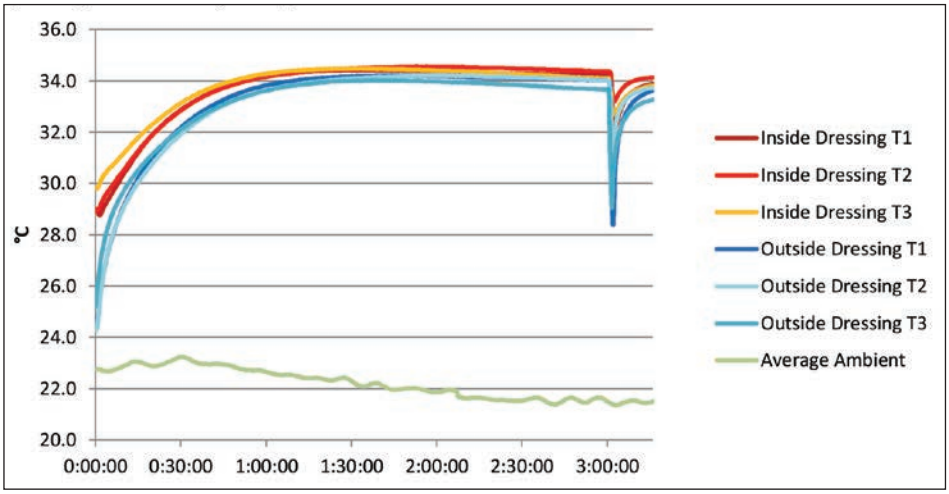
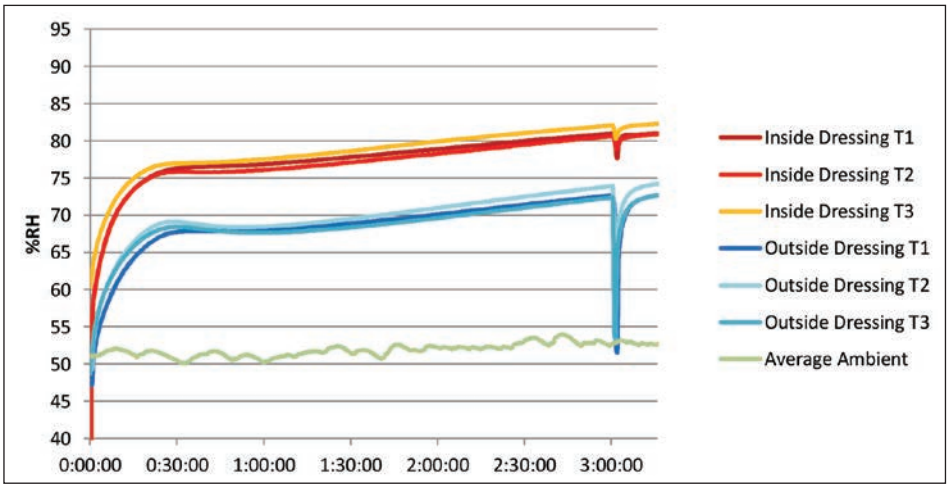


Figure 11. Trajectory of RespoSorb® Silicone testing as an example of a) temperature and b) humidity over test period time.

a) Temperature trajectory.



b) Humidity trajectory.



minutes, so these ranges could be problematic. While Yusuf's study does not prove causation, we need to be aware of a possible effect of temperature on tissue integrity.

Temperature differences are cumulative. The rate at which temperature drops after a pressure release could affect this accumulation. A small difference accumulated over time can make a large difference. The drops in temperatures at 175 and 196 minutes per dressing were greatest for both the RespoSorb® dressings.

Limitations

It would be of interest to perform this study on a heavily exuding wound model rather than a vapour-exuding intact skin model in order to examine the performance of the dressings under conditions in which they are normally used more accurately.

CONCLUSION

This in vitro study concludes that SAF dressings and SAP dressings appear to be equally competent in maintaining a warm and moist microclimate at the wound bed level to enhance wound healing. They absorb more moisture per cm^2 and evaporate or transpire more moisture than more basic dressings. The foam layer in SAF dressings does not appear to improve microclimate conditions at the wound bed over SAP dressings without the foam layer. Neither the SAF nor the SAP dressings dry the wound bed as the term superabsorber may imply. It was also shown that periodic relief of pressure markedly decreases temperature and humidity at the wound bed which enhances the function of the dressing and may increase wound healing.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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