Absorption of blood by moist wound healing dressings

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Abstract

An understanding of the various properties of the many dressings on the market enables the clinician to select the appropriate dressing product for the patient's wound. A comparative analysis of the ability of moist wound healing (MWH) products to absorb blood has not been previously reported. The aim of this study was to compare the rate and the maximal weight of blood absorbed, the ability of the dressings to retain blood within the dressing when under pressure, sheet integrity, and lateral wicking of the blood within the dressing. The MWH dressings tested included 12 'fibre' dressings (alginates and hydrofibre) and 15 'absorptive' (polyurethrane foams, hydroactive and combination products).

The most absorbent fibre dressings were Hydroheal Algin Firm, Sorbalgon, Cutinova Alginate, Kaltostat and Restore Calcicare, absorbing greater than 35g of blood per 100cm^2 dressing. The least absorbent was Aquacel with 21.5g/100cm^2. The integrity of the fibre dressings varied markedly from Sorbsan, which disintegrated, to Curasorb and Seasorb Alginates, which retained full strength. The rate of absorption of all fibre dressings was rapid (<18 seconds). Lateral wicking was least with Aquacel and greatest with Algoderm and Kaltostat.

The absorptive dressings showed a wide variation in absorptive capacity, from Flexipore which absorbed only 1.7g/100cm^2 to Allevyn which absorbed 79.9g/100cm^2 and Hydrasorb 79.4 g/100cm^2. Under pressure, Cutinova Foam retained the greatest amount of blood. Rate of absorption varied dramatically between products, with Polymem Alginate, Polymem, Exu-dry, Biatain and Hydrasorb all taking less than 1 minute to absorb 1ml of blood, whilst seven dressings showed incomplete absorption after 30 minutes.

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Introduction

Moist wound healing (MWH) products have now been recognised as excellent dressings in the management of both acute and chronic wounds. However, a comparative *in vitro* analysis of the ability of these products to absorb blood has not been previously reported.

Currently there are a large number of very 'similar appearing' dressing products on the market and thus it is extremely difficult for the clinically based nurse or doctor to choose the correct product for their patient's wound. Looking at the dressing profile should enable the clinician to make a more informed decision as to the appropriate dressing product for the job.

In certain clinical situations the absorption of blood by the MWH dressing is paramount. For example, in the acute traumatic wound, the chronic wound after sharp debridement

or on the split skin graft donor site. Alginate dressings are used to pack or cover the wound to aid in haemostasis, absorb blood and provide a MWH environment. More recently, polyurethrane foam dressings have been recommended for use on split skin graft donor sites as they absorb blood well, speed re-epithelialisation and reduce wound pain. They have also been recommended for use on acute wounds such as abrasions, lacerations and surgical wounds.

Our aim was therefore to examine and compare the rate and the maximal amount of blood absorbed by MWH dressings that have been recommended for use on bleeding wounds. We also looked at the ability of the dressing to retain blood within it when under pressure, the integrity of the dressing and the lateral wicking of the blood within the dressing.

Literature review – types of dressing

The MWH dressings tested fell into two groups: 12 'fibre' dressings (alginates and hydrofibre – Table 1) and 15 'absorptive' dressings (polyurethrane foams, hydroactive and combination products – Table 2). All products were readily available on the Australian market in August 2001, although two products, Hydroheal Algin Firm and Comfeel Seasorb, have been now withdrawn from the market. Comfeel Seasorb has been replaced by Seasorb soft, a combination of alginate and sodium carboxymethylcellulose. All products were recommended in their glossy brochures for use on wounds that were bleeding.

Fibre dressings

The characteristics of each alginate product is determined by the seaweed it is derived from, with differing ratios of D-Mannuronic and L-Guluronic acid of the alginate and the balance of sodium and calcium alginate within the dressing (Table 1). Alginates rich in D-Mannuronic form soft amorphous gels that disperse more in solution. Alginates rich in L-Guluronic acid tend to swell more in solution, whilst retaining their basic structure. On contacting blood, the calcium ions in the alginate are exchanged for sodium ions in the blood, increasing the solubility of the dressing i.e. gel-forming. Replacement of some of the calcium ions by sodium ions in the dressing has been proposed to accelerate gel

Table 1. Fibre dressing products tested. Product characteristics are determined by the seaweed they are derived from with differing ratios of D-Mannuronic and L-Guluronic acid and the balance of sodium and calcium alginate within the dressing. Alginates rich in D-Mannuronic form soft amorphous gels that disperse more in solution. Alginates rich in L-Guluronic acid tend to swell more in solution, whilst retaining their basic structure.

Dressing	Distributor	Acidic composition (100%)		Calcium alginate	Other	Physical construction
		Guluronic	Mannuronic			
Algisite M	Smith & Nephew	40%	60%	99%	1%	Patterned felt/needle bonded
Algoderm	Johnson & Johnson	58%	42%	99.4%		Non-woven fabric/needled
Aquacel	ConvaTec	-	-	-	100% sodium carboxymethyl-cellulose	Non-woven fabric/interlocked needling
Comfeel Seasorb*	Coloplast	N/A	N/A	N/A	N/A	Non-fibrous/polyethylene net, freeze dried
Curasorb	Tyco	68%	32%	100%		Non-woven fabric
Cutinova Alginate	Smith & Nephew	70%	30%	80%	20% pectin	
Hydroheal Algin Firm*	Faulding	70%	30%	91%	3% sodium alginate 6% alginic acid	N/A
Kaltostat	ConvaTec	60-70%	30-40%	80%	20% sodium alginate	Non-woven fabric
Restore Calcicare	Hollister	65%	35%	70%	30% sodium alginate	
Sorbalgon	Hartmann	N/A	N/A	99%	1% polysorbate	Fibrous mat
Sorbsan	Maersk	34%	66%	100%		Carded
Tegagen HG	3M	40%	60%	80%	20% sodium alginate	Non-woven fabric

*** Products have been taken off the Australian market**
N/A – Data not available from manufacturers

Table 2. Absorbent dressing products tested true foams which siphon fluid into their holes like a sea sponge in comparison to hydroactive dressings which absorb fluid into their structure and lock it away.

Product	Distributor	Dressing Type	Composition (inner layer/outer layer)
Allevyn	Smith & Nephew	Foam	Non-adherent contact layer/polyurethrane hydrocellular core/polyurethrane film
Biatain	Coloplast	Hydroactive	Polyurethrane foam/polyurethrane film
CombiDERM ACD Non-adhesive	ConvaTec	Hydroactive	Non-woven polypropylene/sodium polyacrylate particles + cellulose pad/hydrocolloid adhesive/ polyurethrane film
Cutinova hydro	Smith & Nephew	Hydroactive	Polyurethrane gel + sodium polyacrylate particles/ polyurethrane film
Cutinova foam	Smith & Nephew	Hydroactive	Foamed polyurethrane gel + sodium polyacrylate particles/polyurethrane film
Cutinova thin	Smith & Nephew	Hydroactive	Polyurethrane gel + sodium polyacrylate particles/ polyurethrane film
Exu-dry	Smith & Nephew	Absorbent pad	Polyethylene contact layer/rayon – cellulose pad/ polyethylene
Flexipore	Advanced Medical Solutions	Foam	Hydrophilic adhesive/polyurethrane foam
Hydrasorb	Tyco	Hydroactive	Polyurethrane foam
Lyofoam	SSL	Foam	Heat treated hydrophobic polyurethrane foam (hydrophilic)/hydrophobic polyurethane foam
Lyofoam Extra	SSL	Foam	Heat treated hydrophobic polyurethrane foam (hydrophilic)/hydrophilic polyurethane foam/ polyurethrane film
Polymem	Beta healthcare	Hydroactive	Polyurethrane foam + F68 surfactant + glycerin + starch/co-polymer/film backing
Polymem Alginate	Beta healthcare	Hydroactive	Polyurethrane foam + F68 surfactant + glycerin + starch/co-polymer + calcium alginate/film backing
Tielle light	Johnson & Johnson	Hydroactive	Textured EMA film/hydropolymer island/perforated EMA film/polyurethrane backing
Tielle	Johnson & Johnson	Hydroactive	Hydropolymer island/non-woven wicking layer/ polyurethrane backing

formation but may reduce its ability to activate the clotting cascade.

Blaine [1] in 1947 was the first to demonstrate experimentally that alginate dressings were haemostatic. Subsequent clinical reports were published [2] showing its use in casualty, dental surgery, ENT, gynaecology and neurosurgery. Calcium ions released from the dressing in exchange for sodium ions in the blood activates the clotting cascade by stimulating platelets and clotting factors. Groves & Lawrence [3] in 1986 reported the clinical use of an alginate as a haemostat on split skin graft donor sites. They showed that blood loss was halved compared to conventional gauze dressing. Attwood [4] in 1989 showed that the alginates significantly reduced the time to complete healing of split skin graft donor sites. Blair *et al.* [5] in 1988 showed that alginates were significantly better at stopping haemorrhage from experimentally induced liver lacerations in rabbits than surgical gauze, porcine collagen or oxidised cellulose. Blair 1990 [6] reported that the use of calcium alginate swabs intraoperatively, in comparison to gauze swabs, significantly reduced blood loss in mastectomies and cholecystectomies.

Thomas [7, 8], Johnson [9] and Ichioka [10] have all looked at the ability of these products *in vitro* to absorb deionised water, saline, a solution of sodium chloride/calcium chloride i.e. 'plasma' and 4.5% albumin. The results demonstrated differing performances of all the dressing products with

different test solutions. Kaltostat absorbed the most when tested with deionised water, whilst Sorbsan absorbed the most in saline or 'plasma' solution. Only one study by Groves & Lawrence [3] examined blood absorption by an alginate dressing (Sorbsan) in comparison to gauze. They concluded that the Alginate absorbed nearly three times as much blood as surgical gauze. The variability of fluid absorption with the test solution does not allow accurate extrapolation of a dressing's performance with these other test solutions to the performance of a dressing when absorbing blood.

The strength of the dressing also varies markedly with their chemical composition and manufacturing process. The differences between the dressings can be put to practical use in deciding on a dressing suitable for a particular application e.g. a soft, amorphous gel that may be irrigated away in a painful arterial ulcer versus single coherent sheet removal of packing after nasal surgery. Johnson [9] examined six alginates for tensile strength and found marked differences between the products. Sorbsan broke under its own weight, whilst Kaltostat had a wet tensile strength of 1.8NN/cm^2 and Sorbsan Plus 152.7NN/cm^2. Lateral spread was examined by Ågren [11] who compared four different alginates and found that wound fluid spread more laterally onto surrounding normal skin with Sorbsan than with Algosteril, Comfeel Alginate or Kaltostat after 24 hours.

Aquacel, the only non alginate fibre dressing in this group, is composed of 100% sodium carboxymethylcellulose. It acts by absorbing fluid into the fibres in comparison to alginates which retain fluid around the fibres. It does not have any haemostatic effect.

Absorbent dressings

Polyurethrane foam dressings have been shown in controlled clinical trials to provide excellent healing on split skin graft donor sites. Vaingankar *et al.* [12] showed that a hydrocellular foam (Allevyn) performed as well as an alginate (Kaltostat) in regards to healing, yet performed better in regards to patient comfort.

The absorptive capacity of these dressings for blood has not been examined. An in-house publication by Ferris MFG Corporation [13] looked at the rate of absorption and binding capacity of saline by several foam products in comparison to gauze. They found that there was a marked variance in rate and weight of saline absorbed by the different products. Polymem, Curaform and Hydrasorb absorbed the saline within seconds, Lyofoam and Allevyn took 1.5-2 minutes and Tielle took more than 5 minutes. The weight of saline absorbed varied from only 7.8g/in^3 with Lyofoam to 39g/in^3 with Tielle.

In this study, Sussman has subdivided polyurethrane dressings into two different types. There are the true foams, which siphon fluid into their holes like a sea sponge e.g. Allevyn and Lyofoam. The second group, termed hydroactive dressings, absorb fluid into their structure and lock it away e.g. Biatain, Cutinova foam and hydro, Tielle. Generally the hydroactive dressings adsorb water more rapidly and in greater amounts than the true foams. The hydroactive dressing does not release the water as readily from its structure when pressure is applied to it. Hydroactive dressings do not absorb cellular material as well as water. Thus, in the presence of blood, their performance may be altered. The composition of the various hydroactive dressings is quite different which may result in wide variation in dressing performance.

Method

Absorbency was tested as per the protocol described in the *British Pharmacopoeia*, 1995 [14]. A weighed (w1) 5x5cm piece of dressing material was placed in a Petri dish. The only exception to this was Tielle and Tielle Light where the dressing pad was only 5x3cm. Whole blood warmed to 37^{o}C was added, the volume corresponding to 40 times the weight of the dressing to the nearest 0.5ml. The blood used in this study was whole blood to which citrate phosphate double dextrose adenine anticoagulant, provided by the Red Cross Blood Bank, had been added.

The Petri dish was placed in the incubator and maintained for 30 minutes at 37^{o}C. Using forceps, the material being tested was suspended for 30 seconds by one corner and then reweighed (w2). The absorbency was calculated and expressed as the weight of blood retained (w2-w1) per 100cm^2 of dressing (100cm^2 is a sheet of dressing 10x10cm). This was repeated on five samples of each test dressing. The *British Pharmacopoeia* stated the test was to be repeated on 10 samples; however, in view of the large number of dressings being tested and taking into account the availability of human blood, five samples only were tested. Statistical analysis on the results confirmed adequate sample size and significance. The *British Pharmacopoeia* defines dressings that absorb less

than 12g of liquid per 100cm^2 as of low absorbency and dressings that absorb more than 12g per 100cm^2 as of high absorbency. One gram of blood was measured and was equivalent to 1ml of blood.

Absorbency after immersion in blood for 24 hours was also investigated. After being weighed at 30 minutes, the sample of dressing material was returned to the Petri dish and maintained for 23.5 hours at 37°C. Using forceps, the material being tested was suspended for 30 seconds by one corner and then reweighed (w3). The absorbency was expressed as the weight of solution retained (w3-w1) per 100cm^2 of dressing. This was repeated on five samples of each test dressing.

The diameters of all samples of absorptive dressings were measured (mms) at 24 hours to examine their degree of expansion with absorption of the blood. Absorptive dressings also underwent testing to examine their ability to retain blood under pressure i.e. a measure of how well the product locks away blood within the dressing and does not release it when the patient lies or sits on it. The 'squeeze test', was carried out where the dressing was squeezed with maximal grip strength (equivalent to 30kg measured with Jamar dynamometer) for 30 seconds and reweighed (w4). The weight of blood retained by the dressing was calculated w4-w1 per 100cm^2 of dressing. This was repeated on five samples of the test dressing. The squeeze test, though not a standardised test, provided extremely consistent results within each sample group.

Rate of absorption was tested by placing a 5x5cm piece of dressing in a Petri dish. One ml of whole blood was dropped centrally on to the dressing. The time taken for the blood to be fully absorbed and the maximal diameter of the spread of the blood (lateral wicking) was recorded. This was repeated on three samples of the test dressing.

Fibre dressings were observed for their ability to coagulate blood in the Petri dish and the retention of shape and strength (ability to tear the sheet apart when grasped by two pairs of forceps) after 24 hours of contact with the blood. Sheet integrity was defined as (Figure 1):

1 Loss of all shape and integrity.

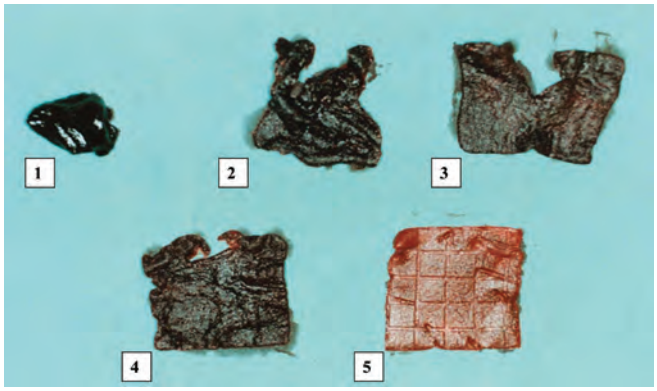
2 Severe loss of shape and integrity.

3 Moderate loss of shape and integrity.

4 Mild loss of shape and integrity.

5 No loss of shape or integrity/unable to be torn.

Figure 1. Fibre dressing integrity. Sheet integrity is defined in the text.



Statistical analysis

All analysis was performed using SAS version 8.015. Absorption time and blood retention were assessed for normality and then analysed using a one-way analysis of variance. Post-hoc pairwise comparisons were made using the Bonferroni method. A Spearman Correlation Matrix was performed to analyse any correlation between dressing properties and composition.

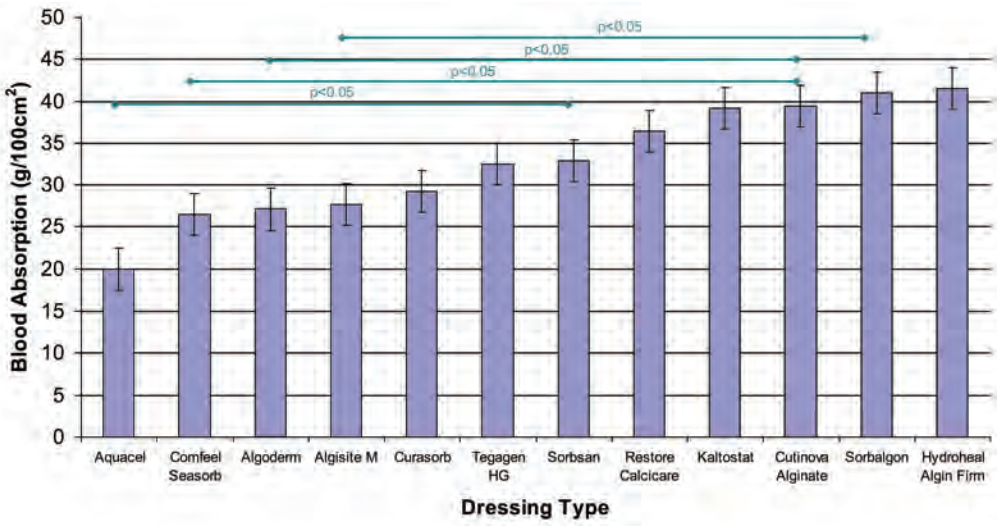
Results

The fibre dressings varied significantly in their mean absorptive capacities at 30 minutes (Figure 2). Aquacel dressing was the least absorptive dressing, absorbing 20.0g blood/100cm^2 dressing, whilst the most absorptive dressing was Hydroheal Algin Firm absorbing 41.5g/100cm^2. Other products that showed excellent absorption were Sorbalgon, Cutinova Alginate, Kaltostat and Restore Calcicare, all absorbing greater than 35g/100cm^2.

After 24 hours little change in the weight of blood absorbed by the dressings was recorded, most having reached peak absorption capacity by the 30 minutes. Only four dressings (Aquacel, Comfeel Seasorb, Algisite M and Curasorb) increased in weight by a further 1-9% at 24 hours. All the remaining dressings fell in weight by less than 6% except for Hydroheal Algin Firm, which reduced its weight by 13%, and Sorbsan, by 26%. The reduction in weight by Sorbsan was most likely to be due to dissolution of the dressing in the blood.

All alginates caused the blood in the Petri dish to clot despite the presence of an anticoagulant. Aquacel, Polymem Alginate and all absorptive dressings were not observed to cause any clotting of blood.

Figure 2. Absorption of blood by fibre dressings at 30 minutes. Significant differences in the performance of the dressings are shown. Data is presented as mean ± standard error.



The rate of blood absorption by all fibre dressings was very rapid. All products absorbed the blood within 2-5 seconds (Table 3) except for Aquacel, Sorbsan and Comfeel Seasorb. The rate of absorption with Sorbsan (17 seconds) and Comfeel Seasorb (18 seconds) were significantly slower than Aquacel ($p<0.05$). Aquacel (13 seconds) was significantly slower than the remaining alginates to absorb the blood ($p<0.001$).

The spread of blood (lateral wicking) in the fibre products tested was least with Aquacel (22mm) and Sorbsan (25mm) and greatest with Kaltostat (35mm) and Algoderm (38mm) (Table 4). Significantly less spread of the blood occurred with Aquacel (22mm) as compared to Sorbalgon (28mm) ($p<0.01$) and Sorbsan (25mm) as compared to Restore Calcicare (29mm) ($p<0.05$). The spread of blood was significantly greater with Algoderm (38mm) as compared to Hydroheal Algin Firm (32mm) ($p<0.001$), Kaltostat (35mm) as compared to Curasorb Alginate (30mm) ($p<0.01$), and Algisite M (33mm) as compared to Cutinova Alginate (29mm) ($p<0.05$).

Table 3. Comparison of rate of absorption with fibre dressings (mean rate of absorption of 1ml of blood into fibre dressing ± standard error).

Product	Rate of absorption (seconds)
Algoderm	2.3 ±0.7
Curasorb	2.7 ±0.7
Hydroheal Algin Firm	2.7 ±0.7
Sorbalgon	2.7 ±0.7
Cutinova Alginate	3.0 ±0.7
Tegagen	3.3 ±0.7
Algisite M	3.7 ±0.7
Restore Calcicare	4.3 ±0.7
Kaltostat	4.7 ±0.7
Aquacel	13.3 ±0.7
Sorbsan	17.3 ±0.7
Comfeel Seasorb	17.7 ±0.7

Table 4. Comparison of lateral spread and dressing integrity with fibre dressings. Lateral spread was the mean diameter of spread of 1ml of blood which had been absorbed by the dressing ± standard error (dressing integrity as defined in Figure 1).

Product	Mean diameter – lateral spread (mm)	Dressing integrity
Aquacel	22 ±0.7	3
Sorbsan	25 ±0.7	1
Sorbalgon	28 ±0.7	2
Tegagen	28 ±0.7	2
Cutinova Alginate	29 ±0.7	2
Restore Calcicare	29 ±0.7	2
Comfeel Seasorb	29 ±0.7	5
Curasorb	30 ±0.7	5
Hydroheal Algin Firm	32 ±0.7	3
Algisite M	33 ±0.7	3
Kaltostat	35 ±0.7	3
Algoderm	38 ±0.7	4

The fibre products differed with regard to their ability to retain their integrity after 24 hours' contact with the blood. Sorbsan disintegrated completely, whilst Curasorb and Comfeel Seasorb retained their square shape and could not be torn. The other products were intermediate in nature (Table 4).

The absorptive dressings varied significantly in their ability to absorb blood (Figure 3). The least absorbent dressings at 30 minutes were Flexipore which absorbed only 1.1g/100cm^2 and Cutinova Thin which absorbed 3.9g/100cm^2. The greatest absorption at 30 minutes was with Biatain (69g/100cm^2), Hydrasorb (76.5g/100cm^2) and Allevyn (79.9g/100cm^2). After 24 hours, Flexipore still had absorbed minimal blood (1.7g/100cm^2) whilst Cutinova Thin had increased its absorption to 20.7ml/100cm^2. The top absorbers at 24 hours were Lyofoam Extra (73.6g/100cm^2), Biatain (77g/100cm^2), Hydrasorb (79.4g/100cm^2) and Allevyn (79.9g/100cm^2).

The squeeze test revealed that with pressure, Hydrasorb retained only 19% of its original weight of blood, Lyofoam and Lyofoam Extra 20% and Allevyn 22% (Figure 4). Maximal retention was achieved by Cutinova Hydro 93% and Cutinova Foam 92%, with Tielle (78%) and Tielle Light (63%) also performing well. Cutinova Foam retained the greatest weight of blood 57.8g/100cm^2. Thus these latter products may be better suited to bleeding wounds that are going to be subjected to pressure upon them.

The mean rate of absorption of the blood for absorptive dressings was most rapid (less than 1.1 minute) for Polymem Alginate, Polymem, Exu-dry, Biatain, Hydrasorb and CombiDERM ACD (Table 5). A moderate rate of absorption was achieved for Lyofoam Extra (3.6 minutes). This was significantly slower than the Hydrasorb ($p<0.05$). Allevyn absorbed the blood in 11.7 minutes which was significantly slower than the Lyofoam Extra ($p<0.001$). All the other products showed incomplete macroscopic absorption of the blood by 30 minutes. If the blood is not absorbed rapidly by the dressing, it may pool beneath the dressing, increasing the likelihood of leakage from the sides of the dressing.

The mean diameter of spread of the blood for absorptive dressings was least with Allevyn, Hydrasorb and Exu-dry (23mm) and greatest with Lyofoam extra (41mm) (Table 5). The lateral spread of blood with Lyofoam Extra was significantly greater than with CombiDERM ACD ($p<0.05$) and other dressings with less spread. When the blood was not all macroscopically absorbed by 30 minutes, the lateral spread of the blood could not be assessed.

Figure 3. Absorption of blood by absorptive dressings at 30 minutes and 24 hours. Significant differences in the dressing products at 24 hours are shown. Data is presented as mean ± standard error.

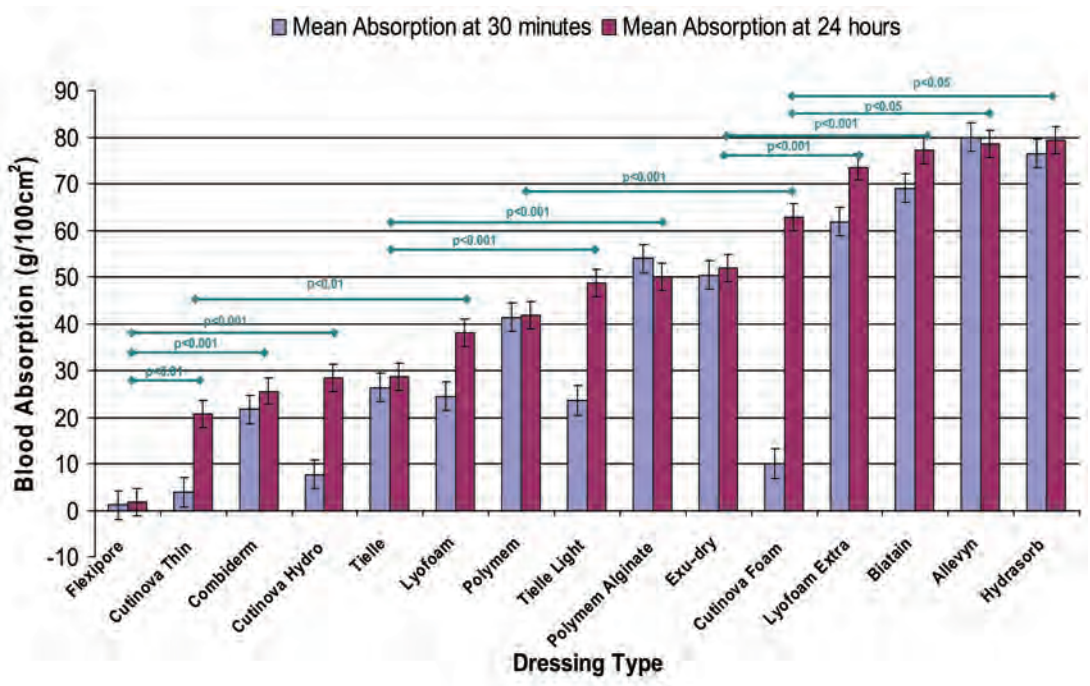


Figure 4. **Percentage of blood retained in the dressing after squeeze test performed at 24 hours. Significant differences in the performance of the dressings are shown.**

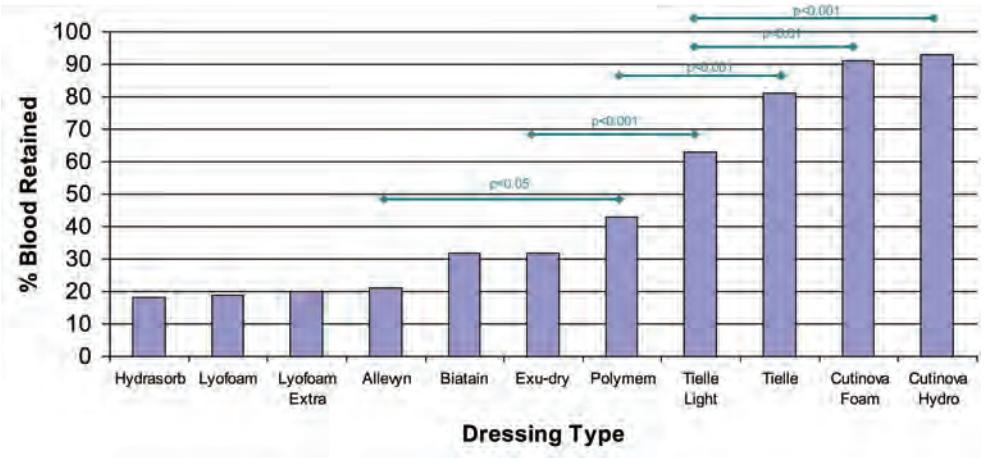


Table 5. **Comparison of rate of absorption, lateral spread and dressing enlargement with absorptive dressings. The mean rate of absorption varied significantly between the dressings. When reported as >30 minutes, incomplete macroscopic absorption of the blood was observed at this time.**

Product	Mean rate of absorption (minutes)	Mean diameter: lateral spread (mm)	Dressing size post 24 hours immersion (mms)
Polymem Alginate	0.07 ±0.5	26±1.9	n/a
Polymem	0.25 ±0.5	25±1.9	55
Exu-dry	0.33 ±0.5	23±1.9	n/a
Biatain	0.5 ±0.5	27±1.9	62
Hydrasorb	0.87 ±0.5	23±1.9	63
CombiDERM ACD	1.1 ±0.5	36±1.9	n/a
Lyofoam Extra	3.6 ±0.5	41±1.9	50
Allevyn	11.7 ±0.5	23±1.9	52
Cutinova foam	>30	n/a	65
Cutinova hydro	>30	n/a	55
Cutinova thin	>30	n/a	54
Flexipore	>30	n/a	n/a
Lyofoam	>30	n/a	50
Tielle	>30	n/a	60x30#
Tielle light	>30	n/a	72x43*#

*** With Tielle Light the inner layer only of the trilayer dressing expanded**
 # Dressing pads tested were 50 by 30 mm
n/a – Data not available as absorption was incomplete
Data reported as mean ± standard error

The foam dressings retained their original size when saturated with blood; however, the hydroactive dressings expanded by up to 20%, Hydrasorb, Biatain, Tielle Light and Cutinova Foam especially (Table 5). This may be a problem if the skin surrounding the wound was prone to maceration. The size of CombiDERM ACD, Flexipore and Exu-dry was not recorded.

Discussion

Absorption of blood by fibre dressings is quite different from 'plasma' (sodium chloride and calcium chloride) as defined

in the *British Pharmacopoeia*. Therefore it can not be reliably used as a model for the performance of these dressings in a heavily bleeding wound. Thomas [8] in 2000 reported his test results for the absorption of plasma solution by fibre dressings, as determined by the BP method. Seven of the products we have also tested in this series by the same test method except for the substitution of blood. All products absorbed a greater weight of blood than plasma solution. By ranking the products, Sorbalgon and Sorbsan showed relatively greater absorbency when tested with blood rather than with plasma, whilst Aquacel, Tegagen and Seasorb showed less. Kaltostat performed equally well with both plasma and blood.

Knowing the characteristics of the different dressing products will help with choosing the correct product for the specific wound. For maximal blood absorption with haemostasis in a heavily bleeding wound, fibre dressings with absorption over 35g/100cm^2 would be recommended. The products suggested by our testing include Kaltostat, Hydroheal Algin Firm, Cutinova Alginate, Sorbalgon and Restore Calcicare. This study did not compare the rate or adequacy of haemostasis between the products, but all fibre alginate products did achieve clotting of anticoagulated blood.

Another feature of fibre dressings to consider is their integrity in regards to ease of removal. Thus for a wound where there is a deep cavity or for nasal packing, one-piece removal is important. Curasorb or Comfeel Seasorb would be the best choice as they are unlikely to tear and leave residual pieces within the wound. The limitation with these two dressings is that they only have 'moderate' absorption of 25-30g/100cm^2. Thus for a wound with anticipated greater blood loss, a reasonable compromise would be Kaltostat or Hydroheal Algin Firm with greater absorbency and moderate integrity. In contrast, a painful arterial ulcer where irrigation of the dressing to remove it would be beneficial, the dressing recommended would be Sorbsan. In wounds where surrounding skin maceration is a problem, a dressing that showed the least lateral wicking would be recommended. Aquacel or Sorbsan would be the best choice.

Many companies claim that their products perform well because of their specific ratio of alginates or acids. A Spearman Correlation analysis was carried out to try and relate the chemical composition of the dressing to its performance. There was no statistical correlation between the percentages of calcium/sodium alginate or guluronic/ mannuronic acid in the dressing and the weight of blood absorbed by the dressing, the rate of absorption of the blood or the dressing integrity.

Generally, but not statistically, by reducing either the percentage of calcium alginate in the dressing or by increasing the percentage of mannuronic acid, the integrity of the dressing was weakened. Algoderm and Curasorb Alginate, which are both comprised of 100% calcium alginate and are low in mannuronic acid (32%-42%), showed excellent dressing integrity. Sorbsan, which has the highest percentage of Mannuronic acid (63%), gelled and disintegrated more rapidly than any of the other alginates.

Prediction of a fibre dressing's behaviour beyond this became difficult as products with similar chemical composition behaved differently. The physical construct/production technique varies between the alginates and this may also influence their behaviour. Tegagen HG and Algisite M, which are also high in Mannuronic acid (60%), retained greater integrity than Sorbsan. These products are all produced by different techniques (carded/patterned felt/non-woven fabric) which may explain in part their difference in behaviour. Comfeel Seasorb retained high integrity, presumably due in part to the inclusion of a polyethylene net within the dressing.

When an absorbent dressing is required for a bleeding wound, Allevyn, Hydrasorb, Biatain and Lyofoam Extra all provide excellent absorption of greater than 70g/100cm^2 at 24 hours. If the area is to be subjected to high pressure e.g. sacrum, then Cutinova Foam should perform well as it absorbs 63g/100cm^2 of blood plus it has the advantage that the blood is 'locked away' within the dressing. The possible downside with this dressing is that absorption is relatively slow. Thus if bleeding was rapid, leakage may occur from the edge of the dressing prior to its absorption. In an area subject to pressure, two other products, Cutinova Hydro and Tielle, should also perform well, locking blood away within the dressing. However the weight of blood absorbed by these products at 24 hours was less than 50% of that with Cutinova Foam.

If bleeding is relatively rapid e.g. the split skin graft donor site, then a product with rapid absorptive characteristics is required. Biatain and Hydrasorb fit this profile best, with a rapid rate of absorption combined with maximal weight of blood absorbed at 30 minutes and 24 hours. Lyofoam Extra and Allevyn were significantly slower at absorbing the blood but after 30 minutes had absorbed a similar weight of blood to Biatain and Hydrasorb. In the study published by Vaingankar *et al.* [12], Allevyn was

chosen as the foam dressing for comparison with Kaltostat for dressing the skin graft donor site. Because of the design of the study, a secondary dressing of gauze, wool and a crêpe bandage was used to hold both the Kaltostat and Allevyn in place and to absorb any leakage. Thus no conclusion can be drawn from this study on leakage rates or the subsequent need for repeated dressing changes. Further studies are required.

Ferris MFG Corporation [13] examined six foam dressing products that were also tested in our series for their ability to absorb saline. Once again, the performance of the products varied with the different test solutions. Lyofoam absorbed the least with both test solutions. Tielle and Polymem (hydroactive dressings) performed relatively better than the other foam dressings when tested with saline, whilst Allevyn performed better with blood.

Polymem Alginate, a combination hydroactive foam/alginate dressing, did not result in clotting of blood in the Petri dish as noted with the fibre alginate dressings. The addition of the alginate to polymem did increase its absorptive capacity from 41.3g/100cm^2 for Polymem to 53.5g/100cm^2 for the Polymem Alginate at 30 minutes.

In regards to the differing characteristics of the true foam dressings in comparison to the hydroactive dressings, the results varied dramatically between the products. When tested with water, hydroactive dressings absorb the water into their structure very rapidly; however, the presence of cellular material i.e. blood, may reduce the dressings' capacity to absorb rapidly. In our study, there was no correlation between the rate of absorption of blood by the dressing or the total weight of blood absorbed and whether the dressing was a true foam or a hydroactive product. Hydroactive dressings were amongst the best and the worst performers. Presumably this is a consequence of the quite differing composition of the hydroactive dressings.

The hydroactive dressings did 'lock away' the blood more effectively within the dressing than the foam dressings. Lyofoam, Lyofoam Extra and Allevyn, the three true foams, all performed poorly on the squeeze test and are thus not recommended for areas subjected to pressure.

The foam dressings did not expand when saturated with blood, whilst the hydroactive dressings increased in size by up to 20%. If the surrounding skin was prone to maceration, a foam dressing may minimise this problem. Allevyn would be the recommended product as it showed minimal expansion of the dressing when saturated with blood, combined with the least lateral spread of the blood.

Conclusion

By knowing the properties of the dressings, their absorptive capacity and integrity, a logical decision can be made on the appropriate dressing for the wound. In a area of rapidly developing technology and change, where the choice of wound dressing materials are overwhelming, hopefully this work will help you, the clinician, make a more educated and rational decision as to which dressing material should be used on the patient's bleeding wound.

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