Enhancing the Absorption Capacity of Multi-Layered Wound Dressing Materials Through the Use of Surface Deposited SAP

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INTRODUCTION

It is well recognized that exudate plays a key role in the natural healing process of wounds.[1,2] Exudate supplies the wound site with compounds essential for healing (e.g., nutrients, electrolytes, proteins, inflammatory mediators, growth factors, MMPs, etc.), aids in autolytic debridement of necrotic/damaged tissue, and provides a moist environment that facilitates cellular migration and proliferation. While vital to proper wound healing, too much exudate can also pose problems. Excessive exudate within the wound bed can expose the wound to elevated inflammatory cytokine levels and/or proteolytic enzymes, lead to maceration of the periwound skin, and promote bacterial growth. For those reasons, multi-layered absorbent dressings are designed to maintain a moist wound site while removing excess exudate. This commonly requires the use of a foam layer, non-woven spreading layer, and a super absorbent layer which can make the dressing bulky and less conformable. This study explores the use of a novel technique to surface treat the foam layer with SAP to improve absorption capacity and fluid retention of the material and the overall dressing.

A preliminary assessment of a polyurethane (PU) foam treated with the surface deposited SAP indicated that the treated foam exhibited a >25.9% increase in free-swell absorption capacity beyond that achieved by the untreated foam. Also, a subjective assessment of the flexibility/stiffness of the foam did not seem to indicate that the material was negatively impacted by the SAP coating. The purpose of this study was to conduct *in vitro* evaluations of foams that contain a surface deposited coating of SAP at two different loading levels and compare relevant liquid handling and mechanical properties of these test articles to an untreated control.

MATERIALS & METHODS

Test Articles

In this study, hydrophilic polyurethane foam material used in multi-layered absorbent dressings was coated with a polyacrylate-based SAP. During the coating process, granules of SAP were deposited on one surface of the PU foam material, along with a polymeric-based binder system using a proprietary deposition technique. A non-treated PU foam control along with two separate test articles containing different concentrations of SAP additive were evaluated in this study.

Table 1. Test samples examined in this study and a brief description of each sample

Sample	Description
Test article 1	Untreated control PU foam, no SAP additive
Test article 2	PU foam material treated with low loading of SAP additive
Test article 3	PU foam material treated with high loading of SAP additive

Fluid Absorbency

To assess the capacity of the test articles to absorb fluid from moderate to heavily exuding wounds, a protocol based on BS EN 13726-1:2002 was used.[3] In short, wound exudate was simulated by an aqueous test solution containing 142 mmol sodium and 2.5 mmol calcium as chloride salt (Test Solution A). A 5 cm x 5 cm sized portion of the dressing was cut from each test article, measured to determine the sample area (A) and weighed in a dry state (M_0). The test article samples were placed into separate petri dishes, and immersed completely in a volume of test solution, prewarmed to 37°C ± 1°C, that corresponded to 40 times the mass of the sample being examined. The test article samples in the petri dishes were transferred to an incubator and allowed to soak for 30 min ± 1 min at 37°C ± 1°C. At the end of the incubation period, each sample was removed from the test solution using self-tensioning tweezers to grip the sample by one corner and excess fluid was allowed to drip off for 30 s ± 5 s seconds. The dressing samples were then reweighed (M_t). Absorptive capacity was expressed as the mass of solution absorbed per 100 cm^2 and was calculated as follows:

$$Absorptive\ Capacity\left(\frac{g}{100\ cm^2}\right) = \frac{(M_t - M_0) \times 100}{A}$$

Fluid Retention

In order to assess the ability of the different test articles to retain fluid when under compression, a custom test was performed.[4,5] After carrying out the free swell test, each test article sample was placed onto a polypropylene perforated surface, with the patient contacting surface facing downward. A 7 cm x 7 cm Plexiglass compression plate was placed on top of the test article sample to help ensure homogenous pressure distribution over the entire sample. A pressure equivalent to the recommended compressive force used for venous leg ulcer compression bandaging (40 mm Hg) was applied to the test article sample using weights amounting to 1,350 g. After 1 min of compression, the test article sample was reweighed (M_r). Fluid retention capacity was expressed as the mass of solution retained per 100 cm^2 and was calculated as follows:

$$Fluid\ Retention\ Capacity\left(\frac{g}{100\ cm^2}\right) = \frac{(M_r - M_0) \times 100}{A}$$

In addition, the percentage of fluid retention was calculated by comparing the ratio of the fluid held after compression (M_r) to the absorptive capacity (M_t).

$$\%\ Fluid\ Retention = \frac{(M_r)}{(M_t)} \times 100\%$$

Conformability

The impact that the surface deposited SAP coatings had on the bending conformability (i.e., stiffness) of the treated foam material was determined by evaluating the bending length of each test article. Bending length was determined using a protocol based on the cantilever procedure described in EN 1644-2, Annex E. In short, 25mm x 200mm samples of each test article were cut. A Shirley stiffness tester was used to manually determine the overhang length of these samples, which were measured on the face and back of both ends of the samples for a total of four readings per sample. The overhang length was divided by 2 to calculate the bending length.

RESULTS

Figure 1. A comparison of the average fluid absorbency capacity and fluid retention capacity for each test article.

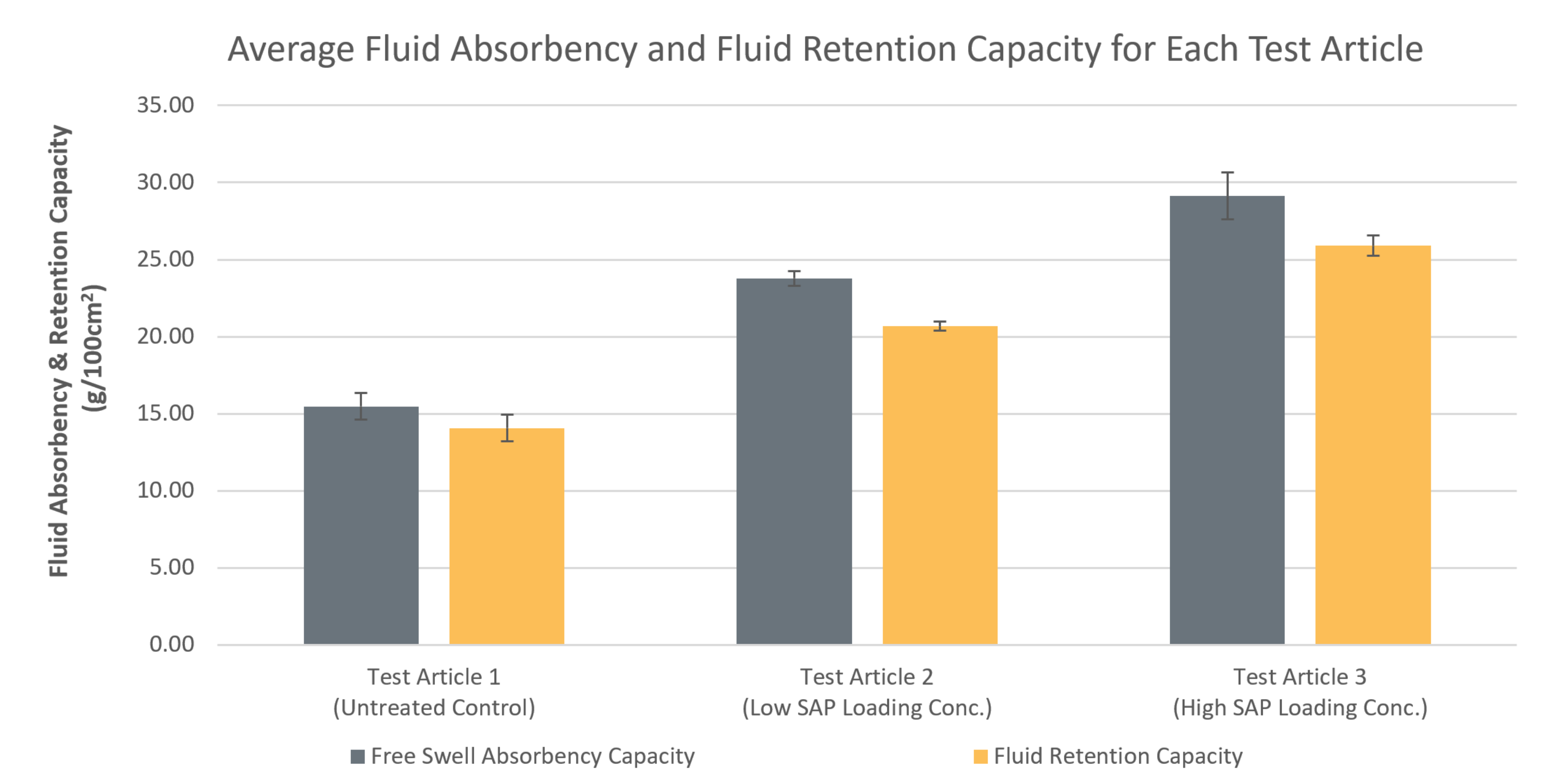

Table 2. The recorded bending length for each test article.

Sample	Overall Mean Bending Length (mm)
Test Article 1 (Untreated Control)	28.89
Test Article 2 (Low SAP Loading Conc.)	26.42
Test Article 3 (High SAP Loading Conc.)	29.00

Table 3. Summary of the average fluid absorbency, percent fluid retention, and conformability values for each test article and the percent change in those variables relative to the untreated control.

Sample	Fluid Absorbency		Fluid Retention		Conformability	
	Average Fluid Absorbency (g/100cm^2)	% Change in Fluid Absorbency (Relative to Untreated Control)	Average % Fluid Retention	% Change in % Fluid Retention (Relative to Untreated Control)	Average Bending Length (mm)	% Change in Bending Length (Relative to Untreated Control)
Test Article 1 (Untreated Control)	15.48	N/A	91.63%	N/A	28.88	N/A
Test Article 2 (Low SAP Loading Conc.)	21.50	+38.94%	92.06%	+0.47%	26.42	-8.53%
Test Article 3 (High SAP Loading Conc.)	29.12	+88.15%	90.80%	-0.90%	29.00	+0.42%

DISCUSSION

The untreated PU foam control was able to achieve an absorbency capacity of 15.48 g/100 cm^2. The absorbency capacity of the PU foam samples that were treated with a surface deposited SAP exhibited a notable and statistically significant increase in absorption capacity that was 38.9% and 88.2% greater than the untreated control for the foam with the low SAP loading ($p=0.0018$) and high SAP loading ($p=0.0009$), respectively.

Although the SAP coated foam samples exhibited a considerable increase in absorptive capacity, the percent fluid retention was shown not to be statistically different for the SAP coated samples at either the low SAP loading ($p=0.92776$) or the high SAP loading ($p=0.5352$), when compared to the untreated control. Additionally, the SAP coating did not appear to exhibit a significant impact on the conformability/stiffness at the highest SAP loading level ($p=0.7233$). There does seem to be a small, but statistically significant, decrease in bending length of the foam samples with the low SAP loading level when compared to the untreated control foam ($p=0.0005$). In summary, the SAP coating was able to confer a statistically significant increase in the absorbency capacity of the treated foam while still maintaining the same percent fluid retention and without negatively impacting the conformability of the material.

CONCLUSIONS

- The surface deposited SAP coating was able to significantly increase the fluid absorbency capacity of the PU foam material by up to 88.2%, compared to the untreated control.
- SAP treated PU foams exhibited the same level of fluid retention as the untreated control foam, approximately 90.8 – 92.1%.
- Conformability/stiffness of the foam was not negatively impacted by the surface deposited SAP coatings examined in this study.
- The proprietary deposition technique explored in this study provides a means by which the overall absorptive capacity of the foam layer in a multi-layered dressing can be significantly increased. This can consequently increase the wear times of the dressing, and/or eliminate the need for a dedicated super absorbent layer, which could improve conformability of the dressing by reducing the number of layers needed.

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