

WOUND DRESSING'S PHYSICAL PROPERTIES: AN IN VITRO ASSESSMENT

S.Mirel¹, A.Tănaşa, A.M. Iuonuţ³, V. Mirel², D. Pop Vornicescu³, D. Mureşan³, C. Gherman³

¹“Iuliu Haţieganu” University of Medicine and Pharmacy Cluj-Napoca, Faculty of Pharmacy

²National Institute for Research and Development of Isotopic and Molecular Technologies Cluj

³“Iuliu Haţieganu” University of Medicine and Pharmacy Cluj-Napoca, Faculty of Medicine

Abstract

Nowadays, the wound management techniques use modern materials, products which are different in composition and structure, but their essential characteristics are to facilitate wound healing. The objective of this study is to evaluate the “in-vitro” properties of some wound dressings present on European pharmaceutical market. The wound-dressing materials ability is given by the combination of the absorbency capability and moisture vapour transmitted in order to ensure an optimal wound moist environment. The results could predict the exudate absorption and the capacity control of the water loss from a wound in order to determine the ideal type of dressing required for different type of wound.

Key words: wound dressings; test method, absorbency, fluid handling capacity, water vapour permeability

1. INTRODUCTION

Materials used in wound care have changed in the past decades following the commercial availability of new wound care methods and dressings materials. From traditional products (dry bandages and dressings— e.g. cotton gauze, lint, viscose) to modern products (e.g. alginates, hydrocolloids, hydrogel, foam, films, etc.), the new trends of “active wound care products” with their ultimate goal - tissue engineering will be the future in the benefits of wound therapy (Harding et al. 2002, Boateng et al. 2008, Horken et al. 2009). If the traditional dressings provide protection of the wound from further trauma or bacterial invasion, the modern products (semi or occlusive dressings) provide an optimum moist environment, retain wound fluid that contains growth factors favoring rapid healing.

The advanced dressing technologies have been developed over the past few years by promoting a moist environment, in order to facilitate the healing of chronic wounds (Bishop et al. 2003, White and Cutting 2006). These products are permeable to oxygen and moisture vapour and impermeable to bacteria and maintain balanced hydration through controlled evaporation. The characteristics of the ‘ideal dressing’ have been described (Thomas 2008, Jones et al. 2006) and most of manufacturers refer to these when marketing their specific and adapting dressing products (Yudanov and Reshetov 2006). Generally, the new dressings can absorb the exudates while keeping the wound bed moist, decrease the healing time and the risk of infection, protect the periwound area and reduce the frequency and the need for dressing changes. For the health care professionals it is important to select the appropriate medical products with consideration to the key performance requirements of dressings according with the exudate management and cost-effective option.

The research must establish quantifiably methods that allow to determine which dressing materials are effective in facilitating wound healing. Several test-method have been developed and used in order to evaluate the properties of dressings materials. But the information about the comparative performance

and effectiveness of different type of dressings (hydrocolloid, foam, film, alginate) are limited because of the test methods' specificity to the individual product groups (Thomas 2001, Thomas 2005). There are also new products which combine diverse materials as films, foams, fibrous materials, hydrogels or hydrocolloid dressings (Iounuț 2008).

In a simple method, the absorbency is determined by a gravimetric test and is calculated by taking into account the weight of the dressings before and after immersion in water (Chen 2007) or in a salt solution simulating the serum and wound fluid (Thomas 2001). Other authors propose a spectrophotometric determination (immersion in picric acid solution, followed by elution and measurement of the absorbance at 355 nm (Betts 1988). The standard tests available for modern wound dressings determine the absorbent properties of dressings and include: fluid handling properties, moisture vapour permeability, fluid affinity, water uptake and gelling properties. Generally, the moisture lost through the dressing is determined by gravimetric analysis. These tests are based on official specifications (British and European Standards for Testing and Materials 2002) and accredited laboratories. All of this *in vitro* tests are developed under standard conditions. The test results showed that the physical properties varies between different products and this influence their behavior. But the success of wound management depends on selection and use of products, and also on the understanding of the healing process and the correct evaluation of the wounds (nature, type, location) and clinical environment.

2. EXPERIMENTAL PROCEDURES

2.1. Materials

Samples: The physical properties of three hydrocolloid dressings were evaluated: *Hydrocoll* (Hartmann), *DuoDerm Extra Thin* (Convatec), *Suprasorb H* (Lohmann & Rauscher). Each dressing product are dried samples cuted 5x5cm piece.

Test solution (A): solution of sodium and calcium chloride containing 142 mmol/L of sodium ions and 2.5 mmol/L of calcium ions (representing values typical of those found in serum or wound exudates). All reagents used were of analytical grade from Merck.

Device: The Paddington - Payne cup (our construction) was developed and tested at the National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-Napoca.

The experiment was performed at a temperature/humidity controlled (Ecocell drying oven). Weighing was performed on Ohaus analytical balance.

2.2. Methods

2.2.1. Absorption capacity

Experiment 1: The test was conducted in according to Standard EN 13726-1: 2002: Test Methods for primary wound dressings – Part 1: Aspects of Absorbency.

Each dressing sample is weighed (w_1) and placed in a Petri dish. The test solution (volume corresponding to 40 times the weight of the dressing) was added and maintained for 30 minutes at 37°C. After extracted and suspended for 30 seconds, the samples were reweighed (w_2). The absorbency was calculated and expressed as the weight of fluid retained ($w_2 - w_1$) per 100cm² of dressing.

Experiment 2: The test was conducted after immersion in test solution for 24 hours.

After being weighed at 30 minutes, the sample of dressing material was returned to the Petri dish and maintained for 24 hours at 37°C. After this, the material was extracted and suspended for 30 seconds and then reweighed (w3). The samples were reweighed (w2). The absorbency was expressed as the weight of solution retained (w3-w1) per 100cm² of dressing.

2.2.2. Fluid Retention Capacity

Experiment 3: Each dressing sample saturated with test solution for 24 h (w3) was press for 3 minutes with a strength equivalent to a pressure of 40 mm Hg (Thomas 2007). After the removal of the weight, the sample was reweighed (w4). The fluid retained by the dressing was calculated (w4-w3 per 100cm² of dressing).

2.2.3. Fluid Handling Capacity (FHC)

Experiment 4: The test was conducted using SMTL test TM-65, based on the method described in EN 13726-1:2002. Part. 1. Section 3.3.

Sample (same sizes, with known weight) from each dressing are applied across the opening of Paddington cup) to which are added 20 ml of test solution. The cup is closed (to prevent vapor loss except through the test sample), weighed and placed in an incubator at 37±0.4°C (in the presence of silica gel, in order to maintain a low relative humidity). After 24 hours, the cups are removed from the incubator, allowed to equilibrate to room temperature and reweighed. The loss in weight due to the passage of moisture vapor through the dressing is determined (g/10cm²). The weight of fluid retained by the dressing is calculated by difference, after the sample is reweighed. The tests were conducted over 24, 48 and 72 hours.

Experiment 5: The same measurements are made with the device placed in an inverted position (with the test solution in contact with the dressing).

2.2.4. Moisture Vapor Transmission Rate (MVTR)

Experiment 6: The test was conducted in according with methods described in BS EN 13726-2:2002. Part 2. Test methods for primary wound dressings - Part 2: Moisture vapour transmission rate.

Sample of each dressing (same sizes, known weight) is applied to a Paddington cup containing 20 ml of test solution. The cup is closed and then is placed in an inverted position (with the test solution in contact with the dressing in an incubator (at 37°C, in a presence of dried silica gel). The assembly was weighed at regular intervals of time and weight loss versus time plot was graphically represented. The MVTR is calculated from the mean loss in weight and the area of the opening in the top of each cup and the results were ex-pressed in water vapor loss over area for 24 hours (g/m²/24 h).

Experiment 8: The same measurements are made if the device is placed without the test solution in contact with the dressing).

Each experiment was done on 5 samples of each product dressing. The tests results are presented using the mean values and standard deviations.

3 RESULTS AND DISCUSSION

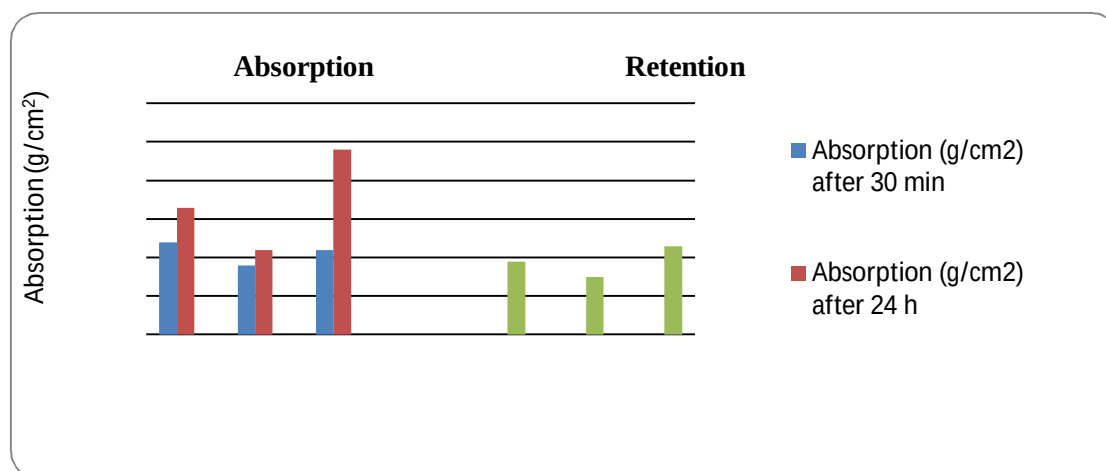
We selected 3 hydrocolloid dressings - the most required modern products on Romanian pharmaceutical market. Generally, the dressings physicochemical properties can be attributed to the hydrocolloid matrix contained carboxymethylcellulose (NaCMC), in combination /or no with gelatin, and pectin. They could also contain elastomeric, mineral oils and adhesive substances attached to their polymeric structure. On contact with wound exudate this matrix absorbs water and liquefies to form a

non-adherent gel, which accelerate the wound healing in a moist environment (Thomas 1997, Queen 2009, Iuonuț 2008)

One of the most important properties of a wound dressing is the absorption capacity. In the proposed in vitro experiments the absorbency is determined by a gravimetric test and is calculated by taking into account the weight of the dressings before and after immersion. The results tests are presented in fig.1. During the experiment 1 and 2, all the three products had shown a moderate absorption after 30 minutes, but after 24 hours the change in the weight of fluid absorbed showed that only *Suprasorb H* dressing increased significantly in weight (by double at 24 hours). It can be considered that *DuoDerm Extra Thin* have reached saturation by the 30 minutes.

The ability of a dressing to handle the exudates can be measured based on its ability to absorb and to retain exudat. Fluid retention capability method (experiment 3) was developed to assess the capacity of hydrocolloid dressings to absorb and retain exudate under compression (in order to evaluate the possibility of using the dressing under compression therapy). The retention capability of the dressing is the ratio between the absorption capacity under pressure and its free absorption capacity. The results (Fig 1) expressed as a percentage of the fluid retained after the saturated dressing was placed under pressure, had shown that *Duoderm* and *Hydrocoll* have the highest residual absorption capacity under pressure. In all cases, in comparison with the free state (without compression), the absorption capacity under pressure is reduced (by 50% for *Suprasorb H*, but by only 10% for *DuoDerm Extra Thin*).

Fig. 1. Absorption and retention capacity



These experimental tests are a simple, economic and reproducible, but not relevant to the clinical situation due to the fact that the wound-dressing ability to maintain a moist wound environment it is given by combination of the absorbency capability and moisture vapour transmitted.

The FHC test (experiment 4 and 5) measures the absorbency of a dressing and the total weight of moisture vapour lost (by transmission through the dressing) during the period of the test. The FHC value is defined as the sum of the weight of test solution retained by the dressing (absorbency) and the total weight of fluid lost (moisture vapor loss).

According to the existent standards, “the Paddington Cup test” regarding the FHC is carried without a direct contact between the test solution and the sample. Taking into account the fact that the modern dressing materials are usually placed directly on the wound, we conducted the experiment in both conditions (in or out of contact with the test solution). The results of the tests are presented in Tab. 1 are expressed graphically for Hydrocoll in Fig. 2.

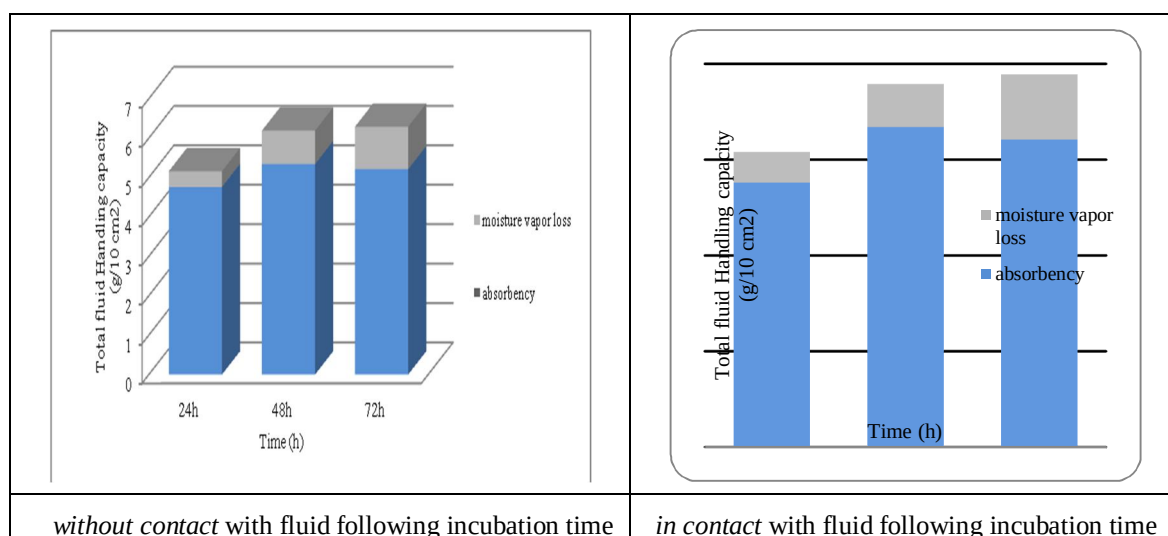
The absorbency capacity is reached after 24 hours, but the dressings continue to allow the passage of moisture vapor through the outer surface during the period of the test. As expected, it was observed that when the dressing was placed in the direct contact with the test solution, the dressing material ability to retain fluid got higher (almost double).

Table 1. Fluid Handling Capacity

Time	wound dressings	Absorbency ² (g/10cm ²)	Moisture vapor loss ² (g/10cm ²)	FHC (g/10 cm ²)
24 h	Hydrocoll	3,03 (0,14)	0,74 (0,10)	3,77 (0,21)
	DuoDerm Extra Thin	1,87 (0,19)	1,06 (0,09)	2,93 (0,18)
	Suprasorb H	4,13 (0,13)	0,55 (0,13)	4,68 (0,27)
48h	Hydrocoll	4,14 (0,12)	1,34 (0,08)	5,49 (0,17)
	DuoDerm Extra Thin	2,88 (0,16)	1,57(0,09)	4,44 (0,24)
	Suprasorb H	5,87 (0,25)	1,07 (0,08)	6,94 (0,21)
72h	Hydrocoll	3,87 (0,2)	1,84 (0,11)	5,71 (0,3)
	DuoDerm Extra Thin	3,65 (0,20)	2,01(0,18)	5,66 (0,15)
	Suprasorb H	5,91 (0,24)	0,94 (0,08)	6,84 (0,17)

*the results are the mean of 5 determinations (mean ± SD)

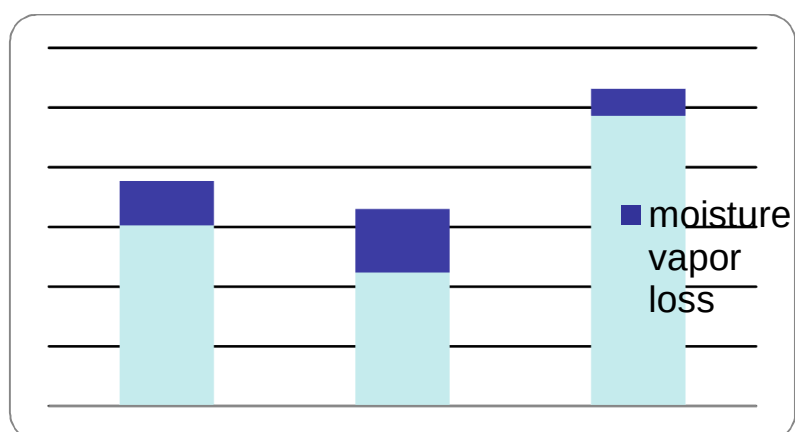
Fig. 2. Hydrocoll Fluid Handling Capacity



On the other hand, when the dressing was exposed only to the moisture vapor, the permeability continued to increase (especially in the case of *DuoDerm Extra Thin* and *Hydrocoll*).

These FHC values are determined by the product composition and structure. In accordance with manufacturer's description, *Hydrocoll* dressing is characterized by a hydrophilic base; gel-forming agents are sodium carboxymethyl-cellulose (NaCMC), with an outer covering of synthetic elastomer. In the case of *DuoDerm Extra Thin*, the hydrocolloid system consists of NaCMC, gelatin and pectin. It is considered that NaCMC can provide an instant absorbency of exudates, the pectin assures medium term absorbency, and the gelatin is the one who provides a long term absorbency. In the case of *Suprasorb H* the hydrocolloid system consists of NaCMC and gelatin, with the properties just mentioned above. This can explain the continuous increase of the absorbency capacity of *DuoDerm Extra Thin* and *Suprasorb H*. Furthermore, it had been shown that in the case of *DuoDerm Extra Thin* the moisture vapor loss increases significantly throughout the period of the test. The biggest capacity of absorbency belongs to *Suprasorb H*, but its permeability is not as significant as it is in the other two cases. Comparatively, after 24 hours, the behavior of the three types of dressings is presented in Fig 3.

Fig.3. Comparative Fluid handling capacity ($\text{g}/10^2$) of dressings



When applied a dressing, the exudate is absorbed into the dressing matrix, and following absorption, the exudate interacts with the dressing material to form a gel covering the wound. The gel remains absorbent until the hydrocolloids are saturated. The dressing becomes progressively more permeable and the loss of water through the dressing enhances the ability of the product to control the exudates production. Generally, it is considered that the dressing's ability to absorb wound exudates influences the frequency of dressing change. But, with the relevance for clinical practice, the MVTR values could determine the wear time of a wound product because the dressing will be changed according to the degree of exudation. MVTR measures the amount of water vapour lost through a dressing to the atmosphere from the wound bed over defined time periods (water vapour permeability).

Time related changes in moisture vapor permeability of the dressings were determined by MVTR test ((experiment 6) and the results of the experiments (in or out of contact with the test solution) are presented in Table 2.

The MVTR values are different between 0.55 and 3.4. If the MVTR value is low, it is considered that an exudate accumulation will occur with adverse effects on wound healing (being the cause of healing processes slowdown and opens up the risk for bacterial infections). Due to our values, the best results belong to *DuoDerm Extra Thin*, which has a very good permeability. In reported case, the MVTR

values explained the possibility to use the dressings under moderate exudating wound conditions and to maintain the all studied hydrocolloid dressings for 3-7 days.

Table 2. The moisture vapor transmission rate

MVTR (g/10cm ² / 24h)	Wound dressings		
	Hydrocoll (Hartmann)	DuoDerm Extra Thin (Convatec)	Suprasorb H (Lohmann & Rauscher)
	1.38 (0.26)	3.4 (0.19)	0.55 (0.36)

*the results are the mean of 5 determinations (mean ± SD)

The in vitro comparative data obtained regarding water absorption rate, air permeability and water transmission rate provide useful information on fluid handling abilities for these dressings, but is not always relevant to the clinical situation. Using laboratory tests, it is difficult to standardize variables that affect the wear time of dressings (the viscosity of wound fluid, the body temperature), the effect of the compression bandage applied, which could affect absorptive capacity and the dressing performance in clinical practice. In consequence, these “in vitro” methods must be correlated with the future “in vivo” tests, in order to explain the role of dressing will help with choosing the adequate product for the specific wound.

4 CONCLUSIONS

The role of occlusive dressings is to create and maintain a moist environment in order to facilitate wound healing. It is considered that the loss of water through the dressing enhances the ability of the dressing to cope with exudates production.

Three hydrocolloid dressings present in pharmaceutical market were studied for their ability to absorb wound's exudate and allow evaporation through the outer surface. An experimental design, using a modified standard method was developed and it involves direct and indirect fluid contact with the dressings in order to determine the total fluid handling capacity and the moisture vapor transmission rate. The results could explain how the equilibrium water content and water absorption determine the absorption of exudates and may be used to predict the exudate's handling properties and the dressing behavior in the clinical situation. The absorbance and permeability results of studied dressing explained their beneficial effects in the treatment of chronic wounds with moderate exudates.

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