This article was originally published in Wounds-UK Volume 6 Issue 2, 2010

PRODUCT FOCUS:

Hydrofiber® Technology: its role in exudate management

Matching dressing properties to wound requirements is a fundamental part of any good protocol of care, but the mechanics of exudate handling are complex and many factors need to be considered. This paper introduces these factors, giving examples of their effects in conjunction with dressing products and materials. It discusses one modern material (Hydrofiber® Technology) in more depth, using scientific and clinical evidence to illustrate how it has been engineered to retain many of the best attributes of traditional wound dressing materials, while addressing some of their shortcomings.

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Caring for and healing chronic wounds is often a long and expensive process. It has been estimated that the annual costs of wound care to the UK's National Health Service is in the region of £2.3–3.1bn which, according to figures for 2005/06, is equivalent to 3% of the total expenditure on health[1]. However, evaluating the true cost is difficult because it involves more than simply the price of a dressing. A wound care audit[2] (of approximately 590,000 members of a local population in the north of England) revealed that one person in 360 had a significant wound and that a relatively high proportion of these (24%) had wounds that had lasted for longer than six months. Another key finding of the audit was that around 80% of the total cost of care was attributable to factors not related to dressing costs but to wound complications (and delayed healing). In particular, the authors suggested: '…that seeking to reduce wound care cost simply by reducing the cost of dressings is likely to have a limited impact'.

Selecting an appropriate protocol of care is an important factor in achieving the best possible clinical outcome.

Selecting an appropriate protocol of care is an important factor in achieving the best possible clinical outcome. The protocol should include guidelines that ensure that dressing selection is based on scientific principles, including consideration of the type and condition of the wound and the dressing's attributes and performance characteristics[3]. However, this is not an easy task as no two wounds are alike, they may have complex anatomy and their behaviour can change rapidly. Therefore, the selected dressing needs not only to generate and maintain an environment that is conducive to healing, but also to respond and adapt to manage the changing demands.

ROLE OF DRESSINGS IN EXUDATE MANAGEMENT AND WOUND PROGRESSION

Since Winter's landmark paper on moist wound healing[4], it has been recognised that the control of fluid in the wound environment is pivotal. In a consensus document issued by the World Union of Wound Healing Societies (WUWHS), it was stated that dressings should have the ability to absorb and retain fluid, control its evaporation and transmission rates, while ensuring that there is sequestration of exudate's harmful components (eg proteolytic enzymes and bacteria)[5].

Dressings differ significantly in their fluid-handling characteristics. Matching these characteristics to the wound's exudate profile is important when trying to establish and

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maintain a moist wound environment[6]. The strength, rate and capacity of absorption, the rate of conversion of unretained to retained absorption (or retention), the rate at which absorbed and retained fluid can be lost by evaporation and how a dressing can modify the rate of exudate production, should all be considered.

POTENTIAL EFFECTS OF THESE FACTORS

Too vigorous absorption, for example one generated by a superabsorbent polymer, may desiccate the wound and result in the wound bed drying out and unwanted adherence to healing tissue[5]. If absorption is slow, such as that provided by hydrocolloid adhesive dressings, use on a heavily exuding wound will be inappropriate. The dressing adhesive will fail and unabsorbed exudate may cause maceration and wound deterioration. However, used appropriately on superficial and partial-thickness wounds (which tend to be dry or only lightly exuding), hydrocolloid dressings have been shown to be more effective in improving healing, reducing pain and levels of infection, when compared with dressings that have minimal fluid retention, eg gauze[7].

A dressing's absorption capacity is a compromise between conflicting needs. Insufficient capacity (for the level of exudate being formed and the dressing change frequency indicated) will result in leakage and maceration, requiring more frequent dressing changes[5]. Alternatively, a dressing with an excessive absorption capacity will be bulky and may become heavy before coming to the end of its useful life; this can lead to issues with fixation, change frequency and patient discomfort. Thin gauzes, films and waxy or oily dressings can fall into the former category, and thicker foams and gauze wadding dressings can fall into the latter[8].

Non-retained fluid can be defined as absorbed fluid that is still free to move within the dressing. This movement may be caused by capillary action, gravity or by variation in applied pressure, as generated by patient movement. While this may be a desirable feature in moving fluid away from the wound, if not controlled this will lead to strikethrough (which can compromise any barrier function of the dressing), leakage and maceration of the periwound skin. Non-retained fluid is a feature of dressings such as gauzes, foams and slow gelling alginate dressings; the common feature being that they all use macroscopic physical spaces to hold fluid *(Fig 1)*[9].The shortcomings of this method of fluid management are that these spaces are interlinked, thus providing continuous channels through the dressing, and that these spaces can be reduced in volume when compressed, which can cause further uncontrolled leakage as fluid is released from the dressing[10].

Retention is usually achieved by transferring fluid from the macroscopic physical spaces into the molecular structure of the dressing material. This effect is observed as gelling in hydrocolloids, alginates and dressings that contain Hydrofiber® Technology (HT) *(Fig 2)*. In such a gelled state,

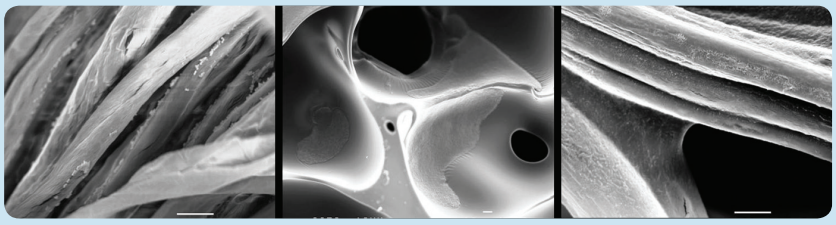

Figure 1 – Scanning electron micrographs (SEMs) of wound dressings whose structures show minimal or no change after a short period of hydration. Left: gauze; centre: foam; right; alginate. Bar = 10µm in each picture.

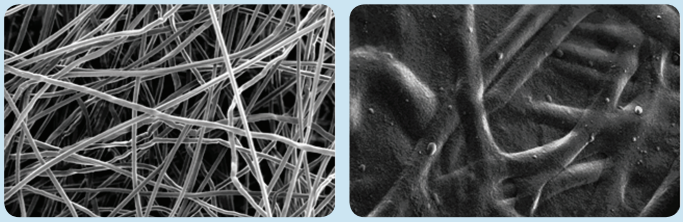

Figure 2 – SEMs of an HT dressing. Left: dry; right: hydrated, showing significant fibre swelling. Bar = 100µm.

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the water component of a fluid becomes lightly bound to the chemical structure by a force known as hydrogen bonding. Hydrogen bonding prevents free flow of fluid through the dressing but retains a moist environment. Fluid in normal (healthy) skin tissue exists in this same 'bound' state[11]. Gels of this nature (mostly water) are non-adherent to wound tissue and non-irritating – a good practical example of this is the modern soft contact lens, which is approximately 50% water[12].

The rate of gelling is a differentiating factor between hydrocolloids, alginates and HT dressings. In hydrocolloids, gelling is limited by the speed at which fluid can diffuse through the adhesive matrix and the rate at which this can expand[12]. Although these effects can be modified in hydrocolloids by the level, size and composition of the hydrocolloid particles, the process is generally regarded as slow (hours or days)[12]. Alginate gelling is also relatively slow and relies on the type of alginate and level of calcium[14]. The removal of calcium from the alginate allows more rapid gelling but progressively weakens the gel structure and can ultimately lead to liquefaction and the loss of all retentive properties[9,14]. In HT dressings, the gelling process occurs within seconds, but gel strength is maintained and not continuously reduced, with the fibres remaining insoluble[10].

Gelling dressings are capable of moderating the rate of exudate production by a process known as gel blocking. Gel blocking progressively reduces the strength of absorption forces and, when approaching the maximum retention capacity, resists further transmission of fluid through the gel[10]. Dressings with HT have a strong initial absorption but, because the gellation process is so rapid, retention and gel blocking quickly come into play slowing down the spread of absorption and thereby preventing undesirable lateral wicking[10]. As alginates have a slower rate of gelling, extensive lateral spreading can occur which subsequently increases the risk of maceration[9]. Despite the slow rate of fluid absorption in hydrocolloid dressings, gel blocking combined with the elastic properties of the adhesive, can have an effect on the rate of exudate formation[15]. Accumulating retained fluid can cause a slight increase in the local pressure over the wound bed and its leaking blood capillaries. This pressure lessens the difference between the internal blood system and the atmosphere, thus reducing one of the main driving forces for exudate production[6].

Evaporative loss (moisture vapour transmission rate [MVTR]) can be used to modify dressing fluid-handling behaviour. With highly exuding wounds, a high MVTR can increase the total fluid-handling capacity, which may extend the lifetime of that dressing[5]. On the other hand, for lightly exuding wounds, dressings that have a low MVTR have shown the provision of a moisture retentive environment is favourable to improving rates of wound healing[16]. For non-retentive dressings such as open foam and cotton gauze, the MVTR is uncontrolled and is typically very high[17]. In this case, better control can be gained by the addition of a secondary dressing or backing such as a semi-permeable film. Films tend to work at a fixed rate and therefore control is still fairly crude. For retentive dressings the binding of moisture into the gel structure also reduces the rate of evaporative loss. The rate of moisture loss from a gel is a function of the degree of hydration; therefore, it is slow at low moisture content but increases as the dressing approaches saturation[17]. This effect is likely to lead to a more balanced moist wound healing environment, as failure to control exudate could result in maceration, or drying out of the wound surface. Optimising fluid retention is a key aspect in determining overall wound dressing performance[17].

Finally, dressing components can be combined, for example, placing a retentive layer in contact with the wound (to provide a moist, non-adherent environment), a non-retentive high MVTR layer behind it (to handle excess exudate during peak flow) and backing this with a semi-permeable film (to reduce the risk of adherence)[6]. Many modern wound care dressings are just such combinations.

In summary, fluid handling is not simply a matter of increased absorption capacity. It is a much more complex and dynamic problem. Ideally, a care-giver or clinician requires a dressing that can combine the above properties, as well as having the ability to adapt its behaviour during use, thereby ensuring that an optimum moist environment is maintained.

HYDROFIBER® TECHNOLOGY AND THE CHALLENGE OF WOUND EXUDATE

Hydrofiber® Technology (HT) is based on an innovative sodium carboxymethylcellulose hydrocolloid fibre material. It was specifically developed for wound care to encompass

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Provide excellent exudate management by rapid absorption[10]
Absorption force is not overly strong because of gel blocking[10]
Maintain moisture balance in both acute and chronic wounds[6]
Reduce risk of maceration[18]
Reduce risk of wound infection[19,20]
Help balance the inflammatory response[21]
Minimise dead space where bacteria can grow[21]
Reduce pain on removal[22]

Table 1 – Properties of HT dressings

the desirable attributes of more traditional dressing materials such as cotton gauze, alginates and foams, and to improve aspects of exudate management *(Table 1)*.

The starting material is a highly refined form of cellulose which has been drawn into near perfect fibres by a process similar to that used for alginates. In wound care we often encounter fibrous cellulose in its more natural form as cotton gauze. Although cotton is a versatile material, it lacks any significant absorbency or the ability to retain fluid[23].This is because the physical spaces in cotton fabrics are easily compressed and, at a molecular level, the cellulose fibres are tightly bound together and are thus impermeable to moisture.

In HT dressings, changes to the macroscopic fibre structure and, at the molecular level, the introduction of routes for moisture permeability and fibre gellation, ensure that improvements in both the absorption and retention properties are achieved. A carefully controlled number of sodium carboxymethyl groups are introduced into the molecular structure of the pre-formed fibres allowing sufficient cellulose characteristics to be retained that provide strength, while the addition of the carboxymethyl groups allows fluid to rapidly permeate and fully expand the fibres. The result is a coherent gel that resists wicking within the fibres and prevents wicking between fibres by gel blocking. An *in vitro* study has shown that the nature of the binding within the gelled structure ensures that fluid is retained and locked in the dressing even under compression[10].

Consequently, HT dressings provide hydration properties that differentiate them from other currently used fibrous dressing materials[8]. These engineered physicochemical properties have resulted in a range of HT-based products that exhibit gelling action. This action has not only brought about better fluid handling, but has also produced many other related improvements in the management of the wound environment, for example, the locking away of harmful wound components such as bacteria and proteolytic enzymes[19,21,24,25].

Wound exudate is a complex and variable fluid but, in general, it has a base of serous liquid which is approximately isotonic and has a large percentage of water. Bacteria and wound tissue cells that have been stimulated by trauma both release potentially damaging enzymes such as matrix metalloproteinase and elastase. In an acute wound, the amount of these components present is under the control of the normal healing mechanisms and will diminish as healing progresses. In a chronic wound, this mechanism is not functioning correctly and levels remain high, therefore the removal of such potentially harmful substances from the wound environment is an important factor in helping the wound to heal[21]. Chronic wound exudate transferred onto the periwound skin can lead to maceration, further wound breakdown[18], and subsequent alteration of normal skin barrier properties[26].

The ability of a wound dressing to absorb and retain exudate, allows a dressing to remain in situ for longer, therefore reducing the frequency of dressing changes and improving cost-effectiveness[22]. Non-retentive dressings can be prone to leakage and this can be exacerbated by concomitant treatments such as compression therapy in the management of venous leg ulcers[15].

The rapid absorption of wound fluid and its conversion to retained fluid within a cohesive gel structure gives HT dressings the ability to lock in the liquid and the harmful components that are contained within it[20,25]. Components such as endogenous proteinases and exogenous bacteria, found in wound exudate, are effectively removed from the wound surface, thus reducing the likelihood of transmission onto the surrounding skin. Consequently, the trapping of liquid and harmful components inside the dressing helps to prevent them from reaching the surface of the wound which, in turn, is likely

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to lead to 'a much more gentle healing process without excess inflammation'[21]. This is thought to be the result of the migration of polymorphonuclear leukocytes (PMNs) into the HT dressing, where they remain viable and active[21]. This effectively helps to provide a physical separation of macrophages from PMNs, thereby allowing the former to operate in a repair mode as stimulation from the latter is reduced[21].

The slower rate of gelling and gel blocking of alginate dressings can lead to fluid moving along the fibres by capillary action, and this can lead to a greater liquid spread[9]. Consequently, wound fluid and its harmful components are less likely to be retained within the dressing[19,24]. An *in vitro* study has shown that dressings containing HT retained significantly more bacteria, eg up to 70% of both *Staphylococcus aureus* and *Pseudomonas aeruginosa*, compared to 7–12% and 32–41% respectively for two alginate dressings ($p<0.05$ for both)[19]. A further *in vitro* study has shown bacteria immobilised between individual fibres in a HT dressing[20] *(Fig 3)*, while an *in vivo* study using an infected animal wound model showed greater (<0.05) sequestration of bacterial populations of *P. aeruginosa* and *S. aureus* within a HT dressing compared to alginate dressings[24].

Gauze dressings are even more vulnerable to these effects, as no gel-like structure is formed. The consequences of a lack of retention has been demonstrated by a previous study in which it has been shown that upon gauze dressing removal, there was airborne dispersal of bacteria[27]. Similarly, foam dressings can only absorb fluid. Harmful components such as bacteria may collect within the spaces of the dressing structure *(Fig 1, centre, page 28)* and, if these dressings are placed under pressure, fluid and its harmful components may be released and leak from the dressing[8].

The base of a wound rarely provides a flat or even surface; in particular, chronic wounds have a unique topography *(Fig 4)*. As previously indicated, the control of moisture (particularly at the wound surface) is a crucial factor in providing optimal conditions for healing. Dressings that cannot adequately conform to the contours of a wound surface will leave voids where fluid may collect, this is often referred to as 'dead space'[28]. Within these dead spaces, the collected fluid can move freely between the dressing and the wound surface and provide a focus for the accumulation of bacterial populations and enzymes. Examples of dressing types where the intimate contact with a wound surface is less likely are those that are made from plastic materials (such as polyurethane or polyethylene) and composite dressings where the combination of layers results in rigidity. The structure of these non-retentive non-gelling dressings leads to alternating regions of textured and open spaces *(Fig 5)*. Some plastic foams expand as they absorb fluid, and, depending on how the dressing is affixed, this results in the dressing losing

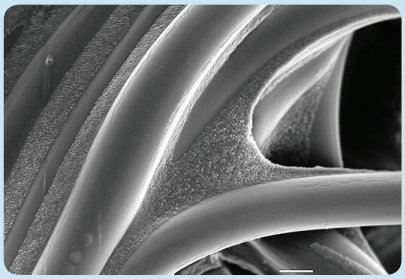

Figure 3 – Scanning electron micrograph of gelling HT fibres showing immobilisation of* Staphylococcus aureus. *Bar = 10µm.

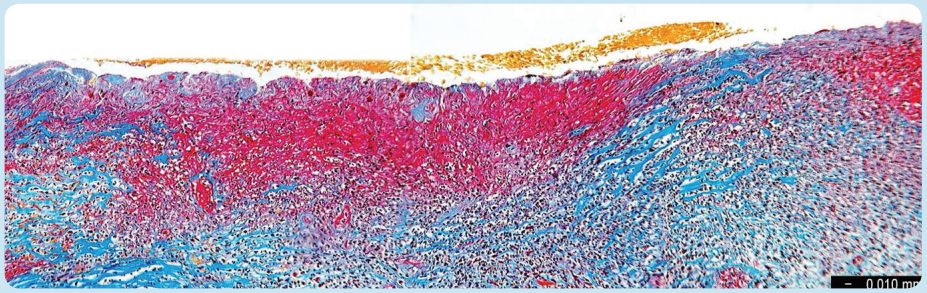

Figure 4. Cross-section of a chronic wound surface stained with MSB (martius/scarlet/blue). Trichrome stain showing an uneven contoured surface with evidence of red blood cells (yellow), fibrin deposition (red) and collagen fibres (blue).

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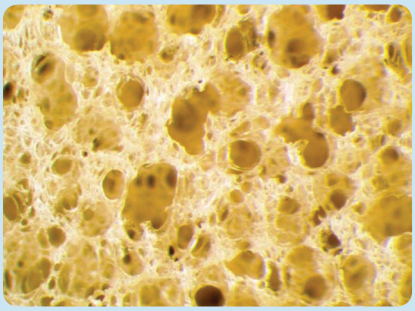

Figure 5. Foam structure showing alternate areas of textured and open spaces.

contact with the wound bed altogether. Due to higher evaporative rates, free fluid dries more rapidly than retained fluid, increasing the risk of creating conditions where the dressing can become adhered to the wound. Removing an adhered dressing can be painful and will disrupt any healing tissue. In some regions, gauze dressings are still routinely used and assumed to provide 'moist' wound healing conditions if soaked with saline, but the reality is that these dressings are rarely kept sufficiently moist[23]. This can result in a 'wet-to-dry' dressing, which is likely to be painful on removal as well as being non-selective in the tissue it removes[23].

Ideally, a dressing should be flexible, conformable and soft on application so that it can take on the same shape of the wound (without exerting undue pressure) and be in close contact. A small expansion on absorption of wound fluid may be desirable to ensure a good fit and the formation of a continuous, moist, non-adherent wound-contact layer. The individual fibres in HT dressings are fine and flexible. When combined as a non-woven pad they form a fabric with the desired dry dressing characteristics. As HT dressings absorb exudate, there is a slight increase in thickness brought about by the swelling and coalescing of fibres. Consequently, the formation of a soft translucent gel provides conformability to uneven wound surfaces, which in turn provides intimate contact with the wound bed. *In vitro* time-lapse microscopy studies have been used to show how HT dressings contour to an uneven simulated wound surface (eg porcine belly tissue) (unpublished data) *(Fig 6 a and b)*. In contrast, plastic (polyurethane) foam dressings failed to

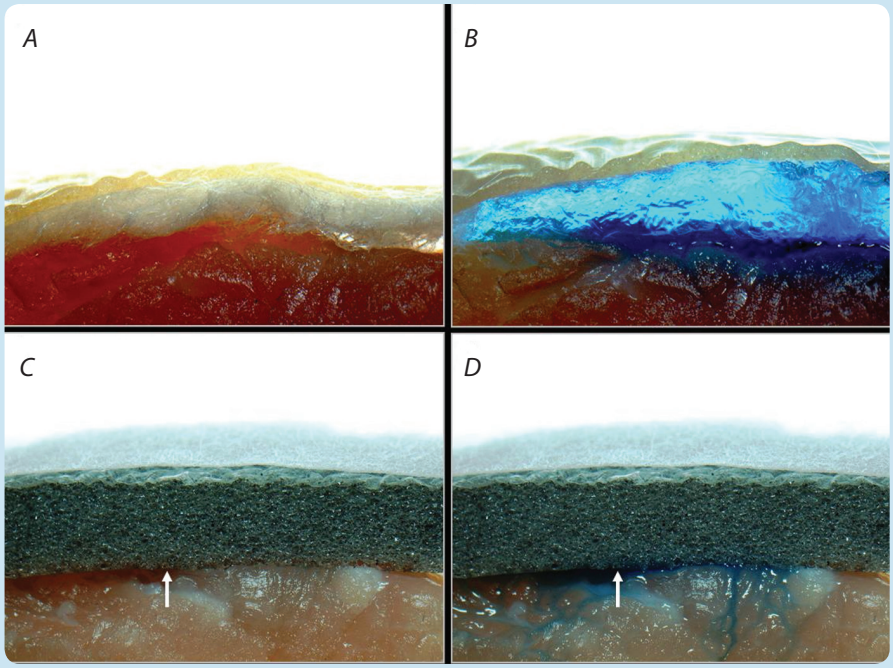

Figure 6 – **In vitro** *time lapse microscopy showing conformability of two silver-containing dressings with a simulated uneven wound surface (porcine belly tissue). A dyed isotonic solution is gently pumped through the tissue to mimic an exuding wound. A: the application of a dry HT dressing. Areas of non-conformability are visible; B: hydrated HT fibres form a cohesive gel that conforms to the uneven surface; C: application of a dry, silver-containing foam dressing. Areas of non-conformability are visible; D: areas are visible where fluid has pooled due to the lack of conformability of the silver-containing foam dressing.*

Key points

Hydrofiber® Technology dressings:

1. *Provide rapid and balanced absorption.*
2. *Micro-contour to uneven wound surfaces.*
3. *Respond to changes in the wound environment.*

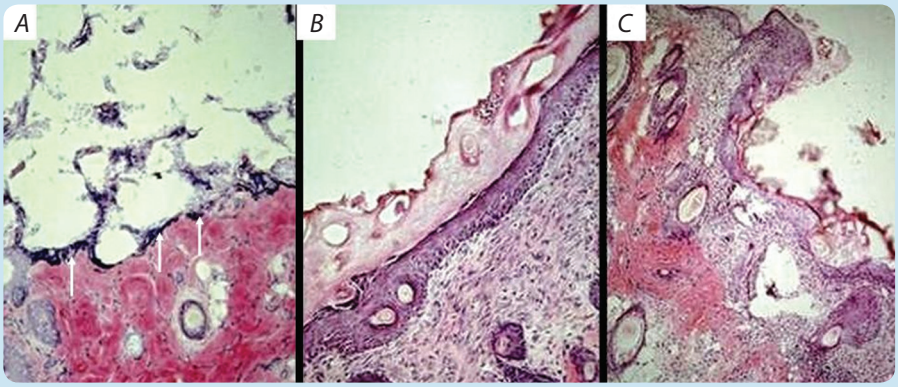

Figure 7 – Application of dressings to an in vivo partial-thickness animal burn model. A: interaction of fibrin at the dressing wound interface provides good conformability of the hydrated HT dressing to the underlying wound tissue (arrowed); B: this allows re-epithelialisation to take place undisturbed; C: the gauze dressing allows cells to grow into the open spaces, such that upon removal there is the likelihood of tissue damage.

conform well to this tissue surface and areas of dead space containing pooled fluid were evident *(Fig 6 c and d)*.

The ability of certain fibrous dressings to swell quickly limits the space between the dressing and the wound where bacteria may proliferate[23]. Further evidence has been provided from histological sections of dressing applications to an *in vivo* partial-thickness animal burn model[21]. In these studies, it was shown that following the application of an HT dressing to a burn wound, conformability with the wound surface *(Fig 7a)* encouraged re-epithelialisation to take place through the interaction of the fibrin layer with the hydrated fibrous HT dressing *(Fig 7b)*[21]. In contrast, using the same model, the cellulose-based fibres of a gauze dressing did not swell and therefore could not absorb fibrin, which resulted in a more chaotic re-epithelialisation process, which is likely to lead to tissue damage upon dressing removal *(Fig 7c)*[21].

A clinical study performed in a primary care setting assessed the dressing performance of two fibrous dressings with respect to their overall performance (eg ease of application/removal, and pain at dressing changes)[22]. The results showed that the HT dressing was significantly better than an alginate dressing for all the parameters tested (exudate retention [p=0.002]; ease of application [p=0.03]; ease of removal [p=0.006]; pain at dressing change [p<0.001]; and dressing adhesion [p<0.001])[22]. Similarly, in a multi-centred study aimed to address practitioners' concerns associated with pain and trauma, HT dressings and hydrogels were rated as the dressing types that were least likely to cause pain at dressing changes[29]. In the same study, foam dressings and hydrocolloids were the next, followed by low adherent dressings, paraffin tulle, film dressings and knitted viscose, with gauze dressings causing most pain at dressing changes[29]. In a review on the use of gauze dressings, it has been suggested that there is substantial evidence to show that moisture retentive products provide greater clinical benefits in relation to healing, pain and infection control[23].

CONCLUSION

As part of their protocol of care, clinicians and care-givers need to make appropriate dressing choices based on a good knowledge and understanding of wound dressings and their respective properties. These should include the ability of a dressing to provide and maintain an optimum moist wound environment through good exudate management, and the ability to minimise periwound maceration by reducing fluid movement. Equally important is the ability of a dressing to provide good conformability with the wound bed and to eliminate dead spaces, as well as locking-in potentially pathogenic bacteria and proteolytic enzymes. Due consideration of these factors should help clinicians and care givers to make better dressing choices, ensuring that the chosen product best matches each individual patient's needs[30].

AUTHOR DETAILS

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