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## Wound Dressings Update

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### ABSTRACT

The availability of different types of wound dressings has increased in the last decade. Wound care practitioners have at their disposal an extensive range of dressings. Emerging dressing types include interactive/bioactive dressings and tissue-engineered skin substitutes. There is no one dressing that is suitable for the management of all types of chronic wounds and few are suited for the treatment of a single wound during all stages of the healing cycle. Successful wound management depends on an understanding of the healing process combined with knowledge of the properties of the various dressings available. Without such knowledge and careful assessment of all the factors that effect healing, dressing selection is likely to be arbitrary and ineffective, wasteful both in terms of time and physical resources. This article is an overview of some of the first-line and second-line interactive/bioactive dressings available. A synopsis of wound assessment and wound bed preparation will aid in choosing the appropriate dressings. It will also touch on advanced technologies including tissue-engineered skin substitutes.

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### INTRODUCTION

Normal wound healing processes require restoration of epithelialisation and collagen formation. The first occurs by migration and proliferation of keratinocytes from the wound edges and by differentiation of stem cells from remaining hair follicle bulbs. The second occurs by influx of growth factors secreted by macrophages, platelets and fibroblasts, by fibroblast proliferation and subsequent synthesis and remodelling of collagenous dermal matrix. However, in the case of full-thickness burn injuries and chronic wounds such as pressure ulcers, venous ulcers and diabetic foot ulcers these processes are damaged and new technologies have been developed to improve the healing in these conditions.<sup>1</sup>

The time it takes for a chronic wound to heal varies due to the idiosyncratic nature of each wound and inherent complex factors, which may impede healing. Infection, poor blood supply, immobility, diabetes, medicines, inadequate hydration and nutrition, trauma and poor wound management are causative or contributory factors. Tissue repair research and advances in moist wound healing pharmaceuticals have been pivotal in improving wound dressing technology.<sup>2</sup> Clinical experience suggests that wound healing is often impaired in the elderly. The elderly have a high prevalence of chronic leg and pressure ulcers and are vulnerable to skin tears that can be slow to heal due to decreased dermal thickness and the loss of proliferative capacity of the ageing dermis.<sup>3</sup> Chronic wounds represent a significant burden in human and economic costs.<sup>4</sup>

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### CHOOSING THE APPROPRIATE DRESSING

The decision-making process to select the most appropriate dressing for the treatment of a wound can be complicated and clarity concerning dressing form and function is often a further challenge.<sup>4</sup> Prior to dressing selection it is important to identify the purpose or principal aim of the proposed treatment. Dressing selection is only one part of a holistic wound management plan with individualised patient goals. It is necessary to assess the whole patient, diagnose underlying disease pathology and assess the patient's concerns before assessing the wound and choosing the dressing.<sup>5</sup> Effective wound management is not only about the availability and use of new dressings, it requires an understanding of the process of tissue repair and the knowledge of the properties of the dressings available.

### WOUND ASSESSMENT

Comprehensive wound assessment, which includes wound classification, colour, depth, shape, size, exudate amount, wound location, and the environment of care will all influence the choice of wound dressing.<sup>6</sup> When choosing the optimum treatment, ease of use, cost-effectiveness and patient satisfaction need to be taken into account. Ideally, a selection of dressings need to be considered to deal with the changing characteristics that chronic wounds exhibit.

Appropriate dressing selection depends on accurate assessment of the patient and the wound. As wounds are dynamic and will undergo different phases of healing the choice of dressing will often change with each phase of wound healing. A system of wound assessment, which is simple and effective is the Colour, Depth and Exudate (CDE) system. When assessing wounds, clinicians should note the colour of wound bed tissue, the depth of the wound and the level of exudate. Dressing selection based on the CDE system is shown in Table 1.

### Colour

The pink wound is in the final stages of healing with new epithelium covering the wound. The aim is to protect this very delicate tissue, prevent the wound from drying out so as to maintain a moist environment and to insulate.

The red wound is a granulating wound with new tissue filling the deficit and with some islets of epithelium present. The aim is to absorb any excess exudate, maintain a moist environment and protect the wound.

The yellow wound contains a level of slough. This is non-viable tissue that must be removed or healing will not take place. The methods of removal are either surgical or rehydration with dressings such as hydrogels or hydrocolloids. The aim is slough removal by rehydration and absorption of exudate.

The black wound has an outer layer of thick hard eschar, that must be removed to start the healing process. The fastest and most effective method is surgical removal. The use of dressings such as hydrogels to aid autolytic debridement will be slow.

The green wound is often an infected wound. The use of topical antibiotics is generally discouraged. The most appropriate treatment is to control high exudate levels, protect surrounding skin from toxic wound exudate, identify microorganisms and treat

**Table 1. Wound assessment and dressing selection**

Colour	Exudate	Aim and dressing selection
Pink	Nil	Maintain moist environment, protect and insulate. Foams, thin hydrocolloids, thin hydroactives, film dressings and simple non-adherent dressing such as the modern tulle will provide the necessary cover.
Red unbroken	Low	Prevent skin breakdown. Thin hydrocolloids or film dressings provide protection.
Red	Low	Maintain moist environment and promote granulation and epithelialisation. Foams, hydrocolloids, sheet hydrogels and film dressings will maintain a moist environment. It is possible to use a combination of amorphous hydrogels with a foam cavity dressing in deeper wounds.
Red	High	Maintain moist environment, absorb exudate and promote granulation and epithelialisation. Foams, alginates and hydroactive dressings help control exudate. Hydrocolloids for deeper areas.
Yellow	Low	Remove slough, absorb exudate and maintain moist environment. Hydrogels in particular will rehydrate the slough and hydrocolloids will also aid in autolysis
Yellow	High	Remove slough and absorb exudate. Hydrocolloids as paste or powder for deeper wounds. Alginates will aid in removal of slough and absorb exudate.
Black	Low	Rehydrate and loosen eschar. Surgical debridement is the most effective method of necrotic material removal. Dressings can enhance autolytic debridement of the eschar. Amorphous hydrogels, hydrocolloid sheet.
Green	High	Absorb infected exudate. Hypertonic saline, silver, cadexomer iodine, interactive wet dressings, capillary wicking dressings.

with systemic antibiotics. Silver dressings, cadexomer iodine and hypertonic saline dressings are beneficial for infected wounds but insufficient alone if there is cellulitis or heavy infection. Critical colonisation is a transition phase between frank infection and colonisation, and is often well managed by antiseptic dressings.

### Depth

The wound may be superficial, partial thickness, deep or a cavity. The choice of dressing will depend on the shape, location and type of wound. The shape and depth of the wound will vary depending on underlying aetiology. For example, venous ulcers are often superficial and highly exuding whereas arterial ulcers are deeper and have a 'punched out' appearance with little exudate. In some instances the wound may have undermined edges and a careful assessment is paramount to ensure that the dressing chosen can be easily removed and to prevent residual dressing from being left in the cavity. Another factor, which may determine the choice of dressing, is the location of the wound. Peri-anal wounds or pilonidal sinus breakdown will require cavity foam dressings to promote healing. Wounds on the face or difficult to fix areas such as the axilla will require other innovative dressing forms.

### Exudate

Most wounds contain some exudate (from very little to copious). Infected wounds exudate more heavily and care needs to be taken to prevent toxic exudate from breaking down the surrounding skin. The choice of primary and secondary dressing will depend on the exudate level and the depth of the wound.

## WOUND BED PREPARATION

Wound bed preparation is also paramount to improved healing. An important factor in wound bed preparation is the maintenance of moisture balance, which often involves exudate management. Failure to manage exudate adequately can expose the peri wound skin to toxic exudate that may impede healing.<sup>6</sup> The TIME principle was developed by an international advisory board on wound bed preparation.<sup>5</sup> The TIME principle is based on four factors: wound, clinical action, suggested product solution and the healing outcome (Table 2).

**Table 2. TIME wound bed preparation**

Description	Factors	Clinical action
Tissue non-viable	Slough or necrotic tissue present	Remove defective tissue (surgical or autolytic debridement)
Inflammation and/or infection	Increased exudate, increased odour or surface discoloration	Remove or reduce bacterial load (antimicrobials, debride devitalised tissue)
Moisture imbalance	Heavy exudate, risk of maceration or dry wound bed, risk of desiccation	Restore moisture balance (absorb exudate or add moisture to dry wounds)
Edge of wound not advancing	Chronic wound with prolonged inflammation	Address T/I/M factors

## DRESSINGS

Wound management has seen many changes over the past few decades. A myriad of dressings have been applied to wounds since ancient times. The list of naturally occurring materials include spider webs, dung from various animals and insects, leaves, tree bark, honey, vinegar, beer and wine. The 20th century has seen a revolution in wound management. Moist wound healing principles are based on pioneering work by Winter in 1962 and a year later by Hinman and Maibach.<sup>7,8</sup>

As research and understanding improves at the cellular level we are better able to assist the body not only by covering the wound to protect it but also by providing wound dressings to aid the healing process. Wound dressings can be divided into two broad groups: inert/passive and interactive/bioactive. Inert dressings can be subclassified into absorbing and non-absorbing and interactive dressings as absorbing, non-absorbing and moisture donating. The interactive group has six different dressing types.

### Inert/Passive Dressings

For many years the dressings used were of the 'passive' or the 'plug and conceal' concept including gauze, lint, nonstick and tulle. They fulfil very few of the properties of an ideal dressing and have very limited use as primary dressings, but some are useful as secondary dressings. In addition to gauze, lint and cotton dressings, other simple modified absorbent pads covered with a perforated plastic film to prevent adhering to a wound such as Melolin, Cutilin and Telfa are used as primary and secondary dressings. They are used in minimal and low-exuding wounds.

Exudry, a modern inert dressing, has a highly absorbent pad and a nonstick non-shear surface. It can be used as secondary dressing over moderate to highly exuding wounds and over hydrocolloid paste, cadexomer iodine, alginate and other primary dressings. Tulle/paraffin gauze dressings are among the earliest modern dressings. Many variations have been developed over the years by changing the loading of paraffin in the base. These dressings produce a waterproof

**Table 3. First-line interactive/bioactive dressings**

Dressing	Brand names	Indications
Semi-permeable films	Aqua protect film, Bioclusive, Cutifilm, Hydrofilm, Opsite (Flexigrid, Flexifix, Post-Op), Polyskin, Tegaderm	Non-absorbent; superficial burns, grazes, closed surgical incisions, small skin tears and IV sites; secondary dressing
Foams	Allevyn (adherent, non-adherent, wound cavity dressing), Cavi-care, Curafoam, Hydrosorb, Lyofoam (flat, extra, C, T, A), PermaFoam, Tegafoam, Truefoam	Moderate to heavily exudating, superficial and cavity wound, venous ulcers (with compression), pretibial lacerations, infected ulcers, skin tears, pressure ulcers, skin grafts or donor site, pilonidal sinuses.
Alginates	Algisite M, Algoderm, Comfeel SeaSorb, Curasorb, Kaltostat, Melgisorb, Sorbsan	Need exudate to function. Heavily exudating leg ulcers, pressure ulcers and dehisced abdominal wounds.
Hydrocolloids	Comfeel (ulcer dressing, transparent, contour dressing), CombiDERM, DuoDERM (extra thin, CGF, paste), Hydrocoll, RepliCare, Tegaserb	Light to moderately exudating wounds that would benefit from autolytic debridement. Leg ulcers, pressure ulcers, burns and donor sites. Thin sheets are useful over suture lines and IV sites.
Hydrogels	Aquaclear, Purilon Gel (amorphous), Curafil (amorphous), Curagel (sheet), DuoDERM Gel (amorphous unpreserved), Hypergel (hypertonic saline, amorphous), Intrasite Conformable (gauze impregnated), Intrasite Gel (amorphous unpreserved), Nu-gel, Second skin, SoloSite Gel (amorphous preserved), Solugel (amorphous preserved and unpreserved), Sterigel (amorphous)	Absorbency is limited; best for minimally exudating or dehydrated wounds such as minor burns, grazes, lacerations, donor sites and pressure ulcers. Indications for the thicker viscosity products include protection of exposed tendon and/or bone from dehydrating and rehydrating eschar prior to debridement. The thinner viscosity products are useful for soothing burns and acute lesions such as chicken pox.
Hydroactive	Allevyn Thin, Biatain, Cutinova Hydro, PloyMem, Tielle	Waterproof, expandable, non-residual and semi-permeable. Highly exudating surface and cavity wounds including leg ulcers, pressure wounds and minor burns. Useful over joints as they expand/contract without causing constriction. Not indicated for dry or lightly exudating wounds.

paraffin cover over the wound, but this may lead to maceration as the water vapour and exudation may not pass through and be trapped within the wound. These dressings are permeable to bacteria, may adhere to the wound and in some cases may cause trauma on removal and will require a secondary dressing. Use is limited to simple clean superficial wounds and minor burns. They are also used as a primary dressing over skin grafts. There are modern alternative dressings composed of synthetic fibres tightly meshed and impregnated with materials that allow moisture to pass through and thus minimise any maceration of the wound and tissues, e.g. Adaptic, Cuticerin, Atrauman.<sup>9</sup>

### First-Line Interactive/Bioactive Dressings

Interactive/bioactive dressings alter the wound environment and interact with the wound surface to optimise healing. The ability to provide a moist, conducive environment for improved healing when compared with traditional passive dressings has meant that new dressing technologies are a better alternative. Interactive dressings use the environment provided by the body to encourage normal healing and stimulate the healing cascade. Table 3 offers a synopsis of dressing form, function and indication of the commonly used dressing groups used in clinical practice. These have been listed as first-line dressings as they are more readily available in acute, subacute and community settings. Other more advanced dressings described in Table 4 may be used when the first-line films, foams, alginates, hydrocolloids, hydroactives, and hydrogels are unsuitable or have not achieved successful healing.

#### *Semi-Permeable Film Dressings*

Film dressings are adhesive, thin transparent polyurethane, which are permeable to gas but impermeable to liquid and bacteria. Films are elastic, conformable and transparent allowing inspection of the wound. As films are non-absorbent they are not suitable for exudating wounds although island dressings with a central nonstick pad are available and can absorb slightly more exudate than the simple films. Films can also be used as secondary dressings to waterproof a primary dressing such as foam. Incorrect removal of film dressings may cause trauma to surrounding skin.

#### *Foam Dressings*

Foam dressings are made from polyurethane, which may in some cases have been heat-treated on one side to create a semi-permeable membrane. This allows the passage of exudate through the non-adherent, semi-permeable surface into the insulating foam. Foams are available in sheets or cavity filling shapes. Foams have several advantages—they are highly absorbent, cushioning and protective, insulate and conform well to body surfaces. Foams facilitate a moist wound environment and absorb excess exudate to decrease the risk of maceration. Foam dressings are also available with charcoal impregnation for malodorous wounds. Depending on the level of exudate, foams can be left in place for up to seven days.

Foam wound cavity dressings reduce dead space in the wound, conform to wound shape and absorb large amounts of exudate, therefore reducing the need for frequent dressing changes although cavity foam dressings require secondary dressings and that adds to cost. Foams are generally non-adhesive and require a secondary dressing or tape/bandage to keep in place. Care is needed when adhesives are used to fix dressings in the elderly, as their skin is often fragile and prone to breakdown. Tubular retention bandages to fix dressing in place are a safer option in the elderly.

#### *Alginate Dressings*

Alginates (calcium or calcium/sodium) are highly absorbent, biodegradable dressings derived from seaweed.<sup>10</sup> An active ion exchange of calcium ions for sodium ions at the wound surface forms soluble sodium alginate gel that provides a moist wound environment. Calcium dressings need moisture/exudate from the wound to function, therefore they are not suitable for dry wounds or wounds with hardened eschar. The fibrous nature of most alginates can leave residual fibres in the wound if there is insufficient wound exudate to gel the fibres. This may precipitate an inflammatory reaction as it stimulates a foreign body response. Caution is also needed when using alginate rope dressings in very deep or narrow sinuses, as complete removal can be difficult. Studies have shown that some calcium alginate dressings promote haemostasis in bleeding wounds due

**Table 4. Second-line advanced interactive/bioactive dressings**

Dressing	Brand names	Indication
Cadexomer iodine	Iodosorb (sheet, powder, paste)	Venous leg ulcers, foot ulcers, and diabetic foot ulcers. Contraindicated in patients sensitive to iodine products or with any thyroid pathology.
Capillary wicking	Vacutex	Heavily exudating and infected wounds. Contraindicated in low exudating wounds within close proximity to blood vessels.
Honey	Medihoney, B-Naturals, L-Mesitran. Medihoney is a blend that includes honey from the <i>Leptospermum</i> species of plants. Medihoney and Medihoney Wound Gels do not contain preservatives. B-Natural's medicated honey is obtained from the <i>Eucalyptus marginata</i> and <i>Santalum spicatum</i> species of plants and does not contain preservatives. L-Mesitran contains 48% honey, aloe, calendula, zinc oxide, medilan and vitamins A, C and E.	May be useful in management of sloughy and septic wounds.
Hydrofibre	Aquacel, Aquacel Ag	Heavily exudating wounds such as dehisced abdominal or pelvic wounds, chronic leg ulcers and infected wounds. Dressing frequency may be reduced depending on level of exudate.
Hypertonic saline	Curasalt, Hypergel, Mesalt	Moist, necrotic, exudating infected wounds. May be effective in decreasing hypergranulation tissue.
Interactive wet	TenderWet	Infected, sloughy and diabetic wounds
Silicone	Mepitel (non-adherent), Mepilex (non-adherent, thin, absorbent, border, transfer), Mepitac (fixation tape)	Painful wounds, skin tears, difficult wound. Mepitel can be reused, and is usually used under another dressing to reduce pain on dressing changes.
	Silicone gel sheets: Cica-Care, Mepiform, Spenco	They soften and flatten scar tissue and can be washed and reused. Large sizes are also useful under secondary dressings for cancer wounds.
Silver	Acticoat, Acticoat Absorbent (calcium alginate), Actisorb 220 (charcoal impregnated), Aquacel Ag (hydrofibre), Atrauman Ag (wound contact tulle), Avance, Contreet (hydroactive), Contreet-H (hydrocolloid), PolyMem Silver	Wounds with high microbial burden and moderate to high exudate. Useful in partial and full thickness wounds (burns, donor sites) and for complementary use in infected or contaminated partial thickness wounds.
Zinc paste	Flexidress, Gelopast, Steripaste, Tenderwrap, Viscopaste, Zincaband, Zipzoc	Chronic venous leg ulcers, particularly where venous eczema is present and when used in conjunction with appropriate compression bandaging.

to the active release of calcium ions that aid the clotting mechanism.<sup>11</sup> Alginate dressings are available in sheet, ribbon or rope form in various sizes and require a secondary dressing.

#### Hydrocolloid Dressings

Hydrocolloids are moisture-retentive dressings, which contain gel-forming agents such as sodium carboxymethylcellulose and gelatin. Many dressings combine the gel-forming properties with elastomers and adhesives which are applied to a carrier such as foam or film to form an absorbent, self-adhesive, waterproof wafer. In the presence of wound exudate, hydrocolloids absorb liquid and form a gel, the properties of which are determined by the nature of the formulation. In sheet form the polymer outer layer can be either semi-occlusive or occlusive. Hydrocolloid interaction debrides by autolysis and can reduce dressing frequency to up to seven days wear time depending on the amount of exudate and the type of hydrocolloid dressing.<sup>12</sup> Hydrocolloids are also available in paste and powders for increased absorption and to decrease dead space in the wound cavity. Generally, hydrocolloids with a waterproof backing are not recommended on clinically infected wounds due to the semi-occlusive nature of the dressing. There have been reports of hypergranulation with prolonged use of hydrocolloids in moderate to highly exudating wounds so wound tissue assessment is paramount when applying hydrocolloids for long periods. Hydrocolloids should be discontinued before hypergranulation occurs.<sup>13</sup>

#### Hydrogel Dressings

As the name implies, hydrogels are designed to hydrate wounds, rehydrate eschar and aid in autolytic debridement. Hydrogels are insoluble polymers that expand in water and are available in sheet, amorphous gel or sheet hydrogel-impregnated dressings. They provide a moist environment for cell migration and absorb some exudate. Autolytic debridement without harm to granulation or epithelial cells is another advantage of hydrogel dressings.

Hydrogels have marked cooling and soothing effect on the skin, which is valuable in burns and painful wounds. The viscosity varies between dressings. Purilon and IntraSite are two of the thickest gels available which helps them stay in the cavity of the wound. Solugel and Solosite are two of the thinnest, allowing easy spread over a large area. Some amorphous gels contain propylene glycol that can cause allergic reactions in elderly skin. Amorphous hydrogels are applied liberally onto or into a wound and covered with a secondary dressing such as foam or film. Hydrogels can remain *in situ* for up to three days. For easy removal of hydrogels the wound is irrigated. In addition to their use in wounds the thin hydrogels are helpful in the management of lesions such as chicken pox and shingles.

#### Hydroactive Dressings

These multilayered highly absorbent polymer dressings, some with a surface adhesive and a waterproof outer layer, are similar to hydrocolloids. However, instead of forming a gel in contact with exudate, the fluid is trapped within the dressing, to maintain a moist environment.

## Second-Line Interactive/Bioactive Dressings

Although most practitioners will be able to improve wound healing with the aid of the six main groups of dressings (film, foam, hydrogel, hydrocolloid, hydroactive, alginate) for the more complex chronic wounds there are alternatives (Table 4).

### *Hydrofibre Dressings*

Hydrofibre dressings are non-woven sodium carboxymethyl cellulose spun into fibres and manufactured into sheet or ribbon packing dressings. Aquacel, a hydrofibre dressing, maintains a moist wound healing environment as fibres convert to form a gel on contact with exudate. The vertical wicking of exudate reduces maceration of surrounding skin. The dressings are claimed to be more absorbent than alginates and to promote non-traumatic dressing removal.

### *Hypertonic Saline Dressings*

Cotton or synthetic gauze is impregnated with sodium chloride 20% and is available in sheet, rope or ribbon form. The hypertonic saline creates an osmotic action to cleanse the wound by wicking necrotic or infected purulent debris. Bacterial growth is inhibited by hypertonic properties.

### *Cadexomer Iodine Dressings*

This is a three dimensional polysaccharide lattice formed into spherical microbeads that contain iodine 0.9%. It maintains a moist wound environment as it absorbs exudate, swells and forms a gel from which iodine is gradually released into the wound. The tissue iodine supply is at a 0.1% concentration and as such is rarely toxic. Iodosorb, an effective autolytic debriding agent, is a broad-spectrum antimicrobial and can absorb six to seven times its weight, which is useful for heavily exuding and infected wounds. It is contraindicated in patients with sensitivity to iodine and not recommended for pregnant or lactating women. There has been anecdotal evidence that some patients have experienced osmotic pain.

### *Interactive Wet Dressings*

These are multilayered dressings with a central core of absorbent polyacrylate, a super absorbent polymer. Dressings are activated with Ringer's solution and released into the wound cavity over 12 hours. In exchange, wound exudate and bacteria are absorbed into the core of the dressing. One example of an interactive wet dressing is TenderWet, which is available in several different sizes. It is important to use the correct size for the wound as wet dressings can cause maceration of surrounding skin. The dressing usually needs to be changed twice a day.

### *Silicone Dressings*

Silicones are polymers with a structure that consists of alternate atoms of silicone and oxygen with organic groups attached to the silicone atoms. The degree of polymerisation determines the various physical forms of the silicone. Soft silicones are a particular form of solid silicones, which are soft and tacky. These properties enable the silicone to adhere to dry surfaces. A soft silicone dressing is coated with soft silicone as an adhesive or a wound contact layer. The intrinsic properties of soft silicone provide gentle adhesion and minimises wound and surrounding skin trauma at dressing change.<sup>14</sup> Soft silicone is not intrinsically absorbent but it can be applied as a facing layer to dressings containing absorbent components that are used for the management of exuding wounds.<sup>15,16</sup> Soft silicone dressings have been shown to reduce wound pain and are helpful in skin tears where there is major loss of epidermis. Soft silicones also have a role in scar management and are used in the treatment of hypertrophic and keloid scars. An international advisory group

of scar management experts have recently published evidence-based clinical recommendations that support the use of silicone gel sheeting as a first-line therapy on immature, linear and widespread burn hypertrophic scars and minor keloids.<sup>17</sup>

### *Silver Dressings*

Silver, a broad-spectrum antimicrobial is effective against methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant *Enterococcus*.<sup>18</sup> Woodward has suggested that the strongest evidence for use of silver dressings is for slow to heal or critically colonised wounds.<sup>19</sup> Silver dressings cannot be used solely to treat infected wounds; these wounds usually warrant systemic antibiotics and possibly debridement.<sup>20</sup> There are a number of silver dressings available with different formulations and delivery of silver. The carrier medium for silver dressings incorporates many of the dressing types discussed, e.g. silver-containing dressings are available for most wound exudate levels. The amount and form of silver in dressings varies and there has been some debate regarding how much silver is needed in the wound for it to be bactericidal.<sup>18</sup> There has also been discussion on the potential for increased resistance if there is indiscriminate use of silver dressings.<sup>21-23</sup>

As there are so many different forms of impregnated silver dressings it is important to follow the manufacturer's guidelines. Sussman describes the range of silver dressings available in Australia.<sup>24</sup> Templeton discusses the role of silver-containing dressings, the implications for practice and recommends the need for evidence-based protocols for the use of silver-containing dressings to assist clinicians to achieve economically sustainable outcomes.<sup>20</sup>

### *Capillary Wicking Dressings*

Capillary wicking dressings are designed to wick exudate and microorganisms away from the wound surface. Vacutex is constructed of three layers of polyester filaments and polycotton fibres. Vacutex claims to absorb 30 times its weight and can be cut to fit wounds and cavities of various sizes and shapes. It may adhere to wounds with minimal exudate and to prevent this from occurring a silicone sheet may be used at the base of the wound as a primary dressing before applying Vacutex.<sup>4</sup>

### *Honey Dressings*

Honey that has been derived from selected *Leptospermum* or *Eucalyptus marginata* and *Santalum spicatum* species of plants and registered with the Therapeutic Goods Administration can be used in wounds. Honey dressings may promote moist wound healing, autolytic and osmotic debridement and have antimicrobial activity claimed to be from the slow release of low levels of hydrogen peroxide. The dressing is best stored below 30 °C as higher temperatures may inactivate the enzyme glucose oxidase responsible for the production of hydrogen peroxide. It cannot be used in those with a known allergy to bee products. Frequency of dressing change may be every one to three days depending on the amount of exudate and there is potential for surrounding skin maceration. Some patients report a stinging or drawing sensation when honey products are used. Mwipatayi et al. state that the high osmolarity of honey has been valuable in the management of sloughy and septic wounds.<sup>25</sup>

### *Zinc Paste Bandages*

Zinc has been used in medicine for hundreds of years; even though very little published data of its pharmacology is available. Zinc is an important trace element in many functions of the body. In wound healing it is essential for cell proliferation and tissue regeneration, and is also involved in collagen synthesis and epithelialisation. Zinc is applied topically as a zinc paste bandage either over the full length of the leg or as a patch over the wound.

## ADVANCED TECHNOLOGIES AND DRESSINGS

There are many other more advanced technologies and dressings that promote healing, ranging from modern wound devices to cell therapy, tissue engineered equivalents, dermal substitutes, dermal regeneration templates and growth factors.

### Negative Pressure Therapy Devices

Controlled negative pressure devices promote vacuum-assisted wound closure. Negative pressure applies non-compressive mechanical forces to the tissue, which allows arterioles to dilate and increases blood flow. Negative pressure is achieved in the wound by positioning a suction tube into the foam dressing and connecting this to a pump. The foam is positioned in the wound and occluded with a semi-permeable film. The most widely used negative pressure therapy device is the VAC, which is portable and comes in different sizes which allows use on different parts of the body.<sup>4</sup> The VAC system provides a moist environment, reduces bacterial colonisation and localised oedema, dead space and the need for frequent dressing changes. It also promotes localised blood flow, granulation and epithelialisation. It is contraindicated in osteomyelitis and malignant wounds and when necrotic eschar is present. Caution is required for bleeding wounds or potential bleeding when patients are taking anticoagulants.

### Ceramic Wound Treatment Devices

These devices are sterile non-woven fabric sachets filled with micro-porous inert ceramic granules. The ceramic granules have a capillary wicking action on wound exudate and trap excess moisture within the sachets.<sup>4</sup> Cerdak, a ceramic wound treatment device is available in different sizes and forms (adhesive, semi-permeable film, cavity fillers). It can be left in place for several days but once saturated the device will become ineffective.

### Wound Matrix Dressings

Oasis, a matrix produced from pig small intestine submucosa, is derived from extracellular matrix-based wound product that is compatible with human tissue. Components of the extracellular matrix that are retained in Oasis include glycosaminoglycans, proteoglycans, fibronectin and other matrix-associated factors such as fibroblast growth factors. It is a thin, transparent layer that is recommended for use in all partial and full thickness wounds and skin loss injuries such as superficial and full thickness burns.

### Promogran

Promogran, a sterile freeze-dried matrix is made up of collagen and oxidised regenerated cellulose (unavailable in Australia). It is recommended for all types of chronic wounds that are free of necrotic tissue and show no signs of infection. Once in place it must be covered with a low-adherent secondary dressing to maintain a moist wound healing environment. It can be used in conjunction with standard compression therapy when treating venous ulcers. Frequency of dressing change will depend on the level of exudate. The matrix absorbs exudate and forms a soft biodegradable gel, which rebalances the wound environment. The gel binds and inactivates matrix metalloproteinases, which when present in excessive levels, have a detrimental effect on wound healing as they damage regenerating tissue.<sup>26,27</sup>

### Tissue Engineered Skin Equivalents

Surgical grafting of split-thickness autologous skin is the standard method for rapid closure of full-thickness burn wounds.<sup>28</sup> Cell culture technique advancement has involved the development of autologous and allogeneic grafts using either sheets of fibroblasts in a biodegradable matrix or cultured keratinocyte sheets.<sup>29,30</sup> Improved results are gained if both dermal and epidermal components are combined, e.g. in a bilayer skin equivalent.<sup>31</sup> A clinical evaluation of skin substitutes has been reported.<sup>32</sup>

### Integra Dermal Regeneration Template

Integra dermal regeneration template is comprised of a porous collagen/chondroitin-6 sulfate matrix overlaid with a thin silastic sheet, which acts as a scaffold for dermal regeneration. Its unique action inhibits granulation and promotes the growth of neo-dermis through the collagen and glycosaminoglycan matrix. The silastic layer provides a temporary epithelial covering, which is removed prior to secondary grafting with a thin split-thickness autograft or cultured keratinocyte sheet. Originally intended for use in acute burn injuries, recently it has had an increased application in general plastic surgery. There are reports on the use of Integra in reconstructive surgery.<sup>33,34</sup> Reported disadvantages include the requirement for a second operation, the risk of infection beneath the silastic layer, the silicone becoming detached, and problems with contraction. Integra's advantages are its immediate availability in large quantities, the simplicity and reliability of its use and the functional and cosmetic properties of the resulting cover.<sup>35</sup>

### Dermagraft

Dermagraft, a cryopreserved human fibroblast-derived dermal substitute is composed of fibroblasts, extracellular matrix, and a bioabsorbable scaffold. Dermagraft is manufactured from human fibroblast cells derived from newborn foreskin tissue. During the manufacturing process, human fibroblasts are seeded onto a bioabsorbable polyglactin mesh scaffold. The fibroblasts proliferate to fill the interstices of this scaffold and secrete human dermal collagen, matrix proteins, growth factors and cytokines, to create a three-dimensional human dermal substitute containing metabolically active, living cells. Dermagraft does not contain macrophages, lymphocytes, blood vessels, or hair follicles. It is indicated for the treatment of full-thickness diabetic foot ulcers of greater than six weeks duration. These ulcers extend through the dermis, and use is contraindicated when there is tendon, muscle, joint capsule, or bone exposure. Dermagraft should be used in conjunction with standard wound care regimens and in patients who have adequate blood supply to the involved foot.

### Apligraf

Apligraf, a bi-layered cell therapy like human skin consists of living cells and structural proteins. The lower dermal layer combines bovine type 1 collagen and human fibroblasts (dermal cells), which produce additional matrix proteins. The upper epidermal layer is formed by promoting human keratinocytes initially to multiply and then to differentiate, to replicate the architecture of the human epidermis. Unlike human skin, Apligraf does not contain melanocytes, Langerhans cells, macrophages, and lymphocytes, or other structures such as blood vessels, hair follicles or sweat glands. It is indicated for use with standard compression therapy in venous ulcers of at least one month duration that have not responded to conventional ulcer therapy.<sup>36</sup> It is also indicated for the treatment of full-thickness neuropathic diabetic foot ulcers of greater than three weeks duration that extend through the dermis but without tendon, muscle or bone exposure.<sup>37</sup>

### TransCyte

TransCyte, a human fibroblast-derived temporary skin substitute consists of a polymer membrane and newborn human fibroblast cells cultured under aseptic conditions *in vitro* on a porcine collagen coated nylon mesh. It is indicated as a temporary covering for mid-dermal to indeterminate depth burns that require debridement and may be expected to heal without surgical intervention, and for surgically excised full-thickness and deep partial-thickness burns prior to autografting. The membrane is biocompatible and protects the burn wound surface from environmental insults. In addition, the membrane is semi-

permeable, allowing for fluid and gas exchange. As the fibroblasts proliferate within the nylon mesh, they secrete human dermal collagen, matrix proteins, and growth factors. The bioengineered human dermal matrix contains essential structural proteins (collagen types I, III, V), provisional matrix proteins (fibronectin, tenascin), glycosaminoglycans (versican, decorin) and growth factors (keratinocyte growth factor, vascular endothelial growth factor). It is indicated for use as a temporary skin replacement for mid-dermal to indeterminate depth partial-thickness burns.

### Growth Factors

Growth factors are polypeptide molecules whose activities affect the wound repair process, including cell metabolism, differentiation and growth (unavailable in Australia). They may stimulate different functions including angiogenesis, enzyme production, cell migration and cellular proliferation.<sup>33</sup> Growth factors are members of the cytokine family. They can be named according to their function, cell origin, or the type of target cell toward which their action is directed. The presence or absence of growth factors significantly influences the wound closure process. Further research is needed to determine the effects of many growth factors and the influence of each on non-healing wounds. Several growth factors believed to affect wound healing have been studied. Autologous growth factors may also be isolated from patients' blood and applied to their chronic wounds. Regranex, which has platelet-derived growth factor was recently approved by the US Food and Drug Administration for the treatment of diabetic neuropathic foot ulcers.

### CONCLUSION

Activity in scientific research to improve wound healing continues to increase. This review has characterised the different types of established and emerging wound dressings. For new advanced dressings 'bioactivity' appears to be the way forward in maintaining a moist healing environment, offering antimicrobial properties and cellular interactions. Wound management is more than the application of a dressing and for many this remains a challenge simply because the choice of dressings is so vast. Dressings can be grouped into generic categories and clinicians have many resources to guide evidence-based practice. There are many associations, journal web sites, books and conferences dedicated to the problem of managing patients with wounds.

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### Appendix. Other useful resources

Australian Wound Management Association web site  
<www.awma.com.au>

European Wound Management Association web site  
<www.ewma.org>

EWMA position document 2005. Identifying criteria for wound infection.

EWMA position document 2004. Wound bed preparation in practice.