

## Wound Healing Process and Wound Care Dressing: A Detailed Review

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**Received on: 06-11-2013; Revised and Accepted on: 19-11-2013**

### ABSTRACT

*Wound care dressings aim to restore the milieu required for skin regeneration and to protect the wound from environmental threats and penetration of bacteria. Any single type of wound dressing can not address the need and management of all types of wound s. The availability of different types of wound dressings and research for newer type of wound dressing has increased in the last decade. This review discusses the common and advanced wound management dressings, their key advantages and shortcomings. It also discusses the need for dressings with their properties in wound management. The definition and classification of wounds together with the different stages of wound healing are also briefly described. In addition to that this article also compiles the list of wound care product available in the market.*

**Keywords:** Wound, Wound Healing, Wound Care.

### INTRODUCTION

The skin has been described as largest organ in the body. Their functions are numerous and any injury to its various layer increase the vulnerability of the organism to additional biological and physical hazards resulting in wound. Wound care is an essential aspect of human survival. Wound care is "the provision of the appropriate environment for healing by both direct and indirect methods together with the prevention of skin breakdown" [1]. Wound dressings have a major role to play in the management of wounds and Successful wound management depends on an understanding of the healing process combined with knowledge of the properties of the various dressings available. Wound healing is a process of restoration that is necessary for tissue repair, typically comprising a continuous sequence of inflammation and repair in which epithelial, endothelial, inflammatory cells, platelets and fibroblasts briefly interact to resume their normal functions [2]. Various formulation like film dressing, alginate dressing, hydrogel dressing, hydrocollide, dressing, foam dressing etc. are being used for wound healing and for wound dressing. The basic function of and role of wound healing in order to obtain both function and cosmetic result [3]. This paper generally reviews the literature on the modern wound dressing for wound management.

#### Wound:

A wound can be described as a defect or a break in the skin, resulting from physical or thermal damage or as a result of the presence of an Underlying medical or physiological condition. According to the Wound Healing Society, a wound is the result of 'disruption of normal anatomic structure and function' [1].

#### 1. Classification of Wounds: [4,5]

Wounds can be classified according to their Thickness, involvement of skin or other structures, the time elapsing from the trauma (breaking of skin continuity), and their morphology and Severity.

#### 1.1 As per thickness of the wound: [6]

*Superficial wounds*, involving only the epidermis and the dermis up to the dermal papillae.

*Partial-thickness wounds*, involving skin loss up to the lower dermis (Part of the skin remains, and shafts of hair follicles and sweat glands are left over.)

*Full-thickness wounds*, involving the skin and the subcutaneous tissue (Tissue loss occurs, and the skin edges are spaced out).

*Deep wounds*, including complicated wounds (eg, with laceration of blood vessels and nerves), wounds penetrating into natural cavities, and wounds penetrating into an organ or tissue

#### 1.2 As per involvement of other structure: [7]

*Simple wounds*, comprising only 1 organ or tissue

*Combined wounds* (e.g., in mixed tissue trauma)

#### 1.3 As per time elapsing from trauma: [8]

*Fresh wounds*, up to 8 hours from the trauma.

*Old wounds*, after 8 hours from trauma or skin discontinuity.

#### 1.4 As per morphology: [9, 10]

- **Abrasions**, also called scrapes, which occur when the skin is rubbed away by friction against another rough surface e.g. rope burns and skinned knees
- **Avulsions** occur when an entire structure or part of it is forcibly pulled away, such as the loss of a permanent tooth or an ear lobe; animal bites may cause avulsions
- **Excoriation or scarification**, the most superficial type
- **Incised wound**, mainly as a result of surgical intervention or any sharp cut in which the tissues are not severed; a clean cut caused by a keen cutting instrument – the wound may be aseptic or infected, depending on the circumstances
- **Cuts** are slicing wounds made with a sharp instrument, leaving even edges; they may be as minimal as a paper cut or as significant as a surgical incision
- **Crush wound**, occur when a heavy object falls on a person, splitting the skin and shattering or tearing underlying structures (e.g., hatchet, sword, sable)

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- **Contused wound (bruises)**, are the result of a forceful trauma that injures an internal structure without breaking the skin; blows to the chest, abdomen or head with a blunt instrument (e.g. football or fist, traffic accident ) can cause contusions
- **Lacerated wound**, when fragments of tissue are torn away with a sharp-edged object and they are produced by a tremendous force against the body, either from an internal source as in childbirth, or from an external source such as a punch
- **Fish-hook wound**: an injury caused by a fish-hook becoming embedded in soft tissue
- **Slicing wound** (A classic example is detachment of epicranial epineurosis.)
- **Penetrating wound** in which the skin is broken and the agent causing the wound enters subcutaneous tissue or a deep lying structure or cavity (the agent might be a nail, splinter or spike)
- **Punctures** are deep, narrow wounds produced by sharp objects such as nails, knives and broken glass
- **Open wound (contusion)** in which the skin is also broken, such as a gunshot, incised or lacerated wound

- **Closed wound** in which the skin has not been compromised, but trauma to underlying structures has occurred(e.g. a bruised rib or cerebral contusion)
- **Stab wound**, made with a pointed tool or a weapon
- **Bullet wound**
- **Bite wound**
- **Poisoned wound**

#### 1.5 As per severity of wound: [11]

##### Acute wounds:

Include lacerations and scratches due to physical factors, such as a knives, firearms, or medical surgery, and damage to the skin due to chemical factors, such as Abrasions, radiation, electricity, acid/base compounds, etc.

##### Chronic wounds:

Refer to wounds that are hard to heal, may recur, and take more than 12 weeks to heal; this occurs due to skin ulcers due to diabetes or tumours, repeated damage of tissues, and insufficient treatment at the early stage of wound occurrence.

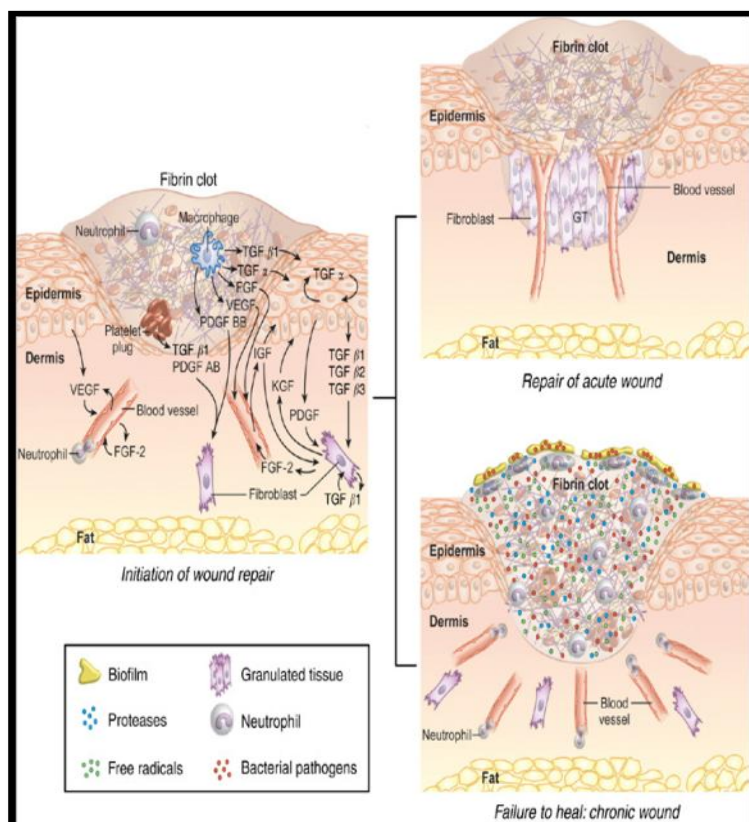


Fig. 1: Differences between acute and chronic wound [12]

Both acute and chronic wounds can be classified as a complex wound if the wound has these characterizes:

- Extensive loss of the integument which comprises skin, hair and associated glands
- Infection which can result tissue loss
- Tissue death or signs of circulations
- Presence of pathology

A wound is colonized when growth and death of bacterial in the wound is balanced by the host. If the host is not able to keep

the bacterial growth in balance, the wound will enter the infection phase (bacterial load in excess of 10). Symptoms for an infected wound are erythema, edema, warmth, pain and exudate. Infections of chronic wounds are often polybacterial with *Staphylococcus aureus* and *anaerobs* being the most common in chronic wound.

#### 2 Wound healing process: [13]

Wound healing is specific biological process related to the general phenomenon of growth and tissue regeneration. The entire process of wound healing is complex and ordered cascade of events, which can be divided into four distant but over lapping phase of homeostasis, inflammation, proliferation and maturation. To

understand this process, the following sections outline the phases of wound healing and the mediators involved.

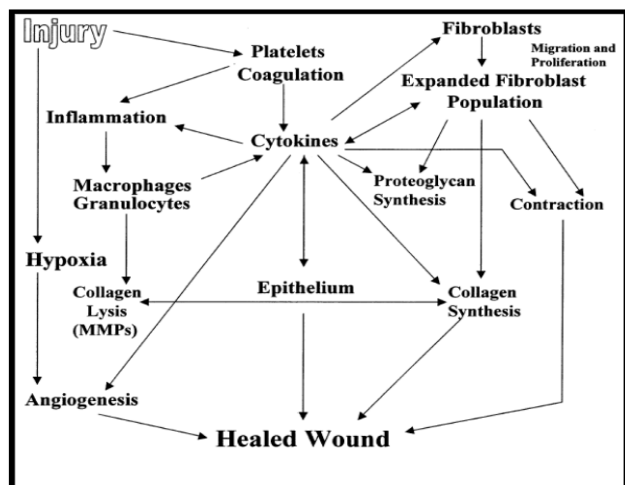


Fig. 2: skeleton structure of wound healing process<sup>[16]</sup>

## 2.1 Phases involved in wound healing:

### 2.1.1 Homeostasis:<sup>[14]</sup>

When the skin is injured Bleeding usually occurs and flush out bacteria, antigens from the wound and release of the exudates component such as clotting factor fibrinogen which was responsible for initiating homeostasis. According to clotting mechanism fibrinogen convert into fibrin which is responsible for coagulation of the exudates (blood without cells and platelets). This fibrin network produces a clot on the wound to stop bleeding. The clot dries to form a scab which provides strength and support to the injured tissue; therefore, homeostasis plays a protective role in wound healing process.

### 2.1.2 Inflammatory phase:<sup>[18]</sup>

This phase occurred simultaneously with homeostasis, sometimes from within a few minutes of injury to 24 h and lasts for about 3 days. It involves both cellular and vascular responses. In this phase release of the protein-rich exudates form the wound site which causes vasodilatation which release histamine and serotonin. Histamine and serotonin allows phagocytes and engulf dead cells (necrotic tissue). Necrotic tissue is hard tissue which liquefied by enzymatic action to produce a yellowish colour mass described as slough.

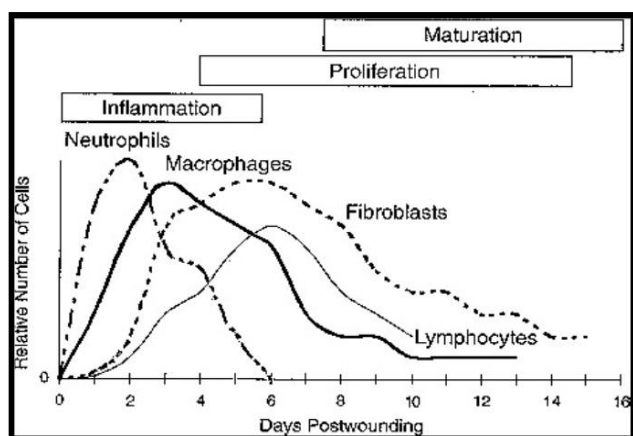


Fig. 3: A timeline plotting the appearance of neutrophils, macrophages, fibroblasts during different phases of wound healing<sup>[19]</sup>

### 2.1.3 Migration:<sup>[15]</sup>

The migration phase involves the movement of epithelial cells and fibroblasts to the injured area to replace damaged and lost tissue. Epithelial cells regenerate from the margins and rapidly growing over the dried scab (clot) which raises the thickness of the wound.

### 2.1.4 Proliferation:<sup>[11, 17]</sup>

The proliferative phase occurs almost simultaneously or just after the migration phases (Day 3 onwards). Here Granulation tissue is formed by growing capillaries and lymphatic vessels into the wound and synthesizing collagens by fibroblasts which give the strength to the skin. By the fifth day, maximum formation of blood vessels and formation of granulation tissue has occurred.

### 2.1.5 Maturation:<sup>[20]</sup>

This phase also called the 'remodeling phase'. In the maturation phase granulation tissue is replaced by fibrous scar tissue. The fibrous scar tissue is shiny and does not contain sweat glands, hair follicles or sebaceous glands. Rearrangement of collagen fibres occur which increase the wound tensile strength.

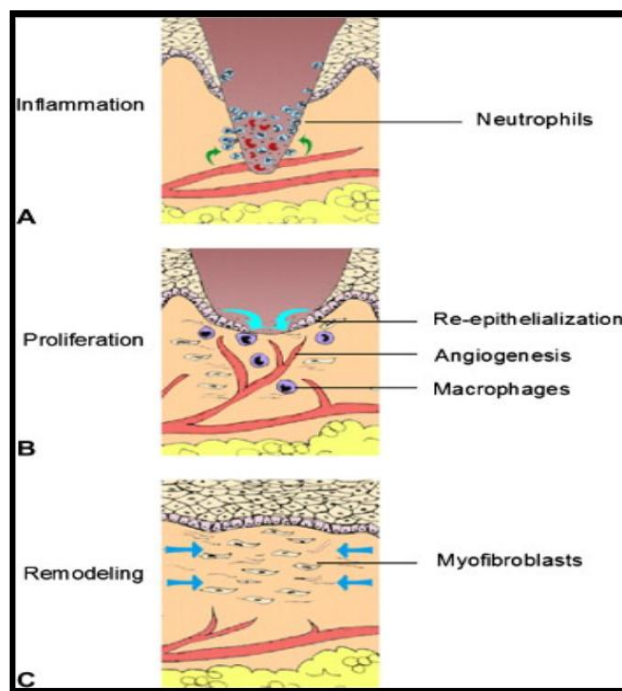


Fig. 4: stages involved in wound healing process. Figure A- Inflammatory phase, Figure B-Proliferative phase and Figure C- Remodeling phase<sup>[21, 22]</sup>

## 3. Wound dressings: Desirable properties:<sup>[23]</sup>

Wound dressings are local therapeutic agents intended to create an optimal environment for wound healing, with specific properties according to the type and physiologic healing stage of the wounds. The ideal properties for wound dressings are directly related to the physiological condition of the wound. This includes

1. Preservation of a humid environment.
2. Creation of a protective mechanical barrier and thermal isolation.
3. Formation of a barrier against secondary infections.
4. Maintenance of the humid environment.
5. Possibility of gas exchange.
6. Absorption of exudates and micro-organisms.
7. Promotion of debridement.
8. Absence of trauma at the site of the healing tissue.
9. Acceptability to the patient
10. Cost/benefit (cost per unit, application time of the dressing period of treatment)
11. Absence of strong toxic, irritant or allergenic potencies.

### 3.1 Classification of wound care dressing:

#### 3.1.1 Adherent dressings:

- a. Film dressings
- b. Simple island dressings

#### 3.1.2 Non-adherent dressings:

- a. petrolatum-impregnated gauze pads
- b. calcium alginate pads

- c. polyester-covered absorbent dressings.
- d. Hydrogel dressings
- e. Hydrocolloid dressings.
- f. Foam dressing

### 1. Adherent dressings:

These may be gauze pads (swabs). Sterile gauze pads may be used as dry or by soaking in sterile saline. These applications are known as 'dry-to-dry' or 'wet-to-dry', and it help to remove necrotic tissue and loose debris [24].

**Dry-to-dry dressings** are used on wounds that are moderately inflamed with obvious debris and pale, translucent-appearing necrotic tissue with watery exudates [25].

#### Wet-to-dry dressings:

It is called a "wet-to-dry" dressing because you place a moist dressing on the exudates which are sticky and allow it to dry. When the dressing is removed, it takes with it the exudate, debris, and nonviable tissue that have become stuck to the gauze.<sup>26</sup> The objective of the wet-to-dry dressing technique is to clean a wound or to prevent build-up of exudate. Wet-to-dry dressings are indicated for wounds that are dirty or infected [27].

#### a. Film dressing:

These dressings can be used as primary or secondary dressings. It is usually not covered by a secondary layer. Film dressings can also be used as a barrier to protect an area of wound and often form part of the construction of other dressing such as hydrocolloids, foam, hydrogel shetts and composite dressing, which are made up of several material with the film being used as the outer layer. film dressing have long history in wound management and are frequently used in day-to-day clinical [28].

The film dressing allows water vapour permission, thus reducing fluid loss from the wound site as well as it is also occlusive to bacteria, thus preventing secondary infection of the wound. The dressing is usually left on wound bed for several days depending on the amount of fluid produced by the wound [29].

This type of wound dressing is that the wound may be visualised without the need to remove the dressing.

#### b. Simple island dressings:

Simple island dressings are only to be used for primary intention like suture line. The dressings have a central pad of cellulose material to absorb any oozing from the suture line during the first 24 hours post-surgery [31].

#### Adherent dressings have several disadvantages:

1. wet-to-dry dressings may need to be changed several times daily in very contaminated wounds.
2. Removal of an adherent dressing is often painful. The patient may require sedation or anaesthesia. Topical anaesthesia is often helpful.
3. Adherent dressings may adhere very strongly to a wound and prove difficult to remove without harming the underlying wound. Addition of a little warmed **sterile** saline can help soften the discharge.
4. Adherent dressings remove the surface of a wound and thus will slow the process of epithelialisation and wound contraction. They must only be used in the initial, inflammatory phase of wound-healing.

### 2. Non adherent dressing:

A non-adherent medical dressing is meant not to stick to the oozing exudates thus easing to removal and causes no pain, trauma or discomfort to the patient or damage to the wound bed. There are many different types of non adherent wound care dressing with some being more effective than others Wound dressings which are coated with silicone, a lipido-colloid contact layer or petroleum emulsion prevent the dressing from adhering to the wound bed from sticking on the wound surface to prevent further damage to the wound on removal. Some examples of no adherent medical dressing are urgotul, mepitel and adaptic [32].

#### a. Petrolatum-impregnated gauze pads:

Petrolatum gauze is a lightweight cotton bandage that is coated with a translucent substance made from petroleum. This type of bandage is used in hospitals and other health care settings. It is a non-adherent dressing that is widely used for various types of wounds. A skin graft is one type of wound on which petrolatum gauze is used. When a skin graft is performed, a section of healthy skin is removed from one part of the body and applied to a wound or burn on another part of the body. The skin graft will usually adhere to the cells surrounding the wound to promote faster healing [33]. Petrolatum gauze is used to cover the skin graft to keep it moist and to promote attachment. Some individuals will have wounds from injury or immobility. On occasion the doctor may order petrolatum gauze dressings to be used on these types of wounds. This dressing will protect the open area from bacteria. It will not stick to the healthy tissue surrounding the wound. Here are very few reported side effects from the use of petrolatum gauze dressings. In rare cases, skin irritation may occur. The petrolatum in this dressing can be an eye irritant. No other side effects from the use of this type of dressing have been reported [34].

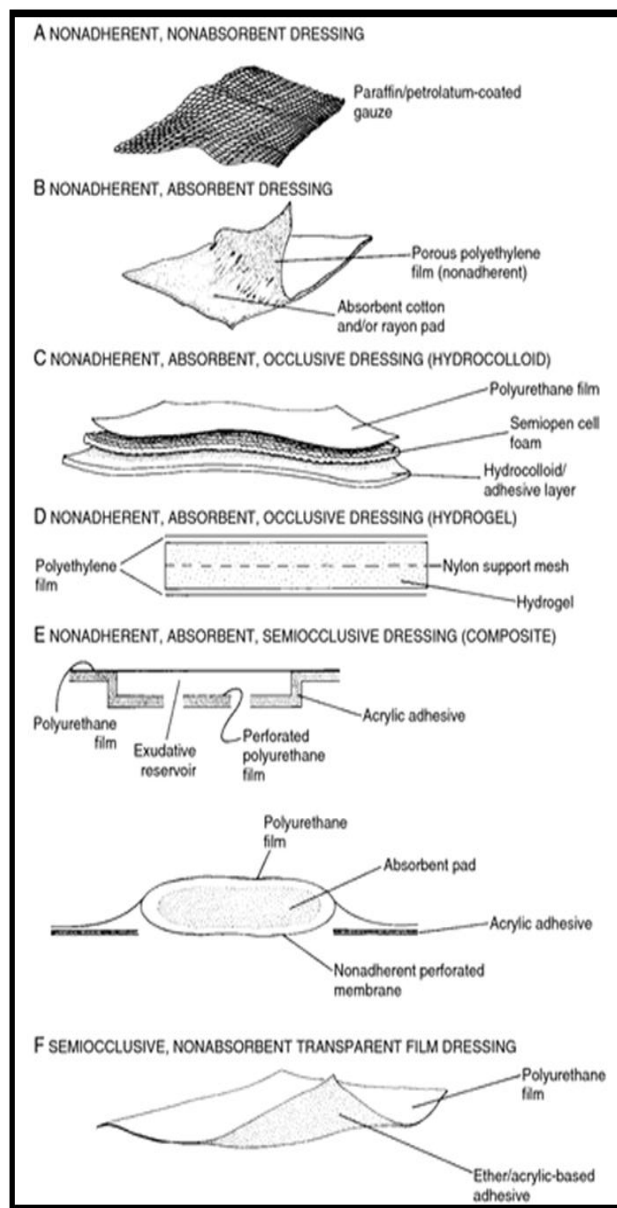


Fig. 5: Wound dressing construction and design [30]

#### b. Alginate dressing:

Alginate product derived from the seaweed with differing ratios of D-Mannuronic and L-Guluronic acid of the alginate and the balance of sodium and calcium alginate within the dressing [35].



Alginates rich in D-Mannuronic form soft amorphous gels that disperse more in solution. Alginates rich in L-Guluronic acid tend to swell more in solution, whilst retaining their basic structure. On contacting blood, the calcium ions in the alginate are exchanged for sodium ions in the blood, increasing the solubility of the dressing i.e. gel-forming [36]. Replacement of some of the calcium ions by sodium ions in the dressing has been proposed to accelerate gel formation but may reduce its ability to activate the clotting cascade [37].

#### c. Hydrocolloids:

Hydrocolloid dressings are composed mainly of cellulose and it is occlusive nature thus it provides moist environment to stimulate new tissue formation which helps to optimal healing of various type of wound. E.g. pressure ulcers, leg ulcers, surgical wounds, abrasions and minor burns [38]. Hydrocolloids have an outer waterproof layer that is impermeable to bacteria also provide thermal insulation enabling the wound bed to remain near body temperature. The inner hydrocolloid layer interacts with wound exudate to form a gel which promotes autolysis. Hydrocolloid dressings are much more complicated than hydrogels because they contain a variety of constituents, such as methylcellulose, pectin, gelatin, and poly isobutylene [39], some of them also contain alginate. After contact with the wound surface, hydrocolloids slowly absorb fluids, leading to a change in the physical state of the dressing and to the formation of gel covering the wound. Thus, they are called interactive dressings.

Depending on the choice of product, hydrocolloids are suitable for the dressing of both acute wounds and chronic wounds. Initially, hydrocolloid wound dressings need to be changed daily (depending of the exudate level), but, once the exudate has diminished, dressings may be left on the wound surface for up to 7 days. With a few exceptions, hydrocolloids require a secondary dressing to be fixed in place. Hydrocolloids should not be used on infected wounds [40].

#### d. Foam dressings:

Hydro cellular foam dressing's use on moderate to highly exuding wounds. The dressings absorb, retain and transpire to achieve the optimal balance of fluid. This process helps to promote faster healing by maintaining an optimal wound healing environment and reduce the risk of maceration by not allowing the wound to become too wet [41]. Adhesive foam dressings are also used as secondary dressings to help primary dressings remain in the wound bed while also assisting with absorbency. Foam dressings are not associated with debriding wounds [42].

#### e. Silicon Dressings:

A soft silicone dressing is a dressing coated with a soft silicone as an adhesive or a wound contact layer. The intrinsic properties of soft silicone are such that these dressings may be removed without causing trauma to the wound or to the surrounding skin. There are different types of soft silicone dressings including a traumatic wound contact layers, absorbent dressings for exuding wounds and also a dressing for the treatment of hypertrophic scars and keloids [43]. The soft silicone cannot enter the circulatory system. It is insoluble in wound exudate and the silicone molecules are too big to penetrate through cell membranes or pass through the skin into blood vessels. They therefore cannot be transported around the body to produce any systemic effects. 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 [44].

#### f. Collagen Dressings:

Collagen is the fibre forming protein of mammalian connective tissues. It is the major component of the extracellular matrix forming an organized structure bridging the basal cells to epidermis [45]. At least 10 different types of collagen have been identified. In the wound dressing applications, the collagen has haemostatic and absorbent functions [46].

#### g. Hydrogel:

Hydrogels are hydrophilic natured three-dimensional networks, held together by chemical or physical bonds. Hydrophilic groups such as hydroxyl (OH) and carboxyl (COOH) on the polymer chains absorb and store water. If enough interstitial space exists within the network, water molecules can become trapped and immobilized, filling the available free volume. This is the quality that brings about the specific benefit of hydrogels in wound treatment [44]. They immediately function as moist wound dressings. At the same time they are capable of absorbing contaminated exudates and safely retaining them within the gel structure. The absorption of secretions causes an expansion of the cross-links in the polymer chains. The basic physical features of hydrogel dressings can be specifically modified, according to the properties of the polymers used [47].

Hydrogels save the wound from fluid loss, are capable of providing the lesion with additional moisture, and securely protect it against external noxae. Under the dressing a micro climate is developed, that stimulates and regulates all cellular activities and nutritional processes during the individual phases of wound healing. Additional advantages such as transparency, cushioning effect, cooling effects etc. considerably increase the utility value of hydrogels, in particular concerning patient comfort and ease of application. The transparent hydrogels have the advantage in that the wound healing process can be easily monitored without removing the dressing [48]. The high moisture content and the soft-elastic, cushioning properties of the hydrogel almost act like a "second skin". The hydrogel dressing removal is almost painless because hydrogel does not stick to the wound but it remains intact in the wound site due to the presence of hydrophilic groups, which forms secondary bonds with the hydrophilic groups at the wound surface [49]. Hydrogel stays permanently moist and can even after prolonged application be removed without pain and risk of wound irritation. Moreover, malodour is reduced with hydrogel dressings, because the odour molecules are retained in the gel structure along with the absorption of secretions. The treatment of wounds with hydrogels may bring about great relief for both the patient and the nursing staff. The acceptance of a wound therapy with hydrogel is thus, in general, very high on the part of the patient [50].

#### 4. New Treatment Modalities for wound treatment:

##### 4.1. Vacuum-Controlled Assisted Closure (VAC) Therapy:

VAC Therapy is a system that uses controlled negative pressure (vacuum) to help promote wound healing. Clinical studies demonstrate that the VAC Therapy System also removes infectious materials and other fluids from the wound. The VAC Therapy System employs a computer-controlled therapy unit to maintain a constant negative pressure on the wound site [51].

##### 4.2. Apligraf:

A bilayered skin substitute that has brought relief to thousands of patients suffering from venous leg ulcers and other types of hard-to-heal wounds [52].

##### 4.3. Hyperbaric Oxygen Therapy:

Hyperbaric Oxygen Therapy is one of several modalities available at the Advanced Wound Healing Centers. It involves placing the patient in a specially-designed chamber that administers a 100 percent oxygen-rich environment under slight pressure. Oxygen reaches the wound through the bloodstream, resulting in improved healing, greater blood vessel formation, and reduced likelihood of infection. This treatment provides a non-invasive procedure for patients with difficult wounds, crush injuries, acute burns, or diabetes-related ulcers [53].

#### 5. New product for wound dressing:

Woundres™ Collagen Hydrogel (Coloplast) [54], Wound Drainage Collector (Hollister) [55], Wound Manager™ Drain Pouch With Skin Barrier (Convatec) [56] Provides a balance between absorption of low to moderate exudate and the release of moisture to rehydrate a dry wound with barrier for wounds.



Fig. 6: New product for wound dressing

## 6. Wound dressing product available in the market:

Table No. 1: Wound dressing product available in the market

Sr. No.	Type of Dressing	Brand Name	Company name
1	Adherent Absorbent Dressing <sup>[57]</sup>	Mepilex™	Molnlycke Healthcare
2	Island Dressing <sup>[58]</sup>	Telfa®	Kendall
3	Gauze Dressing <sup>[59]</sup>	Aquaphor®	Smith & Nephew
4	Alginate Dressing <sup>[60-62]</sup>	Maxorb® Extra	Medline
		Silvasorb™	Medline
		Algisite® M	Smith & Nephew
		Curasorb™	Kendall
5	Foam Dressing <sup>[63]</sup>	Optifoam®	Medline
6	Hydrogel <sup>[64, 65]</sup>	Aquacel® Hydrofiber®	Convatec
		Skintegrity®	Medline
7	Hydrocollide <sup>[66, 67]</sup>	Comfeel® Plus	Coloplast
		Duoderm® Cgf®	Convatec
		Medline Exuderm®	Medline

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**Conflict of interest:** The authors have declared that no conflict of interest exists.

**Source of support:** Nil