

A Thoroughgoing Detail of Surgical Dressings

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Abstract

Injury to the skin provides a unique challenge, as wound healing is a complex and intricate process. Acute wounds have the potential to move from the acute wound to chronic wounds, requiring the physician to have a thorough understanding of outside interventions to bring these wounds back into the healing cascade. Surgical enrichment/dressings are applications for wounds, burns, and ulcers. They should be regarded as supportive of healing; are desirable but not essential in an emergency. There are currently plenty of dressings available in the market to aid in wound healing. Before choosing a dressing for a specific injury, a physician must assess carefully the needs of the wound to understand which dressing would ensure maximum interest. Basically, there is nothing called best choice, and it is crucial that the merits/demerits of each dressing system be understood. This article has provided a framework to assist in dressing assessment. This article reveals measurement of wound healing and the functions of wound dressings. A variety of dressings and their respective details are detailed.

Purpose of the Study: Discussion and projection of wound healing by market available surgical supplies. The present review traces the history of dressings from its earliest inception to the current status and also discusses the advantage and limitations of the dressing materials.

Findings: There is an overwhelming amount of wound dressings available in the market. Modern world and technology gave rise to various way of wound healing with enrichments. Almost all sorts of enrichments are available in surgical outlets; a few of them are confined to hospital settings. This implies the lack of full understanding of wound care and management. The point of using advanced dressings is to improve upon specific wound characteristics to bring it as close to "ideal" as possible. It is only after properly assessing the wound characteristics and obtaining knowledge about available products that the "ideal" dressing may be chosen.

Materials and Methods: Research conducted a year-round comprehensive literature search, which included technical newsletters, newspapers journals, and many other sources. The present study was started from the beginning of 2018. PubMed, ALTAVISTA, Embase, Scopus, Web of Science, and the Cochrane Central Register of were thoroughly searched. The keywords were used to search for different publishers' journals like Elsevier, Springer, Willey Online Library, Wolters Kluwer were extensively followed. Medicine and technical experts, pharma company representatives, hospital nurses and chemists were given their valuable suggestions. Projections were based on different types of surgical supplies available in home and abroad.

Research Limitations: Pictorial presentations of so many types of dressings are not possible to reproduce in an article but for a quick review, the article comprises most of them. Also, sutures are not detailed which will be encompassed by the next article

Practical Implication: The sole of this article was to detail several types of surgical supplies. Along with students, researchers and professionals of different background and disciplines, eg: Therapists, surgery associates, doctors, nurses, hospital authorities and pharmacists have to acquire much from this article.

Keywords: Wound Dressing; Gauzes; Absorbent; Cotton Fiber; Mesh; Sponges; Napkins

Background

Wound healing is a dynamic and complex process which requires suitable environment to promote healing process. Historically, wet-to-dry dressings have been used extensively for wounds requiring debridement. In 1600 BC, Linen strips soaked in oil or grease covered with plasters was used to occlude wounds. Clay tablets were used for the treatment of wounds by Mesopotamian origin from about 2500 BCE. They cleaned wounds with water or milk prior to dressing with honey or resin. Wine or vinegar usage for cleaning the wounds with honey, oil and wine as further treatment was followed by Hippocrates of ancient Greece in

460- 370 BCE. They used wool boiled in water or wine as a bandage. There was a major breakthrough in the antiseptic technique during the 19th century, antibiotics were introduced to control infections and decrease mortality. Modern wound dressing arrival was in 21th century. Woven absorbent cotton gauze was used in 1891. Until the mid-1900's, it was firmly believed that wounds healed more quickly if kept dry and uncovered whereas 'closed wounds heal more quickly than open wound' written in an Egyptian medical text -Edwin smith surgical papyrus in 1615 BC. Oscar Gilje in 1948 describes moist chamber effect for healing ulcers. In the mid 1980's, the first modern wound dressing was introduced which delivered important characteristics providing moisture and absorbing fluids (e.g. polyurethane foams, hydrocolloids, iodine-containing gels). During the mid-1990's, synthetic wound dressings expanded into various group of products which includes hydrogels, hydrocolloids, alginates, synthetic foam dressing, silicone meshes, tissue adhesives, vapor-permeable adhesive films and silver/collagen containing dressing. When the wound is closed with dressing they are continuously exposed to proteinases, chemotactic, complement & growth factors, which is lost in the wound exposed. So, during late 20th century, production of occlusive dressing began to protect and provide moist environment to wound. This dressing help in faster re-epithelialization, collagen synthesis, promotes angiogenesis by creating hypoxia to the wound bed and decreases wound bed pH which leads to decrease in the wound infection. With the advancement in technology, more than 3000 products have been developed to treat different types of wounds by targeting various aspects of healing process.



Figure 1: Surgical dressing for wound healing (Source: 4g Inwi Configuration)

Introduction

A professional service rendered by many pharmacists consists of supplying surgical instruments, sutures, surgical dressings, and other equipment employed by the surgical personnel during and after a surgical operation (Figure1). Some pharmacists who have obtained the necessary background of information carries a complete line of such supplies and even are able to provide operating tables and other heavy equipment. There are comparatively few such completely equipped pharmacies; the major outlet is through surgical supply houses. Every pharmacist, however, should be familiar with two of the products mentioned above, namely, Surgical Dressings and Sutures, which are discussed in detail below. The selection of the correct type of surgical dressing or suture is a crucial factor in protecting the welfare of the patient undergoing surgery. Many items in these categories are handled routinely by pharmacists, and all of these items come within the purview of their professional responsibility.

Types of Wounds

An acute wound is an injury to the skin that occurs suddenly due to accident or surgical injury. It heals at a predictable and expected time frame usually within 8-12 weeks depending on the size, depth and the extent of damage in the epidermis and dermis layer of the skin. Chronic wounds generally result from decubitus ulcer, leg ulcer and burns. Wound healing is a dynamic and complex process of tissue regeneration and growth progress through four different phases (i) the coagulation and hemostasis phase (immediately after injury); (ii) the inflammatory phase, (shortly after injury to tissue) during which swelling takes place; (iii) the proliferation period, where new tissues and blood vessels are formed and (iv) the maturation phase, in which remodeling of new tissues takes place (Figure 2 and 3).

There are a limited number of reasons a wound becomes chronic; however, once these reasons are rectified, the wound resumes its natural course of healing.

- Arterial: Generally speaking, an ABI of less than 50 mm Hg, or an absolute toe pressure less than 30 mm Hg (or less than 50 mm Hg for persons with diabetes) indicates critical limb ischemia and predicts failure of wounds to heal.

- **Venous:** Pressure-induced changes in blood vessel wall permeability then lead to leakage of fibrin and other plasma components into the perivascular space. Accumulation of fibrin has direct and negative effects on wound healing as it down-regulates collagen synthesis.
- **Infection:** Underlying infectious processes including cellulitic and osteomyelitis processes will inhibit wound healing. Culturing for aerobic, anaerobic, and fungal pathogens is recommended.
- **Pressure:** Increased pressure to the area of concern will destroy new tissue growth and prevent proper perfusion of blood to the wound site. These areas need to be offloaded to avoid pressure in the area.
- **Oncologic:** Always biopsy areas of concern in nonhealing wounds, as this can be an atypical presentation of some types of malignancies.
- **Systemic:** There are multiple systemic diseases which inhibit wound healing, with diabetes being the most common culprit. It has been determined that uncontrolled blood glucose levels suppress the body's normal inflammatory response, as well as causing microvascular disease which limits healing.
- **Nutrition:** While serum albumin has not been found to be a good predictor wound healing, there is some evidence that protein malnutrition, as well as insufficient levels of certain vitamins and minerals, will limit the body's ability to heal chronic wounds.
- **Pharmacological:** Hydroxyurea has been reported in multiple instances to cause nonhealing ulcerations.
- **Self-inflicted/psychosocial:** There are instances where a patient is causing the ulceration, either on purpose or as a result of noncompliance. This is often the hardest factor to spot and overcome, but must always be a consideration (Figure 3 and 4) [1-7].

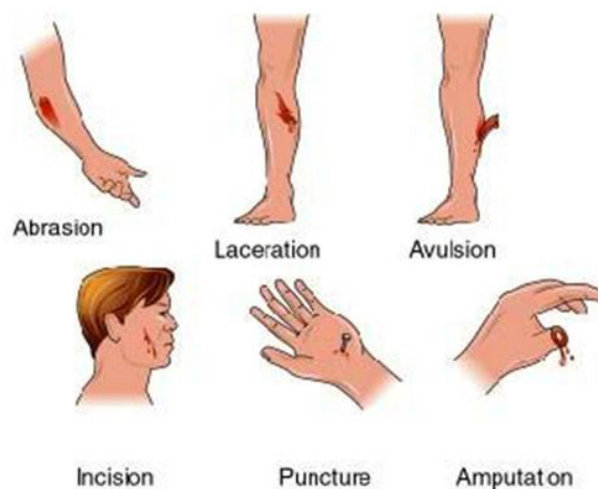


Figure 2: Types of wounds (Source: Blog wound infection management tips Saturday, May 22, 2010)

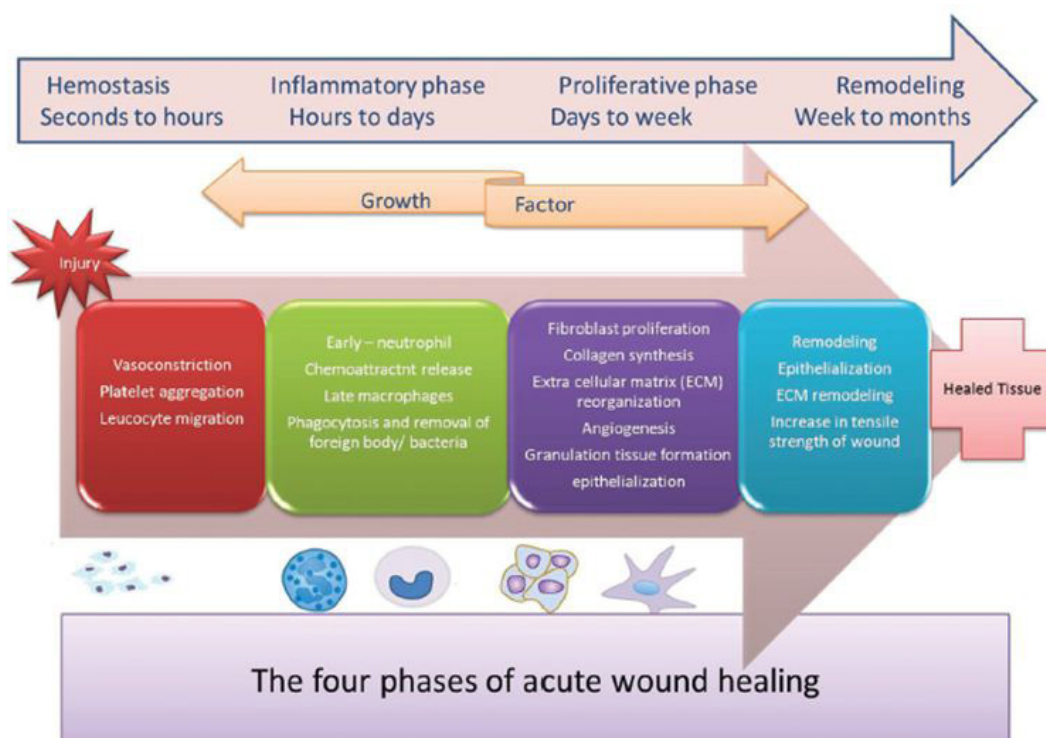


Figure 3: Distinct and overlapping phases of wound healing [4]

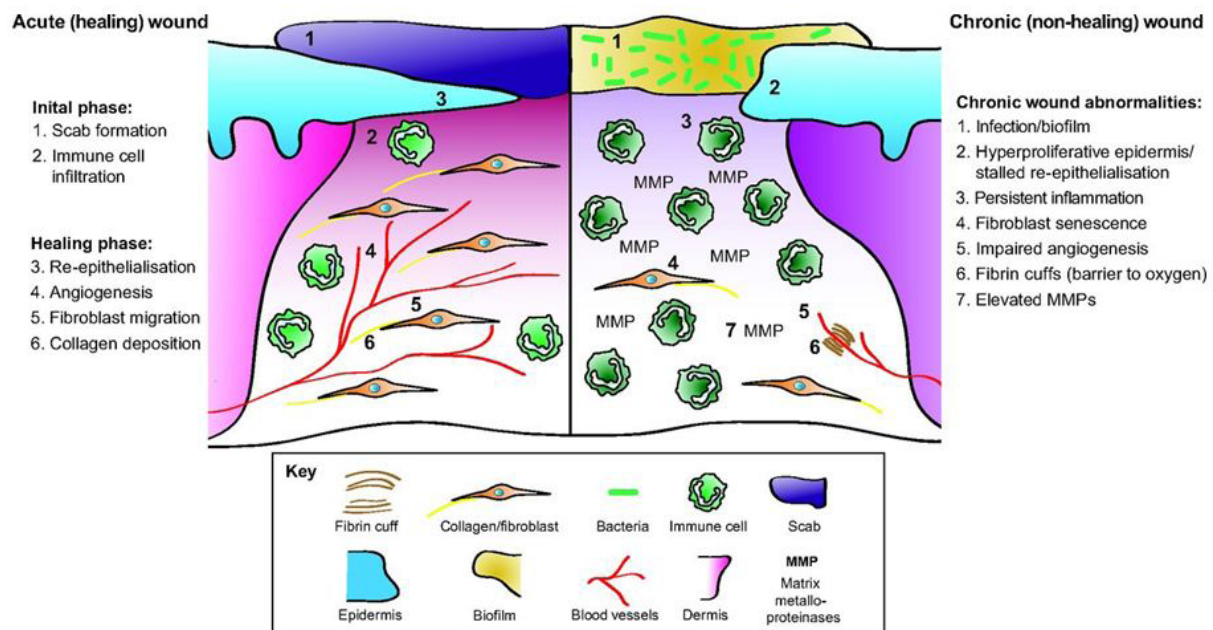


Figure 4: The cellular and molecular differences between acute healing wounds and chronic non-healing wounds [7].

The healing of acute wounds (left) initiates with a transient inflammatory response as granulation tissue is formed, which provides an environment suitable for the re-epithelialization required to complete repair. Chronic non-healing wounds (right) are often infected and exhibit persistent inflammation. By definition, re-epithelialization has stalled but is hyper-proliferative. Granulation tissue is sub-optimal with elevated matrix metalloproteinases (MMPs) present together with poor fibroblast and blood vessel infiltration. Fibrin cuffs can also be present that prevent the diffusion of oxygen through the wound, rendering it hypoxic.

Uses of Dressings

Surgical dressing is a term applied to a wide array of products used for dressing physical injury or diseased tissues. Dressings may serve to

- Provide an environment for moist wound healing. Desiccation of a wound is a major factor in ameliorating injury healing and increasing seaming. Dressings that prevent desiccation provide an optimal environment for autolysis cell migration, granulation, and re-epithelialization.
- Prevent maceration by permitting evaporation or absorption. In highly secretory injuries, excessive moisture and autolytic enzymes will impair repairing tissue and will increase chances of microbial infection.
- Promote hemostasis.
- Protect the wound from further damage (mechanical damage, microbial invasion, dehydration, maceration, chemical damage, alteration in pH).
- Reduce heat loss.
- Control microbial growth (by incorporation of antimicrobial drugs).
- Promote autolysis.
- Promote healing.
- Provide compression, promoting hemostasis, and reducing edema.
- Provide support.
- Reduce pain, increase patient comfort, and improve functional use of Wound site.
- Reduce odor.
- Improve the appearance of the wound site.
- Reduce overall costs associated with wound treatment [8-12], [13].

Selection of Wound Dressing

Based on the wound type, suitable dressing material must be used. Dressing selection should be based on its ability to a) provide or maintain moist environment b) enhance epidermal migration c) promote angiogenesis and connective tissue synthesis d) allow gas exchange between wounded tissue and environment e) maintain appropriate tissue temperature to improve the blood flow to the wound bed and enhances epidermal migration f) provide protection against bacterial infection and g) should be non-adherent to the wound and easy to remove after healing h) must provide debridement action to enhance leucocytes migration and support the accumulation of enzyme and i) must be sterile, non-toxic and non-allergic. Also, selection should be made on the basis of the

degree of exudation, presence or likelihood of infection, presence of necrotic tissue, and anatomical site. The correct selection of a wound dressing depends not only on the type of wound but also on the stage of repair. The use of a wound dressing cannot be considered in isolation, but rather in the context of an integrated wound-care program [14-19].

Types of Wound Dressings

Within this classification, dressings are considered on the basis of use.

- Primary/secondary wound dressings
- Secondary dressings
- Absorbents
- Bandages
- Adhesive tapes
- Protectives [20,21]

Specifications

Surgical dressings and sutures are required to meet specific requirements of the USP for many characteristics. For these specific requirements and the performance of several of the official tests, eg, Absorbency test and Fiber length of cotton, Diameter of sutures, and Tensile strength of sutures, textile fabrics, and films refer to the detailed instructions provided in the USP [21-25].

Classification

Practically, the elemental method of classification uses the terms primary and secondary dressing. A primary dressing directly contacts the wound. It may provide absorbability and may prevent desiccation, infection, and adhesion of the secondary dressing to the wound. A secondary dressing is placed over a primary dressing, providing further safeguard, absorbability, compaction, or occlusion [13,26-29]. Although some dressings are solely primary or secondary in nature, others have the characteristics of both. The following classification is used here:

Primary Wound Dressings

Plain Gauze: has been used as a primary dressing but will stick to all but clean, engraved wounds. Although this property has been used to unbridle exudative, infected, and necrotic wounds, this practice may be painful and is often dysfunctional, causing the removal of contusion tissue and new epithelium [13,16,30]. Gauze and non-woven wound dressings are dry woven or non-woven sponges and wraps with varying degrees of absorbency, based on design. Fabric composition may include cotton, polyester or rayon. Available sterile or non-sterile in bulk and with or without an adhesive border. They are used for cleansing, packing and covering a variety of wounds (Figure 5) [31].



Figure 5: White Plain Gauze Bandage (Source: Web India mart)

Impregnated Gauze: is used to reduce its adherence to wounds. Cotton, rayon, or cellulose acetate gauze has been impregnated with a variety of substances such as petroleum or paraffin (Aquaphor, Beiersdorf, Vaseline (Sherwood), KY jelly (Johnson & Johnson), petrolatum emulsion (Adaptic, Johnson & Johnson), zinc saline (NutraDress, Derma Sciences), or sodium chloride (mesalt, SCA Molnlycke). Coatings may wear off, allowing epithelial ingrowth and necessitating a dressing change [32-35]. Agents most commonly used include saline, oil, zinc salts, petrolatum, xeroform and scarlet red. Indications vary based on the compound. They are non-adherent and require a secondary dressing. A secondary dressing should be used with these dressings to prevent desiccation, provide absorbency, and prevent the entrance of pathogens. When used with an appropriate secondary dressing, these

dressings may be used in heavily exuding wounds [21,31]. Silver, in ionic or nanocrystalline form, has for many years been used as an antimicrobial agent particularly in the treatment of burns (in the form of silver sulfadiazine cream). Iodine also has the ability to lower the microbiological load in chronic wounds. Caution is required in patients with a thyroid disease owing to possible systemic uptake of iodine. Metronidazole gel is often used for the control of odor caused by anaerobic bacteria (Figure 6) [16].



Figure 6: Dermagran SPD-21 Hydrophilic Impregnated Gauze Wound Dressings 4" x 4" - Box/15 (Source: eBay)

Film Dressings: (transparent film, occlusive or semi-occlusive) are films of polyurethane with acrylic or polyether adhesives that provide a semipermeable membrane to water vapor and oxygen yet are waterproof. Suitable for flat, shallow wounds with low to medium exudates. Promote moist environment. Adhere to healthy skin but not to wound. Allow visual checks. May be left in place several days. Provide no cushioning. Not for infected or heavily exuding wounds [16]. In lightly exuding injuries they permit enough dissolution to promote moist wound healing and prevent maceration. Film dressings eliminate bacteria from injuries and



Figure 7: Transparent Film Dressing (Source: Wound Care Advisor)

permit bathing and attention of the wound. Film dressings will adhere well to intact skin and have a low adherence for wound tissue. They should not be used in infected or heavily exuding wounds. Film dressings may wrinkle, forming channels for microbial entrance. Difficulty in handling film dressings has been overcome by special design of various application systems [36]. In addition to their use as wound dressings, adhesive films have been used to protect areas vulnerable to pressure, friction, or shear ulceration or for infusion or cannulation sites. These dressings are highly elastic and flexible, and can conform to any shape and do not require additional taping. Inspection of wound closure is also possible without removal of wound dressing because of transparent films. Hence these dressings are recommended for epithelializing wound, superficial wound and shallow wound with low exudates [3]. Examples of transparent film dressings are Opsite™, Tegaderm™, Biooclusive™, Bioclusive (R) Transparent Dressing (Johnson & Johnson), Opsite (Smith & Nephew), Tegaderm (3M), and Derasite (Derma Sciences) (Figure 7) [37-41].

Primary/Secondary Wound Dressings

Composite Dressings have primary and secondary components that prevent adherence to the wound, with some degree of absorbency. The degree of occlusion provided by these dressings varies. Release (Johnson & Johnson), Telfa (Kendall), and Melolin (Smith and Nephew) consist of lightly absorbent rayon or cotton pads sandwiched between porous polyethylene films. Nu-Derm (Johnson & Johnson) and Lyofoam A (Seton Healthcare Group) consist of polyurethane foams with a film backing [32,42-44]. A composite or a combination dressings dressing has multiple layers and each layer is physiologically distinct. Most of the composite dressings possess three layers. Composite dressings are wound covers that combine physically distinct components into a single product to provide multiple functions, such as a bacterial barrier, absorption, and adhesion. Usually, they are composed of multiple layers and incorporate a semi- or non-adherent pad that covers the wound. May also include an adhesive border of non-woven fabric tape or transparent film [26]. Outer most layer protect the wound from infection, middle layer usually composed of absorptive material which maintains moisture environment and assist autolytic debridement, bottom layer composed of non-adherent material which prevents from sticking to young granulating tissues. Composite dressings have less flexibility and they are more expensive (Figure 8) [45].



Figure 8: Composite Dressing (Source: Fashion Herald)

Hydrogels: Hydrogels are insoluble hydrophilic materials made from synthetic polymers such as poly (methacrylates) and polyvinyl pyrrolidone. The high water content of hydrogels (70-90%) helps granulation tissues and epithelium in a moist environment. They are complex lattices in which the dispersion medium is trapped rather like water in a molecular sponge. Hydrogels are nonadherent dressings that through semipermeable film allow a high rate of evaporation (and cooling) without compromising wound hydration. This makes them useful in burn treatment. Hydrogels are also very useful in hairy areas where entrapment of hair into the dressing would not be traumatic [46,47]. Soft elastic property of hydrogels provides easy application and removal after wound is healed without any damage. Temperature of cutaneous wounds is decreased by hydrogels providing soothing and cooling effect. Amorphous hydrogel dressings are formulations of water, polymers and other ingredients with no shape, designed to donate moisture to a dry wound and to maintain a moist healing environment. The high moisture content serves to rehydrate wound tissue. Indicated for partial- and full-thickness wounds, wounds with necrosis, minor burns, and radiation tissue damage. Impregnated hydrogel wound dressings are gauzes and non-woven sponges, ropes and strips saturated with an amorphous hydrogel

[31]. Examples of hydrogels are Geliperm (Geistlich), Vigilon (Bard), Flexderm (Dow Hickam), and Nu- Gel (Johnson & Johnson). The latter is held together with a fusible fiber scrim (Figure 9) [48-51].



Figure 9: Hydrogel Sheet Dressing (Source: Healthy Kin)

Hydrocolloid Dressings: combine the benefits of occlusion and absorbency. Hydrocolloids are dispersions of particles around which water molecules and solvated ions form a shell-like structure. Fluid absorption occurs primarily by particle swelling and enlargement of this structure. The hydrocolloid mass of these dressings consists of gum-like materials, such as guar or karaya, sodium carboxymethylcellulose, and pectin, bound by an adhesive such as polyisobutylene. Hydrocolloid dressings display wet tack (adhesion to a wet surface) because of particle swelling. This property facilitates atraumatic removal. The dry tack of hydrocolloid dressings is due to an adhesive such as polyisobutylene, which is inactivated by moisture [46]. The dry tack retained by the dressing around the wound preserves the edge seal. Exudate absorption by most hydrocolloid dressings results in the formation of a yellow/brown gelatinous mass that remains on the wound after dressing removal. This may be eliminated from the wound and should not be confused with pus. Because hydrocolloids absorb water slowly, they are of little use on acutely exuding wounds. They are, however, very useful for moderately to highly exudative chronic wounds. Examples of hydrocolloid dressings include Duoderm (ConvaTec), Comfeel Plus (Coloplast), and RepliCare (Smith & Nephew) [52-55].



Figure 10: Hydrocolloid Dressings (Source: health.planetfem.com)

Hydro-cellular foam dressing: Modern wound dressing induces moist wound environment and promotes wound healing. Gauze encourages scab formation, which impairs epithelialization and increases vascular endothelial growth factor (VEGF) expression. In contrast, hydro-cellular foam dressing accelerates epithelialization and new vessel formation in granulation tissue [56]. Hydro

cellular Foam Dressings with Silicone Adhesive are indicated for use on a wide range of acute and chronic wounds like venous leg ulcers, pressure ulcers, diabetic ulcers and traumatic wounds [31]. Hydro cellular foam dressing has become a first choice for the treatment of moderately to heavily exuding wounds which require excessive wound debridement for providing optimum conditions at the wound site while maintaining a moist wound environment [57,58]. may promote wound healing along with decrease in inflammation by reducing gene expression levels of IL-1 β , IL-6, and IL-10 [59]. Hydro cellular foam dressing (HCF) absorbs excessive wound fluid, which contains various cytokines and growth factors, and ensures a moist environment to promote wound healing. However, the molecular mechanisms underlying the wound fluid component changes induced by HCF are poorly understood. dermal fibroblast proliferation is up regulated by HCF due to increased leptin level at the wound surface, and these effects promote wound healing (Figure 11) [60].

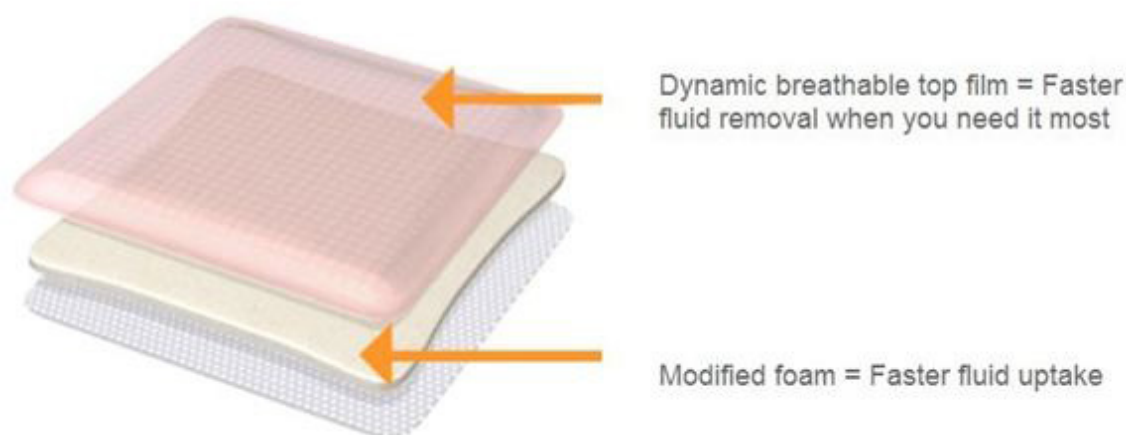


Figure 11: Allevyn Adhesive Hydrocellular Foam Dressings (Source: HighTideHealth.com)

Calcium Alginate Dressing: Calcium Alginate Dressings are a strong, versatile, and natural wound care dressing typically applied to diabetic wounds, venous wounds, full-thickness burns, split-thickness graft donor sites, pressure ulcers, cavity wounds, and chronic ulcers. Alginate dressings can also help wounds that are bleeding [47]. The calcium in these dressings helps stabilize blood flow, which slows bleeding [13]. Alginic acid is a naturally occurring polysaccharide derived from brown seaweeds. As the calcium salt, these fibrous nonwoven dressings are highly absorbent and are used on moderately to highly exuding wounds [14]. They may be held in place with gauze tape or a film dressing. They also may be used to pack wounds (Figure 12). Alginate dressings can absorb up to 20 times their weight in wound fluid [13,14]. Examples of calcium alginate dressings are Sorbsan (Dow Hickam), Algosteril (Johnson & Johnson), and Kaltostat (Calgon Vestal) (Table 1) [61-65].

Commercially Names	Composition	Applications
Algicell™	Sodium alginate, 1.4% silver	Diabetic foot ulcer, leg ulcers, pressure ulcers, donor sites, and traumatic and surgical wounds.
AlgiSite M™	Calcium alginate	Leg ulcers, pressure ulcers, diabetic foot ulcers and surgical wounds.
Comfeel Plus™	Sodium carboxymethylcellulose and calcium alginate	Ulcers such as venous leg ulcers, pressure ulcers; burns, donor sites, postoperative wounds and necrotic wounds.
Kaltostat™	Sodium alginate	Pressure ulcers, venous ulcers, diabetic ulcers, donor sites, and traumatic wounds.
Sorbsan™	Calcium alginate	Arterial, venous, and diabetic leg ulcers Pressure ulcers, post-operative wounds, donor and graft sites and traumatic wounds.
Tegagen™	Sodium alginate	Diabetic and infected wounds.
Guardix-SG®	Sodium alginate and poloxamer	To avoid post-operative adhesions in thyroid and spine surgeries.
SeaSorb®	Calcium alginate	Good for high exuding wounds e.g., ulcers such as diabetic and leg pressure ulcers.
Algivon®	Calcium alginate and Manuka honey	It eliminates odour and ideal for necrotic wounds and wounds with odours.
Fibracol™ Plus	Calcium alginate and collagen	Full and partial-thickness wounds, for ulcers such as pressure ulcers, venous ulcers, diabetic ulcers and second-degree burns.
Hyalogran®	An ester of hyaluronic acid and sodium alginate	Used for ulcers, diabetic wounds, pressure sores ischemic, necrotic wounds.
Tromboguard®	Sodium alginate, calcium alginate, chitosan, polyurethane and silver cations	Used to stop bleeding in postoperative wounds, traumatic wounds, gun shots, skin graft donor sites, bleeding from accidents.

Table 1: Commercially available alginate-based dressings [66]



Figure 12: Maxorb Ag+ Cmc / Alginate Dressings (Source: Home Medical Supplies)

Secondary Wound Dressings

Absorbents

Surgical Cotton: Cotton is the basic surgical absorbent. It is official Purified Cotton USP. *Domestic cotton* grown in the Southern US is suitable for surgical purposes. The domesticated cotton plant reaches a height of 2 to 4 ft. Growing from the seeds is a pod or boll that bursts open upon ripening, exposing a mass of white cotton fibers. Each of these fibers is a minute, hair-like tube, the outer wall being pure cellulose, the opening filled with plant fluids. When the boll bursts open, the fiber collapses into a flat ribbon-like form, twisted and doubled upon itself more than 100 times from end to end. Citric acid can be used both for the disposable (non-durable) materials (gowns, masks, and cuffs for blood pressure measurement) and the materials that require durability to laundering [62,67]. *The raw cotton fiber*, mechanically cleaned of dirt and carded into layers but not otherwise treated, has a limited use for paddings and coverings of unbroken surfaces. This form is supplied under the name nonabsorbent cotton. It also is used frequently as cotton plugs in the bacteriological laboratory because of its non-absorbency [68]. Absorbent Cotton is prepared from the raw fiber by a series of processes that remove the natural waxes and all impurities and foreign substances and render the fibers absorbent. It is a practically pure, white cellulose fiber. Besides the familiar roll form, Purified Cotton may be obtained in various prepared forms such as cotton balls or cotton-tipped applicators [68]. *Recent studies* have shown that chronic wounds contain high levels of tissue and cytokine destroying proteases including collagenase and neutrophil elastase. The reduction in enzyme activity with dialdehyde cotton gauze was confirmed in solution by determining elastase inhibition with dialdehyde starch. The dialdehyde cotton gauze also decreased elastase activity in human wound fluid in a dose response relation based on weight of gauze per volume of wound fluid [69]. Absorbent cotton demonstrates excellent moisture-absorbing and water-retaining properties, and absorbed molecules can be successfully trapped among AC fibers without producing gravity water. However, fine fibers are prone to remain in the wounds even after removal [70]. *Absorbent balls* made of a uniform surgical viscose-rayon fiber also are available. These absorb fluids faster and retain their shape better than cotton balls. *Nonabsorbent Bleached Cotton*, prepared by a modified bleaching process that retains the water-repellent natural oils and waxes, also is available. This cotton is identified easily by its silky feel. Because it is repellent to water, it does not become matted or inelastic. Consequently, it is well-adapted to packing, padding, and cushioning of dressings over traumatized areas and as nonabsorbent backing on sanitary napkins, combines, and drainage dressings. Well bleached and carded cotton having absorbency not less than 12 hours is used in pharmaceutical, maintaining aseptic conditions for manufacturing process and also for packing purposes. Non-absorbent bleached cotton has water repellent properties because while cleansing off fibers the natural wax is retained [71-73]. *Rayon*, or regenerated cellulose, is made from wood or cotton linters. After dissolving it in a mixture of alkali and carbon disulfide, cellulose thread is precipitated in an acid-coagulating bath by passage through fine holes in a metal plate. Because plant lignins have been removed, as well as the more circular cross section, rayon fibers are softer and more lustrous than cotton [74-79].

Surgical Gauzes: The function of surgical gauze is to provide an absorbent material of sufficient tensile strength for surgical dressings. It is known as Absorbent Gauze USP. In the process of making surgical gauze, the raw cotton fiber is cleaned mechanically and then spun or twisted into a thread, and the thread in turn is woven into an open-mesh cloth that is gray and nonabsorbent. It is bleached white and offered absorbent by much the same processes as those used in the readiness of surgical cotton [71]. The gauze thus treated is dried by passing a continuous length through a tentering machine. Tenterhooks straighten, stretch, and hold it taut as it is dried. When it leaves this equipment, the dried gauze is cut into lengths, folded, rolled, and packed. Gauze is classified according to its mesh, or number of threads per inch [74,80]. Some types of surgical dressing require close-meshed gauze

for extra strength and greater protection, while other uses such as primary wound dressings, absorbent secondary dressings, and larger dressings to absorb purulent matter or other drainage require softer, more absorbent gauzes with a more open structure. Various forms of pads, compresses, and dressings are made from surgical gauze, alone or in connection equivalent with absorbent cotton, tissue paper, and other materials [71,74]. *Filmed Gauze* is a folded absorbent gauze with a thin, even film of cotton or rayon distributed over each layer [81]. This filmation fluffs up and gives ample dressing volume, yet costs less than gauze alone of equivalent volume. It possesses quick absorption and unusual softness [74]. Premier filmed swabs are designed for use on surface wounds and incisions. These swabs are a multi-layer non-woven Polyester/Viscose, which sandwiches trapped cotton fiber centers, providing enhanced absorption [82,83]. *Nonwoven Surgical Sponges* Nonwoven fabrics have been developed that are suitable alternatives to woven cotton gauze for use in wound cleaning, wound dressing, and tissue-handling. These nonwoven fabrics depend on dense entanglement of their synthetic fibers (Dacron, rayon, etc) to provide the fabric with an acceptable tensile strength approaching that of woven cotton gauze. They typically offer greater absorbent capacity than cotton gauze sponges of comparable bulk, while generating less lint. Specialty versions of the nonwoven sponges are available pre-fenestrated for IV tubing or drain dressing procedures [84]. One manufacturer (Johnson & Johnson) provides both a nonwoven sponge for wound dressing (Sof-Wick: very soft texture, very absorbent or Topper: highly absorbent, fewer dressing changes) and a nonwoven general-purpose cleansing/prep sponge (Nu Gauze: gauze-like texture, more absorbent than gauze) [85]. Additionally, a new universal sponge which combines the best attributes of woven and nonwoven gauze has been created from a new fabric technology. Mirasorb (Johnson & Johnson) is made from a cotton blend, is more absorbent and resilient than woven gauze, provides fewer adherences to healthy tissue, and reduces wound damage and tissue trauma upon removal. Cotton balls and surgical gauzes (CSG) have been routinely used for mopping fluids and blood in surgeries. Polyurethane sheets (PUS) are increasingly used instead of CSG [71,74,86]. *Selva-Edge Gauze Strips* in widths of 1/4 to 2 inches are designed specially and woven for use both as packing strips in surgery of the nose and sinuses, nasal hemostasis, etc, and as drainage wicks in the treatment of boils, abscesses, fistulas, and other draining wounds. The ravel-proof, selva edges on both sides eliminate all loose threads. These gauzes are available unmediated or medicated with 5% iodoform. These strips are obtainable in sterile form packed in sealed glass jars. Nu Gauze Packing Strips are packaged in polystyrene containers [84,86]. *Gauze Pads or Sponges* are folded squares of surgical gauze. These are so folded that no cut gauze edges or loose threads are exposed. This prevents loose fibers from entering the wound. The pads are folded such that each size may be unfolded to larger sizes without exposing cut edges or loose threads. Sterilized packages of these frequently used allgauze sponges are available in tamper-proof packages [74,87]. Such sterile units particularly are well-suited to the numerous tray sets prepared in hospitals. Gauze pads and gauze sponges are used in a number of different applications and are great for general cleaning, dressings, prepping, and packing and debriding wounds. It can also be used as a temporary absorbent dressing over wounds. The difference between these items are that gauze pads come with one per pack, while gauze sponges come with two or more per pack [88,89]. *X-ray Detectable Gauze Pads* are same as all-gauze pads but contain inserts treated with barium sulfate. Sponges used in surgery can be responsible for serious complication or even death when they are not easily detected and removed [90]. They are nontoxic, soft, and nonabrasive. They remain permanently detectable because they neither deteriorate in the body nor are affected by either sterilization or time [71,91]. Examples of X-ray detectable sponges include Vistec and Kerlix (unique, crinkle weave, soft, and absorbent), both manufactured by Kendall [92]. X-Ray Detectable Sterile Gauze Sponges are economical, multi-purpose gauze sponges ideal for use in surgical procedures. They are sterile, highly-absorbent, and their x-ray visibility corrects unintentional retention (gossypiboma) in patients. Highly absorbent (16-ply), fine mesh 100% cotton gauze is virtually lint-free. Latex free [93]. *Ray-Tec X-Ray Detectable Sponges* (Johnson & Johnson) contain a nonabrasive vinyl plastic monofilament that gives a characteristic pattern in the X-ray. Composite absorbent dressings have been advanced for specific purposes. They usually consist of layers of absorbent gauze or nonwoven fabric with fillers of cotton, rayon, nonwoven fabric, or tissue paper in suitable arrangements. Composite sponges have gauze or nonwoven fabric surfaces with fillers of cotton, rayon, nonwoven fabric, or absorbent tissue [71, 94-100]. The RAY-TEC X-Rayable Sponge took the guess work out of surgical mishaps. If a surgical sponge was accidentally left in a body during an operation, it could now be easily detected by an x-ray. The pioneering sponges saved patients from possible exploratory surgery or additional unnecessary treatment following complications [91,101].

Dressing Combines: are designed to provide warmth and protection and to absorb large quantities of fluid that may drain from an incision or wound. Each combine consists of a nonwoven fabric cover enclosing fiber with or without absorbent tissue. They also may incorporate a nonabsorbent layer of cotton, tissue, or plastic film to prevent fluid from coming through to soil liners and bedding, though some combined dressings are entirely absorbent [102,103]. Excessive bleeding is a complication of wound debridement in patients receiving anticoagulation treatment. Chitosan is a linear, positively charged polysaccharide that has potential as a hemostatic topical dressing. Topical application of Opticell dressing with chitosan has hemostatic effects that could be a useful tool to control bleeding associated with wound debridement [103,104]. Prolonged primary anticoagulation could impair the healing process. A minor wound could be a daily challenge for patients who use anticoagulants and antiplatelet drugs. Standard gauze dressings and direct pressure are often time-intensive for controlling hemorrhage for these patients [104]. Specifically, the composites are antibacterial, hemostatic, biocompatible, good absorbent for anti-coagulated whole blood, and are able to maintain moisture balance for wound healing. For example, the composites were found to inhibit the growth of both Gram positive and negative micro-organisms (including *Escherichia coli* (ATCC 8739), *Staphylococcus aureus* (ATCC 25923), methicillin resistant *S. aureus* (ATCC 33591), and vancomycin resistant *Enterococcus faecalis* (ATCC 51299)). They are nontoxic to fibroblasts, namely fibroblasts were found to grow and proliferate in the presence of the composites [105].

Laparotomy Sponges: also known as Abdominal Packs, Tape Pads or Packs, Walling-Off Mops, Stitched Pads, Quilted Pads, Gauze Mops, etc, are used to form a nonabrasive wall that will preclude abdominal or other organs from entering into the field of operation and to help support body temperature during exposure. The operative control of non-compressible hemorrhage is the single largest impact that could be addressed in reducing the mortality on the battlefield. Laprotomy pads, traditionally used for hemorrhage evacuation, are made of woven cotton, and, while effective, their use requires a substantial amount of space and adds weight. This poses no concern in traditional operating rooms but is a hindrance for mobile providers and providers in austere environments [106]. However, sponges are made of four layers of 28×24 mesh gauze. The edges are folded in and hemmed. The entire pack is cross-stitched, and a looped tape 1/2-inch wide and 20-inches long is attached to one corner. A desirable feature of one type is an X-ray-detectable insert so firmly incorporated into the gauze that it cannot become detached. Treated with barium sulfate, the monofilament is nontoxic and, were it to be left inadvertently in situ, would cause no more foreign-body reaction than an ordinary dressing [63].

Sanitary Napkins: intended for special hospital use, otherwise known as V-Pads, Obstetrical (OB) Pads, Perineal Pads, Maternity Pads, etc, are used in obstetrical, gynecological, or maternity cases. Napkins that have repellent tissue on the side and back surfaces of the napkin usually are preferred because of their greater fluid-holding capacity. Sanitary napkins generally come with two sizes of filler, 3×9-inch or 3×11-inch. The napkin cover generally is made from a nonwoven fabric or a nonwoven fabric supported with an open-mesh scrim. Packaged, sterilized napkins are available and used generally to reduce cross-contamination possibilities. Reducing mental stress during the menstruation period is an important quality of life issue for women. Wearing a sanitary napkin (SN) is believed to influence mental stress responses of women during daily living activities [63,107,108].

Disposable Cleaners: made from various types of nonwoven fabrics are available. They generally offer advantages over paper in wet strength and abrasion resistance, plus having better cleaning ability. Their advantages over cloth are reduced laundry expense and cross-contamination possibilities.

Eye Pads: are scientifically shaped to fit comfortably and cover the eye completely, thus protecting the eyebrow when taped. These pads are made using nonwoven fabric. Eye patches are generally used post eye surgery, at night in order to protect the eye and reduce discomfort. It may or may not be used during the day. The Eyelid must be closed before application of the patch. A properly placed patch must apply gentle pressure on the eye lid to remain closed and the eye itself does not rub against the patch. Since the amount of light going into the eye decreases it helps in easing the discomfort. The eye can still move under the patch. In some cases if the surgical wound is not properly sealed, an additional day of patching might be required. In more severe cases patient might have to get the wound re-operated for proper closure. Eye patches are preferred as they help in limiting the swelling. It is advisable to remove eye patches whenever possible to allow healing and limit the moisture inside the patch which can also sometimes be harmful. Two sides are enclosed to prevent the cotton from escaping and the pad from distorting. When desired, the pad may be folded and used as a pressure dressing. Eye pads especially are useful in the outpatient clinic of the hospital, the industrial medical department, and the physician's office. They are sealed in individual sterile envelopes [109-112].

Nursing Pads: are designed in a contour shape to fit comfortably under the nursing brassiere or breast binder.

Disposable Under-pads: are used for incontinent, maternity, and other patients with severe drainage.

Such pads cost less than the average hospital-made product and provide a neat, clean, easy-to-handle pad that is changed quickly and easily disposed [113]. The construction of an underpad should accomplish three goals. First, its backing should have a low coefficient of friction to prevent frictional skin injuries. Second, an inner absorbent core should rapidly contain moisture and disseminate it throughout the entire pad. Third, the core and cover stock should successfully work together to retain moisture and prevent wet-back or fluid return [114]. Disposable briefs are available (Johnson & Johnson, Kendall). Incontinence products can be enormously helpful. They can prevent leaking onto your clothes, control odor, and prevent skin irritation [113]. Use of disposable incontinence pads reduces hospital-acquired pressure injuries (HAPIs) but not incontinence-associated dermatitis (IAD) occurrences [115]. Tranquility Peach Sheet underpad is able to contain well over one quart of fluid. This product provides for exceptional skin dryness, odor elimination, bacterial control and pH neutralization. Four adhesive tape tabs secure the positioning of nearly 5 square feet of protection to wheelchairs, bedding and furniture. Ideal for those who are at risk of skin breakdown, due to fragile skin or high levels of urine loss [114]. It was found to be very cost efficient, because the Tuck able could remain in place more than a week without changing [115].

Cotton-Tipped Applicators: are used to apply medications or cleanse an area. Makes it easy to clean/culture hard to reach areas. Machine-made cotton-tipped applicators are uniform in size, resulting in no waste of cotton or medications [116]. The cotton is attached firmly to the stick and may be sterilized readily without affecting the anchorage of the cotton. They are available in 3- or 6-inch lengths [54].

Bandages

The function of bandages is to hold dressings in place by providing pressure or support. They may be inelastic, be elastic, or become rigid after shaping for immobilization. Common Gauze

Roller Bandage: is listed in the USP as a form in which Absorbent Gauze may be provided. It is prepared from Type I Absorbent Gauze in various widths and lengths. Each bandage is in one continuous piece, tightly rolled and substantially free from loose threads and raveling's.

Muslin Bandage Rolls: are made of heavier unbleached material (56 ×60 mesh). They are provided in the same widths as the typical gauze bandage. Muslin bandages are very strong and are used wherever gauze bandages do not provide sufficient strength or support. They frequently are used to hold splints or bulky compression dressings in place [71,74,117].

Elastic Bandages are made in several types:

A. *Woven Elastic Bandage* is made of heavy elastic webbing containing rubber threads. Good support and pressure are provided by this type of rubber elastic bandage [118].

B. *Crepe Bandage* is elastic but contains no rubber. Its elasticity is owing to a particular weave that allows it to stretch to practically twice its length, even after repeated cleansings. This elasticity makes it especially serviceable in bandaging varicose veins, sprains, etc, because it conforms closely to the skin or joint surfaces, lies flat and secure, yet allows limited motion and stretches in case of swelling so that circulation is not impaired [119].

C. *Conforming Bandage* is made from two plies of specially processed, high-quality, 14× 8-inch cotton gauze folded to the center. This type is much easier to use and apply than ordinary roller bandage, since it tends to cling to itself during application, thus preventing slipping. It readily conforms to all body configurations without the necessity of reversing or twisting. A further advantage is the fact that there can be no rough or frayed edge. Kling Conforming Gauze Bandage and Sof-King Conforming Bandage (Johnson & Johnson) are available in a variety of sizes up to 6 inches wide. This gauze is used widely to hold dressings or splints firmly in place and occasionally as a primary dressing when sticking to the wound is not a problem. Mercerized cotton Conforming Gauze Bandage clings to itself and thus remains in place better than gauze made of other materials. Sof-King is a one-ply rayon and polyester blend bandage that provides greater bulk for cushioning and greater absorbency [21,71,120,121].

D. *High-Bulk Bandage* is made of multiple layers (typically six) of crimped cotton gauze. The high bulk of this bandage type is designed to provide padding protection in wound dressing applications. It also provides the absorbent capacity of a cotton dressing component [122]. One version (Sof-Band High Bulk, Johnson & Johnson) is made of mercerized cotton to help the bandage cling to it self, which facilitates application and improves dressing stability.

E. *Compression Bandage* is composed of cotton knitted or woven with either viscose, polyurethane, nylon, or elastane threads. Also known as elastic bandages, are often used for the compression part of RICE—Rest, Ice, Compression and Elevation—the gold standard of first aid treatment for bruises and sprains. Probably the most common brand name for an elastic bandage is an Ace wrap [123]. The bandage is comfortable and easy to apply. Its use is primarily to maintain controlled levels of pressure when compression therapy is required. As with all compression bandages, these products should be utilized with caution on patients with marked peripheral ischemia or impaired arterial blood supply. Examples of compression bandage include Tensopress (Smith and Nephew), Yeinopress (Moliner), and Setopress (Seton Healthcare) [124].

Triangular Bandages: usually are made by cutting a square of bleached muslin diagonally from corner to corner, forming two right triangles of equal size and shape. The length of the base is approximately 54 inches. These bandages were brought into prominence by Esmarch and still bear his name. They are used in first-aid work for head dressings, binders, and arm slings and as temporary splints for broken bones. A triangular bandage is used as an arm sling or as a pad to control bleeding. It may also be used to support or immobilize an injury to a bone or joint or as improvised padding over a painful injury. A tubular gauze bandage is used to retain a dressing on a finger or toe [125,126].

Orthopedic Bandages: are used to provide immobilization and support in the treatment of broken bones and in certain conditions of bones and joints. Plaster of Paris—impregnated gauze has been the conventional material for this purpose. More recently introduced are synthetic cast materials made of polyester cotton or fiber glass. Various types of plastic sheets also are offered that can be shaped easily and hardened to a rigid form by cooling or chemical reaction. These are useful chiefly for splints and corrective braces. Individually packaged plaster of Paris bandages and splints are available in a wide variety of sizes [62]. Elastic bandages are commonly used in sports to treat and prevent sport injuries [127]. The Specialist brand (Johnson & Johnson) is made from specially treated plaster, uniformly spread and firmly bonded to the fabric. This result in a high strength-to-weight ratio in casts made from such bandages. Synthetic casts are applied like plaster of Paris. The use of an inelastic, short-stretch compression bandage following total knee arthroplasty is a safe technique that is acceptable to patients [128]. The Delta-Lite Synthetic Casting System (Johnson & Johnson) offers both polyester, cotton fabric impregnated with a polyurethane resin, and fiberglass casting materials. Scotchcast Soft cast (3M) consists of a knitted fiberglass substrate impregnated with a polyurethane resin containing a surface modifying agent (reduce tack, facilitate application) [129]. The casts are water-resistant, light weight, and durable. Soft, smooth and conformable to the body's shape. It is tear able and feather able, has low moisture retention, and is porous enough to allow air circulation and to reduce skin irritation. It can be used under all types of casting materials, providing effective, comfortable and safe casting [130].

Orthoflex Elastic Plaster Bandages: (Johnson & Johnson) are plaster of Paris bandages containing elastic threads in the fabric and are intended for specialized prosthetic uses. Stockinette Bandages are made of stockinette material knitted or woven in tubular form without seams. Surgical stockinette is unbleached. Because it is soft and will stretch readily to conform comfortably to the arm, leg, or body, it is used to cover the skin prior to the application of a plaster of Paris or synthetic cast [131,132]. The physical

properties of plaster bandages are a very important factor in achieving the basic functions of immobilization (maintaining bone fragments in the best possible position), which directly affects the speed and quality of fracture healing [133].

Cast Paddings: are soft, absorbent, protective paddings, applied like a bandage to the areas affected, before application of a cast. They are composed of various fiber constructions that conform and cling, absorb moisture, and allow the skin to breathe [134-140].

Adhesive Tapes

Surgical adhesive tapes are made in many different forms, varying both in the type of backing and in the formulation of the adhesive mass according to specific needs and requirements. The tapes available today may be divided into two broad categories: those with a rubber-based adhesive and those with an acrylate adhesive. Both types have a variety of uses. When strength of backing, superior adhesion, and economy are required (eg, athletic strapping), rubber adhesives commonly are used. Acrylate adhesives on a variety of backing materials are used widely in surgical dressing applications, when reduced skin trauma is required, as in operative and postoperative procedures; they are supplied in various strength and adhesion levels [141-145].

Acrylate Adhesives: Acrylate adhesives on a nonwoven or fabric backing have been accepted widely for use as surgical tapes, owing largely to what may be termed their hypoallergenic nature. Because acrylate adhesives are basically a uni-polymeric system, they eliminate the use of a large number of components in rubber-based adhesives. In poly (alkyl-acrylate) adhesives, the desired balance between adhesion, cohesion, and flow properties is determined by the choice of monomers and the control of the polymerization reactions. Once the polymer is made, no other formulating or compounding is needed. In addition, the acrylics have an excellent shelf-life because they are not affected readily by heat, light, or air, factors that tend to degrade rubber-based adhesives. Acrylate adhesives combine the proper balance of tack and long-term adhesion. Their molecular structure permits the passage of water vapor so they are nonocclusive and thus when coated on a porous backing material do not cause overhydration in the stratum corneum. Traumatic response to surgical tapes is minimized substantially when tapes are constructed to allow normal skin moisture to pass through adhesive and backing material. With this construction, the moisture content and strength of the horny cell layers remain relatively normal. When a porous tape is removed, the planes of separation develop near the surface of the stratum corneum, in the region of the naturally desquamating cells. This allows repeated use of tape over the same site with minimal damage to the skin. Hypoallergenic Surgical Tapes with acrylate adhesive are available with a variety of porous backing materials. Rayon taffeta cloth backing provides a high-strength tape well-suited for affixing heavy dressings. Lighter dressing applications can be accomplished with lower-strength, economical, paperbacked surgical tapes. A knitted backing tape (Dermiform, Johnson & Johnson) provides some of the economies of paper surgical tape with the strength and conformability of a cloth backing. Other tapes feature elastic cloth or foam backing materials for special taping needs [146].

Rubber-Based Adhesives: A second group of surgical adhesive tapes is the cloth-backed and plastic-backed rubber adhesives. These are used primarily where heavy support and a high level of adhesion are required. Modern rubber-based adhesive tape masses consist of varying mixtures of several classes of substances and are composed of an elastomer (para or pale crepe rubber in the case of natural rubber tapes, and synthetic elastomers made from polymers of isobutylene, alkyl-acrylate, or similar materials), one of several types of rosin or modified rosin, antioxidants, plasticizers and fillers, and coloring agents to give the tape the desired tint or whiteness [147].

Adhesive Tape Reactions: While skin reactions formerly were accepted by the medical profession as almost predictable sequelae to the use of adhesive tape, with better understanding of the mechanisms of such reactions and progress in research and technology, the long-sought-for objective of hypo-reactivity has, in large degree, been attained. Because adhesive tape masses historically have consisted of heterogeneous and complex mixtures of organic compounds, it is not surprising that many workers have ascribed adhesive tape reaction to allergy. More-recent work, however, has shown that a true allergic response to the modern adhesive tape mass or its components is a factor in only a small proportion of clinical reactions and that most observed reactions are ascribed properly to other factors, mainly mechanical irritation and, to a lesser degree, chemical irritation. There apparently is no significant difference in reaction between patients with or without a history of allergy, but true specific dermatitis may occur more readily in persons who have manifested some other form of contact dermatitis. Adverse manifestations produced by adhesive tape are characterized by erythema, edema, papules, vesicles, and in severe cases, desquamation. Itching may be intense, or it may be absent. The reaction may be demonstrated readily by patch testing, and usually manifests itself early—within 24 to 48 hr. Characteristically, the reaction becomes more severe the longer the tape is left in place and continues to increase in intensity for some time after the tape is removed. This type of reaction is long-lasting and requires days for its complete subsidence. Two distinct types of irritation can result from the mechanical dynamics of removing tape from the skin. One response—induced vasodilation—is a relatively nontraumatic, transitory effect in which no actual damage to the skin occurs. A second type—skin stripping—is a traumatic response in which skin is removed with the tape and actual damage to the epidermal layers results. Such mechanical skin removal is possibly the dominant cause of clinical reactions seen with the use of adhesive tape. Chemical irritation from adhesive tape results when irritating components in the mass or backing of the tape permeate the underlying tissues of the skin. The tape construction can influence the reactivity of such ingredients substantially. For example, many compounds that normally do not penetrate intact stratum corneum can penetrate overhydrated corneum. When portions of the stratum corneum are removed, the barrier capacity of the skin is damaged substantially. In this situation, any irritating components of the tape have ready access to underlying tissues.

These substances then can cause a degree of irritation that is far greater than would be observed on intact skin [141-145,148,149].

Protectives

Until recently, protectives included only the various impermeable materials intended to be used adjunctively with other dressing components to prevent the loss of moisture or heat from a wound site or to protect clothing or bed liners from wound exudate. Film dressings are excellent devices to protect against infection and dislodgement of vascular cannulae and drainage sites. In addition, they may be used to protect unprotected areas against pressure sores. Protectives also are employed to cover wet dressings and hot or cold compresses. In common use as protectives are plastic sheeting and waxed or plastic-coated paper. These prevent the escape of moisture or heat from the dressing or the compress and protect clothing or bed linens. Rubber sheeting is a rubber-coated cloth, waterproof and flexible, in various lengths and widths for use as a covering for bedding. So called nursery sheeting is supplied, coated only on one side [150-152].

Products for Adhesion Prevention

Adhesions are abnormal connections between organs or tissues that form after trauma, including surgery. They consist of systematic fibrin and fibrovascular scar tissue and complicate all areas of surgery. In gynecological surgery, adhesions may result in infertility and pelvic pain; in intestinal surgery they may result in intestinal obstruction; in cardiac surgery they may render a second sternotomy hazardous, and in tendon surgery they will prevent mobility. Although careful tissue handling and good hemostasis may reduce adhesion formation, there are few proven entities designed for the prevention of adhesions. Gynecare Interceed Absorbable Adhesion Barrier (Ethicon) is a knitted fabric of oxidized regenerated cellulose that is placed at a site where adhesions are suspected to occur. It swells and gels to form a barrier between two adjacent surfaces, allowing re-mesothelialization to take place. The fabric then degrades grossly by about 14 days and microscopically by about 28 days. Interceed Barrier is indicated for reducing the incidence of adhesions in pelvic gynecological surgery. Other mechanical barriers used for the prevention of adhesions include Seprafilm (Genzyme) and Gore-Tex Surgical Membrane (Gore). Newer products available for the prevention of postoperative adhesions that are not site-specific for application include Gynecare InterGel Adhesion Prevention Solution, a ferric hyaluronate gel (Lifecore Biomedical) and Sepracoat, a dilute hyaluronic acid solution (Genzyme) [87,153-155].

Operating Room Supplies

Hemostatic Products: accelerate hemostasis by providing a thrombogenic surface that promotes platelet aggregation and fibrin polymerization. These topical hemostatic agents include collagen, gelatin, cellulose, and thrombin. These include collagen sponges and powders (Instat, Johnson & Johnson; Helistat, Integra Life Sciences; Actiofoam, Bard; Avitene, Davol; Helitene, Integra Life Sciences), gelatin sponges (Surgifoam, Johnson & Johnson; Gelfoam, Upjohn), and Oxidized Regenerated Cellulose USP (Surgicel, Johnson & Johnson). Both oxidized cellulose and oxidized regenerated cellulose are agents whose actions depend on the formation of a coagulum consisting of salts of polyanhydroglucuronic acid and hemoglobin. When applied to a bleeding surface, they swell to form a brown gelatinous mass that is absorbed gradually by the tissues, usually within 7 to 14 days. They are employed in surgery for the control of moderate bleeding when suturing or ligation is impractical or ineffective.

Thrombin (USP) solutions: of bovine origin (Thrombinar, Jones Medical) promote hemostasis by catalyzing the conversion of fibrinogen to fibrin. They may be used in conjunction with fibrinogen concentrates prepared from autologous cryoprecipitate or from pooled donor blood.

Tissue sealants: are absorbable and are used for a variety of indications including sealing of arterial punctures, sealing of air leaks during pulmonary surgery, and supporting wound healing. The area of tissue sealants is expanding rapidly, with new products reaching the market for numerous indications. Angio-seal (Kendall), an absorbable material, is used as a sealant for arterial punctures. AdvaSeal (Focal), a synthetic absorbable sealant, is used to seal air leaks during pulmonary surgery. Tissell (Immuno AE), a two-component fibrin sealant, is used to promote wound healing as well as achieve hemostasis and tissue adhesion. BioGlue, (Cryolife) is bovine albumin-based glue used to seal aortic aneurysms and anastomotic sites.

Tissue glues: are used for topical skin adhesives and replace the need for sutures, staples, or adhesive strips for certain types of lacerations requiring closely approximated wound edges. Dermabond (Closure Medical), an octyl cyanoacrylate, is used as a topical skin adhesive that sloughs from the wound as re-epithelialization of the skin occurs, providing sufficient time for wound healing. Indermil (Tyco Healthcare), a butyl cyanoacrylate, is another topical skin adhesive.

Disposable Sterile OR and OB Packs: are prepared, packaged, and sterilized assemblies of diapering and gown units, designed to fulfill the operating and delivery room needs. They eliminate the problems of laundering, storage, assembly, and sterilization of muslin drapes and gowns. They introduce many special materials with particular properties of porosity; repellency to water, alcohol, blood and other fluids; abrasion resistance; and other desirable attributes.

Double packages: of contamination-resistant paper have been developed to permit opening and use without compromising sterility. Retention of sterile characteristics until used, eliminates the need for re-sterilization. Face masks for use in the operating

room and where contamination must be controlled generally are made of plied, fine-mesh gauze, shaped to cover the nose, mouth, and chin. They are laundered and autoclaved. Disposable face masks with special filtration material giving high retention of particulate matter and designed for more effective fitting are available from several manufacturers. Surgine Face Mask (Johnson & Johnson) claims 94% filtration efficiency with high user comfort [63,156-161].

Surgical Dressings

Adhesive Bandage

Adhesive Absorbent Compress; Adhesive Absorbent Gauze: A compress of four layers of Type I absorbent gauze, or other suitable material, affixed to a film or fabric coated with a pressure-sensitive adhesive substance. It is sterile. The compact may contain an appropriate antimicrobial agent and may contain one or more suitable colors. The adhesive surface is covered by a suitable removable covering.

Description--The compress is substantially free from loose threads or ravelings; the adhesive strip may be perforated, and the back may be coated with a water-repellent film.

Gauze Bandage: Type I absorbent gauze; contains no dye or other additives. **Description--**One continuous piece, tightly rolled, in various widths and lengths and substantially free from loose threads and ravelings.

Oxidized Cellulose: *Absorbable Cellulose; Absorbable Cotton; Cellulosic Acid; Hemo-Pak* (Johnson & Johnson); *Oxycel* (Deseret Medical) Sterile gauze or cotton that has been oxidized chemically to make it both hemostatic and absorbable; contains 16% to 24% carboxyl (COOH) groups. Description in the form of gauze or lint. Is slightly off-white in color, is acid to the taste, and has a slight charred odor. Solubility insoluble in water or acids; soluble in dilute alkalis. Comments the value of oxidized cellulose in various surgical procedures is based upon its properties of absorbability when buried in tissues and its remarkable hemostatic effect. Absorption occurs between the second- and seventh-day following implantation of the dry material, depending on the adequacy of the blood supplied to the area and the degree of chemical degradation of the implanted material. Complete absorption of large amounts of blood-soaked gauze may take 6 weeks or longer, and serious surgical complications and cyst formation have been reported as the result of failure to absorb. Hemostasis depends upon the marked affinity of cellulosic acid for hemoglobin. When exposed to blood, either in vitro or in surgical conditions, the oxidized gauze or cotton turns very dark brown or black and forms a soft gelatinous mass that readily molds itself to the contours of irregular surfaces and controls surgical hemorrhage by providing an artificially induced clot. Pressure should be exerted on the gauze or cotton for about 2 min to facilitate the sealing off of small, bleeding vessels.

Two factors require emphasis:

- (1) cellulosic acid does not enter the physiological clotting mechanism per se but forms what might be termed an artificial clot as described and, therefore, is effective in controlling the bleeding hemophiliac and
- (2) the hemostatic action of cellulosic acid is not enhanced by the addition of other hemostatic agents, such as thrombin (which in any case would be destroyed by the pH of the gauze unless some means of neutralization were practicable). The hemostatic effect of either one alone is greater than the combination.

It is useful as a temporary packing for the control of capillary, venous, or small arterial hemorrhage, but since it inhibits epithelialization, it should be used only for the immediate control of hemorrhage and not as a surface dressing. A purer and more uniform product prepared from oxidized regenerated cellulose has been developed and is available as Surgicel Absorbable Hemostat. This offers many advantages over the older, less-uniform oxidized cellulose derived from cotton and, because of its chemical uniformity, ensures dependable performance and overcomes many of the difficulties encountered with the older type of cotton product. The knitted fabric strips do not fragment, may be sutured in place easily if necessary, and provide prompt and complete absorption with minimum tissue reaction.

Oxidized Regenerated Cellulose

Surgicel; Surgicel Nu-Knit; Surgicel Fibrillar (Johnson & Johnson)

Contains 18–24% carboxyl groups (COOH), calculated on the dried basis. It is sterile.

Preparation—Cellulose is dissolved and regenerated by a process similar to the manufacture of rayon, which is then oxidized.

Description—Creamy white gauze, lint, or woven material.

Solubility—Insoluble in water; soluble in alkali hydroxides.

Comments—Absorbable hemostatic.

Purified Cotton

Gossypium Purificatum; Absorbent Cotton

The hair of the seed of cultivated varieties of *Gossypium hirsutum* Linné or other species of *Gossypium* (Fam Malvaceae), freed from adhering impurities, deprived of fatty matter, bleached, and sterilized in its final container.

Description—White, soft, fine, filament-like hairs appearing under the microscope as hollow, flattened and twisted bands, striate and slightly thickened at the edges; practically odorless and practically tasteless.

Solubility—Insoluble in ordinary solvents; soluble in ammoniated cupric oxide TS.

Dextranomer

Debrisan (Johnson & Johnson)

Dextranomer is a three-dimensional cross-linked dextran polymer prepared by interaction of dextran with epichlorohydrin.

Description—White, spherical beads, 0.1 to 0.3 mm in diameter; hydrophilic. Also available dispersed in polyethylene glycol, as a paste.

Solubility—Insoluble in water or alcohol. Each gram absorbs about 4 mL of aqueous fluid, the beads swelling and forming a gel.

Comments—Topically to cleanse secreting lesions such as venous stasis ulcers, decubitus ulcers, infected traumatic and surgical wounds, and infected burns. It absorbs the exudates, including the components that tend to impede tissue repair, and thereby retards eschar formation and keeps lesions soft and pliable.

Absorbable Dusting Powder

Starch-derivative Dusting Powder

An absorbable powder prepared by processing cornstarch and intended for use as a lubricant for surgical gloves; contains not more than 2% magnesium oxide.

Description—White, odorless powder; pH (1 in 10 suspension) between 10 and 10.8.

Absorbent Gauze

Carbasus Absorbens; Gauze

Cotton, or a mixture of cotton and not more than 53.0%, by weight, of purified rayon, in the form of a plain-woven cloth. If rendered sterile, it is packaged to protect it from contamination. Description—White cotton cloth of various thread counts and weights; may be supplied in various lengths and widths and in the form of rolls or folds.

Purified Rayon

A fibrous form of bleached, regenerated cellulose. It may contain no more than 1.25% titanium dioxide.

Preparation—By the viscose rayon process.

Description—White, lustrous or dull, fine, soft, filamentous fibers, appearing under the microscope as round, oval, or slightly flattened translucent rods, straight or crimped, striate and with serrate cross-sectional edges; practically odorless and practically tasteless.

Solubility—Very soluble in ammoniated cupric oxide TS or dilute H₂SO₄ (3 in 5); insoluble in ordinary solvents.

Comments—Hemostatic.

Adhesive Tape

Sterile Adhesive Tape

Fabric and/or film evenly coated on one side with a pressure-sensitive, adhesive mixture. If rendered sterile, it is protected from contamination by appropriate packaging [13,21,71,74,71,135,162-168].

Pharmacist's Role

In regular practice, it is often during these comprehensive medication reviews that a pharmacist should be able to assess the patient's risk factors for wounds and note any early signs of venous compromise. Community pharmacists are often in contact with the patient or patient's representative frequently as the patient tends to return to the pharmacy several times a month for a variety of healthcare needs. The most obvious contribution of a community pharmacist would be in the management of local wound care, specifically the management of inflammation and infection control. Many antibiotics will interfere with other medications, including over-the-counter medications. For example, fluoroquinolones, such as ciprofloxacin, will bind to calcium, magnesium and iron in the gastrointestinal system and reduce the absorption and efficacy of the antibiotic. Pharmacists need to advise patients to stop their multi-vitamins and/or antacids when taking fluoroquinolones, or to take the products at separate times of the day. Again, high doses of antibiotics may cause gastric irritation, could be prevented by PPIs. By recognizing venous skin changes (for example), knowing when to refer patients to their primary care providers and recognizing the patient's readiness to change, pharmacists can play an integral role in supporting the timely review and reassessment of wounds. The priorities (and management plans) of the patient can change rapidly and drastically, particularly in the complex case of wounds where there are several concurrent co-morbid conditions. The prevention and treatment of wounds is complex, often multi-factorial in origin and best practiced through an organized, interprofessional team approach. This collaborative approach poses challenges such as facilitating communication when team members are physically located in separate offices and work different hours [169-174]. For quick reference, a quick wound care chart is detailed in Table 2 and barriers to effective wound care in (Table 3).

Dressing Type	Wound type	When to change dressing	Comments/Expectations
Paraffin dressings <ul style="list-style-type: none"> Cuticerin Jelonet Bactigras 	<ul style="list-style-type: none"> Superficial, clean, minor abrasions Skin tears that require review within 24 to 48 hours 	<ul style="list-style-type: none"> 2 days 	<ul style="list-style-type: none"> Prevent maceration Granulation Protect epithelizing wound
Long wearing impregnated mesh <ul style="list-style-type: none"> Mepitel (silicone) 	<ul style="list-style-type: none"> Epidermal and clean superficial dermal Epithelised burns 	<ul style="list-style-type: none"> 7 days 	<ul style="list-style-type: none"> Healing Epithelization
Absorbent Pads <ul style="list-style-type: none"> Mesasorb Zetuvit 	<ul style="list-style-type: none"> Oozing wounds Secondary dressing to absorb exudate 	<ul style="list-style-type: none"> PRN 3 days 	<ul style="list-style-type: none"> Absorb fluid Prevent maceration
Films <ul style="list-style-type: none"> Tegaderm Opsite 	<ul style="list-style-type: none"> Secondary dressing for burns and sutures Stage I pressure injuries 	<ul style="list-style-type: none"> 2 to 7 days "A week or a leak" 	<ul style="list-style-type: none"> Not to be used on infected wounds Keep dressings intact Keep dressings dry Water resistant not waterproof Protect against shear and friction
Foams <ul style="list-style-type: none"> Allevyn Lyofoam 	<ul style="list-style-type: none"> Pressure injuries Ulcers Toe wounds 	<ul style="list-style-type: none"> 2 to 5 days When exudate is 1 cm from the edge of dressing 	<ul style="list-style-type: none"> Protection Draws fluid from wound preventing maceration and promoting healing
Soft silicone <ul style="list-style-type: none"> Mepilex border 	<ul style="list-style-type: none"> Skin tears Epithelizing wounds Superficial dermal burns Epithelized burns 	<ul style="list-style-type: none"> 2 to 7 days (depending on skin tear) 	<ul style="list-style-type: none"> Healing Protect epithelializing tissue Prevent maceration Ensure hemostasis prior
Hydrocolloids <ul style="list-style-type: none"> Duoderm Duoderm extra thin Comfeel 	<ul style="list-style-type: none"> Stage I pressure injuries Superficial dermal burns 	<ul style="list-style-type: none"> 2 to 5 days Change if leakage occurs or rolled up 	<ul style="list-style-type: none"> For wounds with minimal exudate Prevent maceration Protection
Hydrocolloid paste <ul style="list-style-type: none"> Comfeel paste 	<ul style="list-style-type: none"> Pressure injuries with slough Ulcers with slough 	<ul style="list-style-type: none"> 2 days 	<ul style="list-style-type: none"> De-slough Re-hydrate Fills dead space
Hydrogels <ul style="list-style-type: none"> Solugel Intrasite gel Purilon 	<ul style="list-style-type: none"> Necrotic ulcers Pressure injuries with slough 	<ul style="list-style-type: none"> Daily to 2 days 	<ul style="list-style-type: none"> Rehydrate De-slough Prevent maceration
Calcium Alginate <ul style="list-style-type: none"> Kaltostat Kaltostat rope 	<ul style="list-style-type: none"> Promote haemostasis Bleeding ulcers Bleeding skin tears Around bleeding insertion site 	<ul style="list-style-type: none"> 24 hours (until haemostasis is achieved) 	<ul style="list-style-type: none"> Prevent trauma (soak off if stuck to wound) Haemostasis Absorption (absorbs up to 20 times its weight in fluid) Granulation
Hydrofibre <ul style="list-style-type: none"> Aquacel Durofibre 	<ul style="list-style-type: none"> Moderately to heavily exudating wounds Not bleeding wounds 	<ul style="list-style-type: none"> 2nd to 3rd daily 	<ul style="list-style-type: none"> Prevent maceration Maintain a moist wound environment
Cadexomer Iodine <ul style="list-style-type: none"> Iodosorb 	<ul style="list-style-type: none"> Heavily colonised infected wounds Infected or slow to progress wounds 	<ul style="list-style-type: none"> 2nd to 3rd daily In severe cases may need to be dressed daily 	<ul style="list-style-type: none"> Check for iodine/shellfish sensitivities Change to paste when powder begins to crust up Remove all product before reapplication Can be painful on application

Table 2: Quick Reference Wound Care Chart [175]

Barriers	Examples
Educational factor	Poor quality of research, lack of appropriate training, ritualistic practice and lack of appropriate skills.
Organizational factor	Lack of standardisation of practice that is acceptable, lack of expert opinion, instability in the health services.
Clinical factor	Bacterial infection, hypersensitivity, malnutrition, poor tissue perfusion, copious exudate, too much or too little information on wound management.
Psychosocial factor	Social isolation resulting in depression and reduced motivation with treatment, pain resulting in loss of sufficient sleep and lack of self-care.

Table 3: Barriers to effective treatment of wounds [64]

Factors Delaying Wound Healing

Holistic assessment of the patient is an important part of the wound care process. A number of local and systemic factors can delay or impair wound healing. These may include:

- **Malnutrition**- inadequate supply of protein, carbohydrates, fatty acids, and trace elements essential for all phases of wound healing

- **Reduced Blood supply** - Cardiovascular disorders and Ischemia
- **Medication** - Non-steroidal anti-inflammatory drugs and Corticosteroids.
- **Chemotherapy** - suppresses the immune system and inflammatory response
- **Radiotherapy** - increases production of free radical which damage cells
- **Psychological stress and lack of sleep** - increase risk of infection and delayed healing
- **Obesity** - decreases tissue perfusion
- **Infection** - prolong inflammatory phase, use vital nutrients, impair epithelialization and release toxins
- **Reduced wound temperature** - prolonged dressing changes or use of cold cleansing products.
- **Underlying Disease** - Diabetes Mellitus and Autoimmune disorders
- **Maceration** - excess wound exudates or contact with bodily fluids reduces wound tensile strength
- Inappropriate wound management
- Patient compliance
- Unrelieved pressure
- Immobility
- Substance abuse including alcohol and cigarette smoke [176-181]

Future Directions

The development of new and effective interventions in wound care remains an area of intense research. Negative pressure wound therapy has undoubtedly changed wound care from this point forward and has proven beneficial for a variety of wounds. Hydroconductive dressings are another category that is emerging with studies underway. Other modalities such as hyperbaric oxygen, growth factors, biologic dressings, skin substitutes, and regenerative materials have also proven efficacious in advancing the wound-healing process through a variety of mechanisms. The future of wound healing at this point remains unknown. Few high-quality, randomized controlled trials evaluating wound dressings exist and do not clearly demonstrate superiority of many materials or categories. Comparative effectiveness research can be used as a tool to evaluate topical therapy for wound care moving into the future. Until further data emerge, education on the available products and logical clinical thought must prevail.

Conclusion

Wounds will easily acquire bacteria, unless supportive measures are taken. The bacterial protection afforded by typical absorbent cellulose dressings has been shown to be restricted, particularly in the presence of serous exudate that may imperil dressing integrity. In addition, dressings may shed particles that linger the wound. By contrast, many modern dressings are impervious to bacteria, are eliminated completely, have been found to optimize re-epithelialization rates and reduce the occurrence of wound sepsis. Recently, it has been found that they could also play a role in preventing cross-contamination. Removing typical cellulosic dressings from bacterially colonized wounds liberates wound bacteria into the air, and the numbers are slow to decline. However, using an in vitro wound model, use of the hydrocolloid dressing on experimentally colonized wounds resulted in significantly fewer numbers of airborne bacteria. Dispersal from wet typical dressings was lower than from dry dressings; notwithstanding, the numbers of bacteria per liter of air following expulsion of the hydrocolloid dressing were approximately 20% of those observed for gauze. These findings have also been settled in the clinic. To reduce the incidence of complexities, injury care in general, and infection control approaches in particular, requires carefully disciplined team work [182].

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