The Wound Healing Spectrum: A Timeline for the Utilization of Advanced Technology

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Abstract:

There is a clear relationship between the development of lower extremity diabetic ulceration and subsequent non-traumatic lower extremity amputation. Therefore, it is vital that clinicians involved in the care of the lower extremity manifestations of patients living with diabetes mellitus have a thorough knowledge of the pathophysiology as well as current management principles for diabetic foot ulcers. There are numerous advanced modalities and therapies available in the management of complicated lower extremity wounds. However, a search of the literature demonstrates no discussion regarding when each modality should be utilized to appropriately progress a wound through the phases of wound healing. This paper presents the three phases within the continuum of wound healing: wound bed preparation, promotion of granulation tissue, and wound closure. We seek to demonstrate the appropriate utilization along the timeline for wound healing for the numerous advanced wound healing modalities available.

Key words: Diabetes, Wound, graft, collagen, stem cell, growth factor, Negative Pressure, Larvae, bioengineered tissues.

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Introduction

With the incidence of diabetes on the rise worldwide, practitioners involved in the care of these patients have seen an increase in the subsequent complications associated with diabetes. Among these, lower extremity ulcerations are very commonly observed.[1,2] Numerous studies have demonstrated that lower extremity ulcerations are a major risk factor for amputation, and the morbidity and mortality associated with amputation in this patient population is severe.[2-6] It is incumbent on the physician participating in the care of these complicated patients to be well versed in the principles of wound care. There are numerous basic and advanced wound care modalities and techniques available to the clinician to promote wound healing. However, a search of the current literature demonstrates that there have been no clear attempts to quantify a timeline as to when each technique should be appropriately utilized until now.

Prior to initiation of the wound healing timeline, it is necessary that those predisposing factors which contribute to wound development, progression, and chronicity be addressed. Vascular status, infection, and pressure are known as the “VIPs” of diabetic wound healing. These factors significantly contribute to wound formation and therefore must be addressed prior to initiation of wound healing modalities and progression through the continuum of wound healing.[5,7-11] Without appropriate diagnosis and management of these VIPs, wounds will not heal, regardless of the modalities that are utilized.

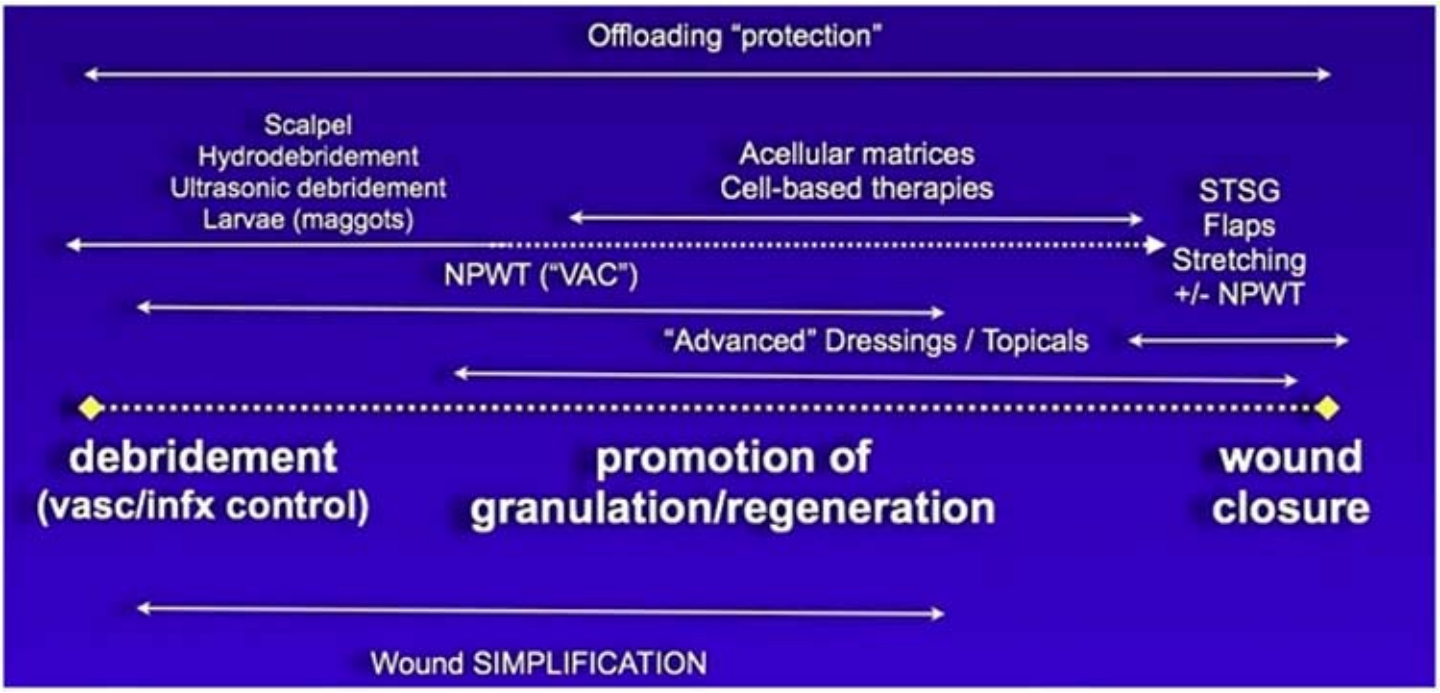

Figure 1 Temporal sequence of Wound Simplification and modalities utilized.

Debridement

Debridement is a vital component of wound management, and it is the necessary starting point on the spectrum of wound healing in the treatment of lower extremity ulcerations.[12,13] (Figure 1) Debridement provides for the removal of all fibrotic, necrotic, and nonviable tissue in addition to any undermining that will impede wound healing and promote infection.[14] This tissue can appear yellow, gray, black, or tan, and can be wet or dry. Removal of necrotic, nonviable tissue down to a bleeding, base is necessary to allow for wound bed preparation and the formation of healthy granular tissue and neoepithelialization.[15] Additionally, debridement is useful in stimulating senescent cells observed in chronic wounds.[16] In this way, debridement removes nonviable tissues while also stimulating the cells contained within the wound bed. In effect, it converts a chronic wound to a more acute, active wound.

Studies have demonstrated that wounds respond to such maintenance debridement with decreased healing times associated with increasing numbers of debridements. In fact, Armstrong et al. found that diabetic foot ulcers that were debrided on each visit had a 5.3-times greater chance of healing in 12 weeks than ulcers that were debrided less often.[17] There are numerous methods of debridement available to the clinician and these will be discussed in detail below.

Mechanical

Mechanical debridement is one of the oldest modalities that has been used by wound care clinicians to effect wound debridement.[18,19] The two most common examples of mechanical debridement include whirlpool hydrotherapy and wet-to-dry dressings. In hydrotherapy debridement, the pressure of water in a whirlpool is utilized to provide tissue debridement.[20-22]

Wet-to-dry dressings provide mechanical debridement by essentially allowing a saline-moistened gauze to dry and adhere to the wound bed.[19] When the dressing is removed, all tissue that has become adherent to the dressing is mechanically removed as well.

While effective and inexpensive, these modalities are nonselective and can damage burgeoning healthy tissue that is trying to form in the wound bed. In addition to being nonselective, mechanical debridement therapy can be very painful. Whirlpool hydrotherapy is generally less painful, but there is significant risk of skin maceration and breakdown, in addition to risk of contamination and infection with waterborne pathogens.[20,22] Attempts to disinfect the circulating water utilized in hydrotherapy have yielded mixed results and often the additives utilized for disinfection are cytotoxic. This can further damage the wound retard wound healing. Considering the numerous disadvantages of mechanical debridement, this method is not recommended unless the circumstances necessitate its use.

Autolytic

Autolytic debridement therapy utilizes the body's own enzymes and moisture to liquefy hard eschar and slough.[23] Autolytic debridement is selective; only necrotic tissue is liquefied, and this modality is virtually painless for the patient. Autolytic debridement can be achieved with the use of occlusive or semi-occlusive dressings that maintain wound fluid in contact with the necrotic tissue.[24,25] However, autolytic therapy may promote anaerobic bacterial growth if occlusive hydrocolloids are utilized and therefore the wound must be monitored closely for signs of infection. Autolytic therapy can be used on its own after surgical debridement in conjunction with enzymatic or mechanical debridement. This is helpful for patients who cannot tolerate other forms of debridement.[26]

Enzymatic

Enzymatic debridement utilizes topical ointments which contain chemicals that actively breakdown fibrotic and necrotic tissue.[23,27,28] Some enzymatic debridement agents are selective, such as collagenase, while others are not.

Often, this therapy is used in conjunction with other modalities and, like autolytic therapy, enzymatic debriding agents can be utilized in those patients who are not candidates for more aggressive surgical debridement.[23] One enzymatic debriding agent available to the clinician is collagenase (Santyl®, Healthpoint Ltd, Fort Worth, Texas). This contains 250 collagenase units per gram of white petrolatum base, and the enzyme, produced by the fermentation by *Clostridium histolyticum*, specifically targets the collagen in necrotic tissue while newly formed or healthy tissue is not attacked.[25,27] In this way, only nonviable tissue is removed thereby promoting the formation of healthy granulation tissue and neo-epithelization.

Surgical

Surgical debridement is the most rapid means of removing the nonviable and necrotic tissue contained in a wound. It can be performed in the operating room or at bedside depending on the extent of the debridement required and the clinicians' ability to manage the patient's pain level.[19, 32-35] There are multiple methods to effect surgical debridement, ranging from sharp debridement with a scalpel to newer advances in technology that speed and improve efficiency of surgical debridement. Among these, hydro-surgical and ultrasonic debridement devices are showing promise in providing significant, selective soft tissue debridement.[36,37] Much of this technology was initially described in the literature regarding the surgical management of full and partial thickness wounds, and has now been incorporated into the management of complex lower extremity ulcerations.

The only available hydro-surgical device for wounds is the Versajet® hydrosugery system (Smith & Nephew, St. Petersburg FL) that utilizes a high velocity tangential stream of liquid (most commonly normal saline) flowing through a specifically designed hand piece at pressures greater than 10,000 P.S.I. to debride tissue layer by layer.[38] This is accomplished due to generation of a Venturi vacuum across the operating window on the distal end of the hand piece. The localized vacuum that is formed by the flow of liquid across the operating window pulls target tissue into the window and into the high-pressure stream of liquid, where it is debrided and then aspirated from the surgical site. The surgeon can control the degree of excision and aspiration via changing the orientation of the hand piece with regard to the target tissue and the hand pressure used against the wound bed. The closer the operating window is to parallel, the more aggressive the tissue excision while a more oblique window position generates more aspiration. Additionally, the surgeon can control the excision and aspiration effects by increasing or decreasing the power settings on the console from 1 to 10. In this way, this hydro-surgical device allows for rapid, selective, sharp debridement of necrotic, nonviable tissue while leaving healthy tissue to promote wound healing.[39]

Studies have demonstrated that this technology reduces both the procedure time, the overall number of serial debridements required to appropriately prepare a wound bed for wound healing. Numerous studies have demonstrated the cost-effectiveness of such increased efficiency in surgical wound management, although further study would be beneficial.[38]

Another developing technology that is showing promising results utilizes ultrasound technology to selectively remove necrotic and nonviable tissue from wounds. *Ultrasound* refers to sound waves vibrating at frequencies greater than what can be detected by the human ear, which is approximately 18 kilohertz (18,000 Hertz) and higher.[40]

Ultrasonic wound debridement (UWD) systems such as the *SonicOne* (Misonix) and the Qoustic Wound Therapy System™ (Arobella Medical LLC) utilize these sound waves to ultrasonically fragment necrotic tissue from the wound bed and non-migratory cells from the ulcer edge.[20] This fragmentation is generated by a process called cavitation, which is the formation and collapse of microscopic vacuum bubbles due to the formation of pressure differentials. In the setting of debridement, cavitation is extremely important as a form of mechanical tissue fragmentation because different tissue types respond differently to varying levels of cavitation shearing forces.[41,42] In this way, clinicians can selectively remove necrotic or nonviable tissue from healthy tissue because they respond differently to imploding cavitation bubbles. Tissue is removed in a layer-by-layer fashion; the clinician can easily distinguish between viable and nonviable tissue layers and simply stop when the appropriate level is reached.[42,43]

UWD devices also allow for removal of all necrotic tissue debris *via* an integrated irrigation system contained in the probe tip. This serves to reduce the risk of contamination and wound stagnation. Several of the many benefits of the UWD system include its portability and the precision of control that make the system easy to use for all skill levels in the hospital, clinic or professional office. This portability increases the intervention opportunities, and can potentially allow for greater patient access to advanced, selective surgical wound debridement.

Biosurgical

Maggot debridement therapy (MDT) supplied by Monarch Labs (www.monarchlabs.com) utilize the larvae of the *Phaenicia sericata* (green blowfly) to selectively remove necrotic tissue from a wound.[44] MDT has effectively been utilized in the management of wounds for thousands of years and is currently the only FDA approved “device” that is a living organism.[45] Larvae arrive in a sterile container numbering 250-500 and are placed upon a fibrotic or necrotic wound and covered with a semi-permeable mesh dressing for 3 days.

The therapy can be repeated until all necrotic tissue has been removed. The *Phaenicia sericata* is unique because it only consumes fibrotic and necrotic tissue. Therefore, it is well suited to provide selective debridement of nonviable tissue. This modality is especially useful in the management of patients who require wound debridement but are unsuitable candidates for other modalities due to pain issues or other comorbidities.[44,46]

Promotion of granulation tissue

Following appropriate tissue debridement and wound bed preparation, the next step along the continuum of wound healing is to effectively promote granulation tissue in the wound bed while minimizing risk of contamination and wound infection. There are a number of modalities available to the clinician to affectively stimulate the promotion of granulation tissue, and these can be utilized alone or in combination to effectively stimulate wound healing.

Negative Pressure Wound Therapy

Negative pressure wound therapy (NPWT) is perhaps the most significant modality available in the promotion of granulation tissue following appropriate wound debridement.[47] Generally speaking, this modality utilizes creation of localized negative pressure at the wound site to stimulate fibroblastic activity, collagen formation, and neovascularization. Other benefits include providing moisture control and exudate management.[48-50] While multiple devices exist on the market, the Wound Vacuum Assisted Closure device (Wound V.A.C.® KCI, San Antonio, TX) is well supported in the literature for demonstrating significant increase in healing rates, speeding closure, and reducing amputation rates.[51]

This therapy utilizes specially designed reticulated polyurethane foam dressing with 400-600 micron micro-pores that provides equal distribution of sub-atmospheric pressure along the wound bed that generates both a physical and biological response.

Studies have demonstrated that it is the properties of the foam, in addition to the negative pressure, that are responsible for the robust increase in granulation tissue.[49,51,52]

In addition to simple reduction of wound volume due to control of exudate, and removal of inflammatory substances, NPWT promotes granulation tissue by increasing cellular activity of the wound bed in response to the micro-strain of the cells interacting with the micro-pores in the reticulated foam.[52] This micro-strain, which occurs under pressure, stimulates increased cellular metabolism, fibroblastic migration, and extra cellular matrix (ECM) formation –all vital in formation of granulation tissue and wound healing.

There have been many studies that demonstrate the successful use of NPWT to promote wound healing and prevent amputations, in both the diabetic and non-diabetic population. Frykberg demonstrated that NPWT had a lower incidence of amputations than those undergoing traditional wound therapy.[50] However, the literature reveals a variety in the methods used and length of treatment. In 2004, Armstrong and colleagues demonstrated a need for a consensus statement to determine appropriate use of negative pressure wound therapy in the management of lower extremity ulcerations.[53] This statement was then revised and updated by Andros et al..[54] This consensus document included a summary of current clinical evidence as well as appropriate indications, treatment regimes, and updated practical guidance for the clinician likely to be utilizing NPWT as part of their armamentarium in the management of lower extremity ulceration and amputation

There have been several studies that demonstrate the cost-effectiveness of NPWT as compared to standard of care. Apelqvist and Armstrong demonstrated that diabetic patients with lower extremity wounds who were treated with NPWT resulted in lower resource utilization and greater overall healing at a lower cost of care as compared to the moist wound therapy (MWT) control group.[48]

The average cost to achieve healing per patient in the NPWT group was $27,270, as compared to $38,806 in the MWT group.[50]

Often, this therapy will be utilized to bridge the gap in the continuum of wound healing between wound debridement and final wound closure via flaps or grafts. NPWT has largely replaced the need for significant free flap transfer to provide soft tissue coverage in large wounds due to the increased efficiency in generation of granulation tissue and the overall decrease in time to healing.[55]

Cellular Modulation

There are a number of current advanced wound healing modalities which focus on promotion of granulation tissue at the cellular level. These include the use of collagen-based dressings, topically applied synthetic growth factors, and autogenous stem-cell mediators. As a class, these modalities can be utilized once the wound bed is appropriately prepared following the necessary soft tissue debridement.[14,56]

There are numerous collagen-based wound dressings available to promote granular tissue. Largely, these dressings act as a competitive substrate for MMPs and elastase which exist in disproptionate numbers in chronic wounds. As such, they can prevent breakdown of newly forming native collagen matrix in the wound.[57-59] Puracol Plus (Medline, Mundelein, IL) is one of the dressings that is purely native collagen and has a higher affinity for elastase than other available collagens.

These dressings modulate the local wound bed environment to limit breakdown of ECM, promote fibroblastic migration and the laying down of new collagen fibers.[60,61]

In addition to topically applied exogenous collagen wound dressings, there is literature using topically applied growth factors to speed the development of granulation tissue in a clean wound bed. Becaplermin (Regranex®, Systagenix Wound Management) is indicated in the management of noninfected diabetic ulcerations, and functions much like endogenous platelet derived growth factor (PDGF).[62]

When applied in a wound bed, becaplermin promotes the recruitment and proliferation of monocytes and fibroblasts. These are important participants in chemically mediated pathways that stimulate cellular migration, the production of new ECM, and endogenous collagen synthesis resulting in the development of healthy granulation tissue.[63] Studies have demonstrated that this agent, used in combination with appropriate wound debridement, increases the incidence of wound healing while also shortening the duration of wound healing.[64-67] More recently, there has been come concern over the use of becaplermin following the FDA's 2008 issuance of a black-box warning regarding potential cancer risk in patients utilizing the product. This warning followed a retrospective cohort study that demonstrated risk for cancer mortality was 5-fold higher in patients exposed to 3 or more tubes of becaplermin over two years as compared with similar patients who had not been exposed.

There were several problems with this study. Among these concerns, in the four cases in which cancers developed the types of cancers were varied and were remote from the treatment site. Furthermore, in the retrospective study patients demonstrated significantly long courses of becaplermin therapy (>2 years) —far longer than patients should require in the management of lower extremity wounds.[68]

Wounds that appear to be stagnating beyond this time frame should be re-evaluated and alternative treatment modalities considered.

Working along similar chemically mediated pathways as becaplermin, bone marrow-derived stem cells are an emerging modality in the wound care setting that is showing promise in the promotion of granulation tissue. Stem cells are naïve endogenous cells that have yet to develop into any specific cell type, but have the ability to transform many different types of cells depending on where they are placed in the body.[69] Research has demonstrated that bone marrow derived stem cells are biochemically active and are involved in normal skin maintenance and in maintaining the matrix environment and integrity of the skin.[70]

Thus, stem cells act as potent stimulators of granulation tissue by production of growth factors and cytokines which affect chemically mediated pathways to promote cellular migration, differentiation, and synthesis of ECM and collagen.

Stem cell therapies have also been shown to be effective as adjunctive modalities in the treatment of osseous nonunion and are routinely utilized by the orthopedic community to help promote osseous bridging between bone margins. In lower extremity surgery, bone marrow stem cells can be harvested from the distal tibial metaphysis or the body of the calcaneus.[71,72] Clinicians can utilize large-bore biopsy needle, or one of the commercially available harvest systems, such as the GPS® III (Biomet, Warsaw, IN), which have all the components necessary for bone-marrow harvest ready available in a kit. Once the bone marrow aspirate has been harvested and the stem cells obtained, they can be re-injected into the wound bed and periwound area. Additionally, bioengineered synthetic skin graft substitutes can be soaked in the bone marrow aspirate prior to graft placement to theoretically promote increased graft uptake.[73]

Providing for wound closure

Following appropriate tissue debridement and formation of granulation tissue, it becomes imperative to provide wound closure rapidly to reduce the risk of critical bacterial colonization and to allow the patient to return to normal activities. There are numerous ways to effect wound closure, and these modalities rest along the right hand end of the continuum of wound healing. Selection of the appropriate wound closure modality is largely dependent on the overall health of the patient, the location of the ulceration, and the biomechanical forces likely to exist at the ulcer location.

Secondary Intention

In this type of wound healing, full-thickness wounds are allowed to close *via* neoepithelialization. As compared to primary healing, which occurs when wound margins are placed in close apposition, secondary intention healing results in a greater inflammatory response with greater potential for pronounced wound contraction and scar formation.[74] Wound contraction is believed to occur due to differentiation of fibroblasts into myofibroblasts, although wound contraction is more pronounced in the murine model as opposed to humans.[75] Small wounds that are not located in weight-bearing areas are often allowed to heal *via* secondary intention. This is especially in true in patients whose comorbidities prohibit more aggressive wound closure modalities.

Split-thickness Skin Grafting

Split-thickness skin grafting (STSG) is a valuable tool to provide wound closure and has been well documented in the literature for general wounds, but less so for wounds of a diabetic etiology. By definition, a STSG includes the epidermis and portions of the dermis, however the thickness of the graft varies the amount of dermis that is included.

STSGs are generally classified as thin (0.008 to 0.012 inch), intermediate (0.013 to 0.016 inch), and thick (0.017 to 0.02 inch), and can be commonly harvested from the thigh, proximal calf, or trunk. They are best used to provide wound closure on dorsal foot wounds or other wounds in non-weight-bearing areas.[76,77] NPWT can be used as a bolster dressing at 125 mmHg continuous for approximately 3-5 days post-grafting which improves success by reducing the risk of hematoma/seroma formation, and limiting the shearing forces at the graft-wound bed interface.[53] A non-adherent dressing, however, must be used between the foam of the NPWT and the graft to prevent trauma to the graft when discontinuing the NPWT.

Local and Free Flaps

Local, rotational, and free flaps can be utilized to provide soft tissue coverage and closure over soft tissue defects,. Local flaps, such as 1-, 2-, or 3-lobed flaps, can be used to provide soft tissue coverage of small wounds on both the dorsal and plantar surfaces of the foot.[74,76] Rotational flaps are those that use adjacent tissue rotated in an arc to close a defect and are commonly oriented around the neurovascular bundles or contain a pedicle at the base.[78-80] A commonly used flap in the plantar foot is the medial plantar artery flap, which can be utilized to cover soft tissue defects along the calcaneus or the distal weight-bearing areas of the metatarsal heads.[81-84] Free flaps, such as the gracilis or latissimus dorsi free flap, involve the harvest of a musculocutaneous unit at a distant site with implantation at the site of soft tissue deficit and reanastamosis of the vessels.[85,86] The harvest of these flaps generates a wound at another location, which often can be covered via STSG or primary closure. In addition, these flaps require significant post-operative care including appropriate offloading of shear forces as well as appropriate exudate management to limit hematoma/seroma formation. Occasionally, leech therapy is needed to mitigate venous congestion that can cause flap failure.[87,88]

Bioengineered tissue

Bioengineered tissues have greatly increased the clinician's ability to provide soft tissue closure of lower extremity ulcerations.[89,90] There are essentially two current categories of these products: Living tissues, such as Dermagraft® (Advanced BioHealing) and Apligraf® (Organogenesis), and nonliving tissues, such as Integra® Bilayer Matrix (Integra LifeSciences) and GraftJacket® Regenerative Tissue Matrix (Wright Medical). These bioengineered tissues can be utilized both to promote healthy granulation tissue as well as to speed closure of wounds.[90] In this manner, these modalities are effective both in the middle and right hand portions of the continuum of wound healing, and all of these modalities are most effective when used in combination with standard local wound care regimens.[91]

Dermagraft® (Advanced BioHealing, La Jolla, CA) is a cryopreserved human fibroblast-derived dermal substitute that is composed of living fibroblasts and ECM on a bioabsorbable scaffold. Research has demonstrated that this product significantly promotes wound healing in full thickness ulcerations.[89,92,93] The living fibroblasts help to promote *in situ* production of endogenous ECM, collagen, and growth factors to promote healthly granulation tissue formation as well as neoepithelialization.[94-96] Apligraf® (Organogenesis) is a living skin equivalent that contains live cells that produce many growth factors.[97,98] Accordingly, this modality functions largely like a "growth factor factory" which, when placed in the wound bed, provides significant stimulation of the native wound bed cells to become more active, increasing cellular migration, ECM production, and collagen synthesis.

Both of these products utilize living tissue to speed wound healing through inducing native tissue to become more active and do not "engraft" in the conventional sense. However, they do provide some element of protection against bacterial inoculation.

There are non-living bioengineered tissues, which truly do provide protective soft tissue coverage when applied to the wound bed. These modalities promote the formation of granulation tissue and are usefully in providing soft tissue coverage over deep structures like tendon or bone.

Integra® Matrix (Integra Life Sciences, Plainsboro, NJ) consists of a cross-linked bovine tendon collagen and glycosaminoglycan matrix and, in the case of the bilayer matrix, a semi-permeable polysiloxane layer. Glycosaminoglycans are large saccharide polymers that are important elements of the extracellular matrix. These proteins aid in cellular adhesion to the matrix, as well as playing a role in cell and tissue differentiation necessary for wound healing.[99] The semi-permeable polysiloxane membrane functions as a temporary epidermis by protecting the deeper collagen graft tissue in the wound while also controlling water vapor loss. Below the silicone layer, the collagen-glycosaminoglycan biodegradable matrix provides a scaffold for cellular migration and capillary growth.

As the graft is incorporated, the silicone layer peels away to expose new granulation tissue formation and neo-epithelialization.

GraftJacket® Regenerative Tissue Matrix (Wright Medical) is a collagen based graft processed from cadaveric human skin. As an allograft, this product contains components of normal skin including collagen, elastin, hyaluronan, fibronectin, and blood vessel channels.[100-102] In this way, GraftJacket® provides soft tissue coverage over deep structures, functions as a scaffold for new cellular in-growth, and with the preservation of vascular channels in the donor graft, it allows for rapid revascularization necessary for wound healing, and its increased durability allows for usage in areas of higher stress –such as the plantar aspect of the foot.[103]

Skin stretching devices

Skin stretching devices can aid in wound closure by reapproximating a large wound. One such device, the Dermaclose™ RC (Wound Care Technologies, LLC), can be utilized to close wounds up to 15 cm in diameter. To utilize these devices, anchors are implanted approximately 1.5 cm from the wound margin in the healthy periwound skin. Continuous tension is placed to slowly stretch the skin along the subcutaneous planes to gradually bring the wound edges into close apposition. These modalities are especially helpful to provide closure on wounds on the dorsum of the foot or leg, and occasionally on the plantar foot.[104,105]

Discussion

While there are a number of modalities available to the clinician to heal lower extremity wounds, there has heretofore not been a combined continuum to establish the recommended time along the spectrum of wound healing where each product can be most effectively utilized. It is important that the wound care specialist not become complacent while treating lower extremity ulcerations and become satisfied wound *care*, as opposed to wound *healing*.

Sheehan et al., found that a wound which does not reduce in area (simple length x width) by at least 50% in 4 weeks, has greater than 90% likelihood of *not* healing at 12 weeks.[68] Should a wound be progressing too slowly, it is appropriate to alter the modality in an effort to restart healing.

Essentially, there are three major stages along the continuum of wound healing in which products and devices can be categorized. In order to achieve wound bed preparation, it is vital for wounds to be debrided *via* the most effective method possible for the patient.

Once the wound is adequately debrided, the clinician can focus on those modalities that can be utilized to promote healthy granulation tissue, albeit maintenance debridement is frequently necessary. Within this zone on the spectrum, there is a some overlap with the final zone in the continuum of wound healing –wound closure. Wound closure methods should be based especially on location, as dorsal and plantar wounds respond differently.

Once a wound has been closed, the clinician's focus should transition from wound healing to wound prevention. Appropriate biomechanical off-loading and potential prophylactic surgery is indicated at this interval to reduce risk of reulceration. Additionally, post-ulcerative patients should be encouraged to purchase a dermal thermometer (TempTouch, Diabetica Solutions, San Antonio, TX) to monitor their foot temperatures and titrate/taper their level of activity accordingly. Research has demonstrated that foot temperatures will become elevated preceding ulceration, thus giving the patient and clinician time to intervene before re-ulceration occurs.[106]

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