Diabetic Foot Ulcers: Debridement and Reduction of Bioburdens

The optimal debridement technique will protect the healthy host tissues, while releasing detrimental contaminants.

BY ADAM LANDSMAN, DPM, PHD

One of the most fundamental techniques for the management of diabetic foot ulcers is debridement. When done properly, this process will decrease necrotic tissue, reduce callus, eliminate biofilms, and stimulate angiogenesis, mitogenesis, and chemotaxis. In response to debridement, diabetic foot ulcers are stimulated to begin the healing process. In this article, various methods of debridement are reviewed, along with the potential effects they have on reduction of bioburdens; and enhancement of wound closure is also examined.

Debridement of diabetic foot ulcers can be broadly divided into chemical and mechanical techniques. Traditional mechanical debridement is performed at the bedside or in the clinic using a scalpel. Generally, the objective of debridement is to leave a wound essentially free of callous and necrotic tissue, with an exposed, well-vascularized wound bed. The process of debridement is not without controversy. Proponents of wound debridement point to the fact that debridement converts a chronic wound to an acute wound when it results in bleeding. The familiar description of the wound cascade is that there is an initial inflammatory phase, followed by a proliferative phase, which ultimately becomes the maturation phase.[1]

In the inflammatory phase, the wound is mechanically debrided and starts to bleed. The bleeding brings platelets into the area to stop the bleeding and degranulate to release the growth factors. Growth factors communicate with the host to stimulate angiogenesis (new blood vessel growth), mitogenesis (new cell proliferation), and chemotaxis (the complex signaling process which tells the host that a new wound exists and mobilizes the body to deliver materials needed to close the wound). The entire inflammatory phase usually peaks about 36 hours after debridement, and is more or less complete about three days after debridement.

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About three days after debridement, the proliferative phase begins. During this phase, new cells are being formed, and the wound is beginning to be covered with the neodermis, an immature, cell-laden skin precursor. The peak of the proliferative phase occurs around the tenth day. It is very important to allow cellular proliferation to reach this peak and not repeat debridement again too quickly. If a wound is debrided every seven days, for example, the patient will barely reach 50% of proliferative capacity before return to the inflammatory phase. Thus, it is possible to debride a wound too often. In some cases, the purpose of debridement is to reduce infection rather than to stimulate growth. In those cases, removal of the neodermis is not critical, because the goal is different.

The maturation phase is probably not really a phase at all, in the sense that it represents the continual growth and remodeling of the wound bed, for an extended period of time until the wound is debrided again. The precise beginning of this phase is a matter of controversy, but the consensus is that it begins just after the peak of proliferation at day ten.

The phases of wound healing describe the ideal scenario that occurs in an otherwise healthy patient who has the ability to heal. However, more often than not, the progression

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of phases is hindered by some factor. Blood supply is frequently a problem, as peripheral vascular disease is common among patients with diabetes. Similarly, the presence of necrotic tissue in the wound bed will frequently lead to bacterial contamination and formation of biofilms. Furthermore, diabetic patients with chronic wounds are believed to be lacking in the quantities of growth factors and collagen necessary to get a wound to close.

Although debridement is an important part of managing diabetic foot ulcers, this is only one of many aspects that will influence a patient's ability to heal. Reducing ground reactive forces, nutritional state, and blood glucose control are also critical factors. Excessive exudate or desiccation, as well as contamination, may also affect outcomes.

1) Mechanical Debridement

As mentioned earlier, the principle benefit of mechanical debridement is to remove bioburdens while stimulating bleeding at the wound site. Bioburdens such as biofilms are formed from tough polysaccharides that protect the bacteria encased within them. These layers are not easily removed, and will hinder wound healing. As bacterial load increases, so do inflammation and the formation of matrix metalloproteases (MMP). Biofilms are resistant to topical and oral antibiotics that are usually unable to reach the underlying bacteria.[2] Mechanical debridement can scrape away the necrotic tissues and biofilms to reveal underlying tissues which should have a significantly lower level of contamination.

Scalpels and tissue nippers are the most commonly used tools for removal of this superficial tissue, but there are other options which may provide deeper and more complete removal of the wound surface. Devices like VersaJet squeeze liquid through a tight aperture to create a jet-stream that peels away loose tissues. Similarly, pulsed lavage uses saline or other liquid solutions to thoroughly cleanse the wound surface.

Low frequency ultrasound devices also can be used to clean and debride wound surfaces. In theory, the healthy, firmly attached viable tissues are selectively spared, while the less viable debris is cleanly removed. There is also a non-contact system that uses acoustic therapy to agitate and loosen debris on the wound surface (MIST Therapy® System, Celleration Inc., Eden Prairie, MN). At the same time, the localized irritation from ultrasound and acoustic therapy causes slight vasodilation that enhances the healing process. There are also ultrasonically assisted devices (Sonic One®, Misonix Ultrasound Surgical Devices, Farmingdale, NY; Qoustic Wound Therapy System™, Arobella Medical, LLC, Minnetonka, MN; and Sonoca 180, Söring Medical Technology, North Richland Hills, TX) that resemble a curette, and can be used to gently scrape away debris using a combination of cavitation within the tissues and heat, as well as direct mechanical agitation.

Although mechanical debridement is a highly accepted method of removing necrotic tissue and reducing biofilms, chemical debridement is often necessary, particularly with tunneling wounds and deep wounds, where the mechanical debridement devices cannot reach. Also, mechanical debridement methods only work while they are being used. Once the scalpel is removed, the biofilms start to reform. For this reason, chemical methods should also be considered.

2) Chemical Debridement

Chemical debridement involves the use of liquids and gels that are effective at reducing slough, bioburden, and penetrating into biofilms. When a wound is clean with a nice granular surface, nothing more than a saline or hypotonic solution may be necessary to gently rinse away debris before and after debridement. However, when more resistant material is found on the wound surface, a more effective solution is necessary. More traditional topical antiseptics like povidone iodine may kill surface bacteria, but will have little benefit in the presence of a biofilm. Similarly, hydrogen peroxide is also ineffective against the tough biofilm armor, and may actually be cytotoxic to the host's tissues.

One particular chemical that is effective against biofilms and in reducing bioburdens is hypochlorous acid (HOCl). It can be found in several preparations that are readily available for clinical use (eg, Microcyn® Skin and Wound Cleanser, Oculus Innovative Sciences, Petaluma, CA; Vashe Wound Therapy®, PuriCore, Malvern, PA; Puracyn Plus®, Innovacyn, Rialto, CA, and NeutroPhase® Wound Cleanser, NovaBay Pharmaceuticals, Inc., San Francisco, CA). Hypochlorous acid is a naturally occurring molecule that is produced by white blood cells. After engulfing a pathogen, the neutrophil releases the highly potent oxidizing agent HOCl to bind to the cell membrane of a bacteria cell, fungus, or virus, and destroy the membrane, killing the cell. Studies with HOCl have shown that it is highly effective against even resistant strains of bacteria such as MRSA and VRE.[3] HOCl also will not damage keratinocytes or fibroblasts, and does not harm collagen. It has the added benefit of reducing pain and odors.[4]

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Wounds that have slough and necrotic material have always been especially difficult to treat. Mechanical debridement tends to leave behind large quantities of more deeply embedded necrotic material, and may require destructive gauging of the tissues to remove it. In response to these types of wounds, clinicians have historically chosen enzymatic debriding agents. Materials such as papain and urea con-

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tain mild caustic agents which slowly dissolve necrotic tissue and reduce slough, while sparing the underlying healthy tissue. One difficulty associated with these agents is the need for very regular re-application. Normally, the agent is applied at least once per day, and should be thoroughly rinsed with saline each time it is replenished.

A another option for treatment of slough and necrotic tissue involves the use of a desiccant capable of withdrawing so much fluid from the wound bed, that bacteria is destroyed and slough ceases being so "soupy". An old treatment for wounds with slough and exudate was to dry them out with povidone iodine mixed with sugar. The sugar was such a powerful absorbing agent that the wound would be desiccated and the slough would be dried out. A similar affect occurs with dressings containing honey.

This year, the next generation of surfactant was introduced. Surfactants act to lower the surface tension between two liquids or a liquid and solid, allowing them to intermingle. In its newest form, there is a dense hydrogel that contains micelles in suspension (PluroGel®, Medline, Mundelein, IL). The micelles surround and capture debris and excess moisture from the wound, and can remain absorbent for several days, depending on the degree of exudate (Figures 1a and 1b). It has been described as a super-surfactant because of its ability to capture many times its weight in debris while maintaining a moist wound-healing environment.

3) Combination Therapy

Mechanical and chemical debridement techniques can be used separately, or in combination. For example, some of the HOCl products are sold in bottles with hangers attached and spike caps, so that they can be used with pulsed lavage devices directly from the bottle. Ultrasonic devices used in conjunction with these solutions give the advantage of driving the solutions further into the tissues being debrided.

4) Debridement from Wound Dressings

In most cases, dry gauze will adhere to the surface of a wound. If the dressing is being changed on a daily basis, it is likely that each time, the delicate, newly formed neodermis can be disrupted. In the case where there is significant debris on the wound surface, debridement may be intentional and desired. However, in other cases, this type of excessive debridement may slow the healing process. Highly absorbent dressing materials may help to control exudate, and can be an integral part of the debridement process.

There are combination dressings now available which provide a non-adherent surface backed by a hydrogel which protect the surface of the wound while absorbing exudate.

In other cases, a non-adherent dressing may also be beneficial to reduce excessive debridement. There are combination dressings now available which provide a non-adherent surface backed by a hydrogel (eg. Optilock®, Medline, Mundelein, IL), which protect the surface of the wound while absorbing exudate.

5) Biologics with Antimicrobial Activity

Although not strictly a debridement treatment, there are two recent decellularized collagen products that have been introduced that contain antimicrobial activity. Puraply AM® (Organogenesis, Canton, MA) contains polyhexamethylene biguanide hydrochloride (PHMB) and Primatrix Ag® (TEI Biosciences, Boston, MA) contains silver. Both of these products are effective at reducing bioburdens, while delivering collagen, which is generally critical for the progression of wound healing.

Conclusions

Ultimately, debridement is a critical aspect of optimizing the wound environment for closure. The purpose of debridement is to remove contamination and stimulate growth. Mechanical and chemical techniques must be used judiciously so as not to disrupt delicate neodermis, particularly during the first 10 days fol-

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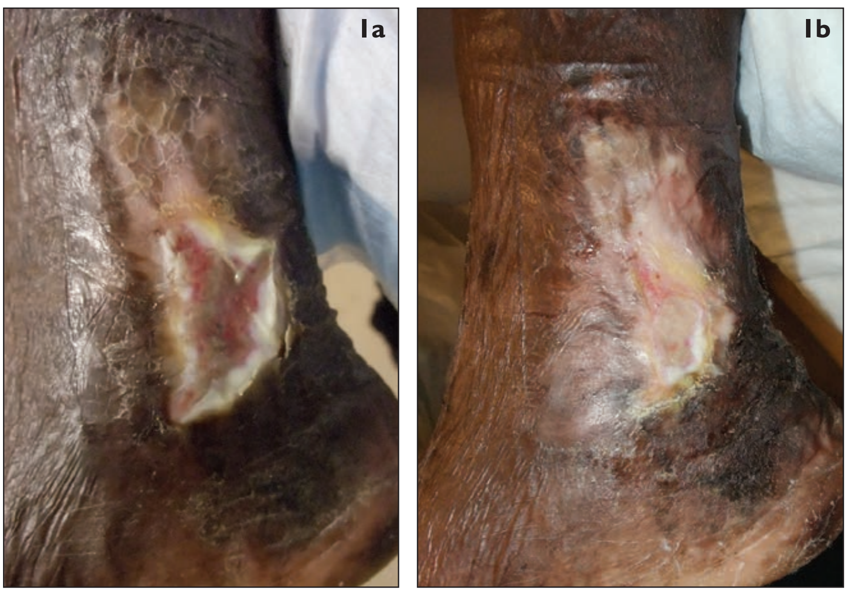

Figure 1a: Wound containing exudate and slough, before; and 1b: after three weeks of treatment with a strong surfactant (PluroGel®)

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lowing the inflammatory period of healing. Although debridement is a fundamental part of caring for diabetic foot ulcers, there are many variations in technique. Mechanical debridement offers a quick solution to removal of debris and necrotic tissue, and helps to break up biofilms which can impede wound healing. Conversely, chemical debridement offers a more gentle release of debris, but usually requires more time. Wounds with lots of slough and unexposed tunneling areas may benefit from chemical debridement. In some cases, a combined approach may be the best option. The optimal debridement technique will protect the healthy host tissues, while releasing detrimental contaminants. Debridement is particularly important when the treatment plan includes the use of an advanced biologic such as a living cell product since these materials benefit from an optimized wound bed for attachment. **PM**

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Dr. Landsman is Assistant Professor of Surgery at Harvard Medical School and Chief, Division of Podiatric Surgery at Cambridge Health Alliance.