Wound Debridement Methods Review

Introduction

When an injury persists, the inflammation response is perpetuated which often extends the damage. Complications like this occur in trauma and in diseases which disrupt the normal repair process such as diabetes and venous hypertension. This situations often create non-healing wounds.[1] Devitalized tissue has strong adverse effects on wound healing which pushes the importance of research in the field of wound debridement. Devitalized soft tissues has the potential to damage defenses and thus, may lead to infection within the host. The ability of devitalized soft tissue to cause infection stem from the fact that it acts as a medium to promote bacterial growth, inhibits leukocyte phagocytosis of bacteria, and creates an environment which limits leukocyte function. [2] The presence of necrotic tissue can be life-threatening by preventing wounds from healing and inhibiting the removal of devitalized tissue from a wound. Thus, debridement is very important in wound care.[3]

Wounded cells show different properties than normal cells. A 2007 study characterized the differences using in vitro models undergoing cell stress using biochemical tests. Diabetic wounded cells were part of this study. Results showed that diabetic wounded cells had a decrease in ATP viability, increase in cytotoxicty, and in DNA damage compared to normal cells.[4] The difference between dead and viable tissue plays an important role in wound debridement where the removal of dead tissue plays a part in the promotion of wound healing. Selective wound debridement methods such as maggot therapy and surgical methods must be able to differentiate between dead and viable tissue. In the last section of the paper, the potential of a debrider mechanism to differentiate these tissue properties in the usage of wound debridement will be discussed.

Burns are a source of dead cells. A main characteristic of burns is the formation of an eschar, which comprises both burned and traumatized tissue. This eschar may lead to an improper burn depth diagnosis, further injury to neighboring tissues, and possibility of an infection. Thus, the healing of burns often requires the removal of eschar. According to Rosenberg in 2004, the primary choice in burn debridement methods is surgical. This process may be effective but is also often painful and non-selective, possibly hurting viable tissue and hurting the burn further. Enzymatic debridement is currently being researched and has shown promise in clinical trials. Results from the study will be referred to later in the review.[5] Diabetic ulcers are also a source of dead cells and commonly need wound debridement intervention.

Wound Debridement

According to the review titled Enzymatic Wound Debridement, debridement refers to the “removal of foreign material and devitalized or contaminated tissue from the wound bed until surrounding healthy tissue is exposed.”[6] Debridement focuses on the removal of necrotic tissue; necrotic tissue creates the possibility of an infection, begins the inflammatory response, and impedes healing. Foreign debris must

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[1] Clark, Richard. *The Molecular and Cellular Biology of Wound Repair*. New York: Plenum, 1988. Print.

[2] Haury, B, Rodeheaver, G, Vensko, J, et al. (1978). Debridement: an essential component of traumatic wound care. The American journal of surgery, 135(2), 238-42.

[3] Hampton, S. & Collins, F. (2004). *Tissue viability the prevention, treatment, and management of wounds*. London Philadelphia: Whurr Publishers.

[4] Zungu, Innocent L., and Denise H. Evans. "Biological Responses of Injured Human Skin Fibroblasts to Assess the Efficacy of in Vitro Models for Cell Stress Studies." *African Journal of Biochemistry Research* 1.4 (2007): 60-71. *Academic Journals*. Web. 3 Jan. 2015.

[5] Lior Rosenberg, Oren Lapid, Alex Bogdanov-Berezovsky, Ronen Glesinger, Yuval Krieger, Eldad Silberstein, Amiram Sagi, Keith Judkins, Adam J. Singer, Safety and efficacy of a proteolytic enzyme for enzymatic burn débridement: a preliminary report, Burns, Volume 30, Issue 8, December 2004, Pages 843-850, ISSN 0305-4179, http://dx.doi.org/10.1016/j.burns.2004.04.010.

[6] Ramundo, J., & Gray, M. (2008). Enzymatic Wound Debridement. *Journal of Wound, Ostomy and Continence Nursing, 35*(3), 273-280. Retrieved December 31, 2014, from Lippincott Nursing Center.

be removed before the formation of granulation tissue can be promoted and the wound can close.[7] Previous research has shown that debridement is a key necessity of wound preparation when any type of slough or eschar is present. This is especially the case when dealing with chronic of non-healing wounds which are hampered in the inflammatory phase. Debridement allows for wound healing by reducing inflammatory products, promoting growth that are inhibited by the inflammatory products, and removing bacterial presence. Effectiveness of multiple techniques for wound debridement are currently being studied in clinical trials and researchers are still looking for the optimal technique.[8] Wound debridement can be surgical, biosurgical such as larvae therapy, chemical, enzymatic or through autolysis which is the rehydration of the devitalized tissue.[9] Bradley et. al gave a comprehensive review of the available debridement methods which include dextranomer polysaccharide beads or paste, cadexomer iodine polysaccharide beads or paste, hydrogels, enzymatic agents, adhesive zinc oxide tape, surgery or sharp debridement, and maggot therapy.[10] The technique used must be based on a number of properties of the wound such as wound size, type and amount of necrotic tissue, presence of bacteria or infection, pain possibility, patient preference, accessibility, and cost.[11] Figure 1 gives a simplified summary of the key factors in selecting a specific debridement methods.[12]

	Surgical	Sharp	Enzymatic	Autolytic	Mechanical	Biologic
	(by Physician)	(by Clinician)				
Speed	1	3	5	6	4	2
Tissue Selectivity	4	3	1	5	6	2
Painful Wound	6	4	2	1	5	3
Exudate	1	2	5	4	3	6
Infection	1	3	5	6	4	2
Cost	6	4	2	1	5	3
1 indicates the most desirable method; 6 indicates the least desirable method.						

Figure 1. Important factors in debridement method selection.[13]

Surgical Method

Surgical debridement, often referred to as sharp, is currently considered the fastest method, but requires an experienced surgeon. In this type of debridement, sterile scissors or a scalpel is used to dissect necrotic tissue from viable tissue. This method allows the healthy tissue to be exposed which is necessary to begin the healing process. Sharp debridement prevents clinical infection as well by removing microbial contaminants. However, this method can be very dangerous since it requires a knowledgeable practitioner to be able to segregate the two types of tissue present. Fibrous tissue can often have the appearance of slough and accidental cutting may lead to severed ligaments or severed small arteries. Tendons in leg ulcers, for example, may mimic slough and wrongful cutting may lead to serious consequences. Some surgical consultants agree to cut the necrotic tissue until bleeding tissue is exposed with the ideology that the initiation of bleeding will start the healing process. However, there is obvious concern with this method with the potential consequences being infection or haemorrhage. Sharp

[7] "Debridement Methods." *Vancouver Island Health Authority*. British Columbia, 2013. Web. 1 Jan. 2015. <http://www.viha.ca/nr/rdonlyres/469c9208-e310-4b5d-9ff8-4a7de7eaaede/0/debridementmethods.pdf>.
[8] Enzymatic Wound Debridement
[9] *Tissue viability*
[10] Bradley, M. "The Debridement of Chronic Wounds: A Systematic Review." *Health Technology Assessment* 3.17 (1999): 1-73. *The University of Manchester*. Web. 21 Dec. 2014.
[11] Enzymatic Wound Debridement
[12] "Debridement Methods"
[13] "Debridement Methods"

debridement has been known to be used together with autolysis. Any wound extremely sensitive to bleeding or pathogen invasion should not be surgically debrided. In terms of pain, necrotic tissue removal is usually painless since there is no viable nerve supply. However, the presence of healthy tissue in the wound may cause pain and discomfort during the surgical procedure which may result in the usage of anaesthetics. [14] A 2005 clinical study studying the effect of sharp debridement on chronic venous leg ulcers found that sharp debridement was effective in stimulating healing.[15] Overall, the surgical method should primarily be used with wounds with a large area of necrotic tissue or an extremely contaminated wound. It is also performed to prepare a wound for grafting and is often a good choice for diabetic foot ulcers.[16]

Autolytic Method

The autolytic method acts by using the body's own enzymes to soften and break down the eschar in the wound. It is a relatively painless method, but also acts slowly. It is not to be used with in the treatment of infected pressure ulcers or heavily exudating wounds. It is used for Stage 3 ulcers: venous ulcers and traumatic ulcers with light exchar. Another form of debridement is used if tissue autolysis is not seen in approximately 24 to 72 hours.[17] This method, which to an extend naturally occurs in all wounds, acts by phagocytic cells and proteolytic enzymes liquefying and separating necrotic tissue and eschar from healthy tissue. Maintaining a moist wound area by using wound dressings allows an optimal environment for this debridement to occur since it promotes granulation. Autolytic debridement is relatively easy to do, does not result in any damage to viable tissue, and creates minimal pain. Hydrogel dressings are types of advanced wound care products that help in autolytic debridement by re-hydrating tough necrotic tissue and loosening and absorbing exudate and slough. And during the later stages of wound care, particularly wound closure, hydrogels provide an ideal moist wound environment.[18] In a systematic review study, it was found that most trials performed showed no statistical difference in wound healing between advanced wound dressings and simple dressings.[19] Depicting the lack of evidence, another review study claimed that some trials showed that advanced wound dressings showed improved wound healing rates compared to other dressings or compression alone in chronic venous leg ulcers. It is important to note that this 2014 review on advanced wound dressings stated that "the poor quality of the literature limits conclusions and necessitates future, well-conducted studies to evaluate the effectiveness of advanced wound dressings on chronic venous ulcers."[20] Further studies must be done to show statistical significance of an optimal technique in wound debridement that may vary on individual wounds.

Enzymatic Method

Enzymatic debridement refers to the application of exogenous enzymes to the wound site to deteriorate necrotic tissue and sustain viable tissue. These enzymatic debriding agents are applied to the wound site and usually daily but depend solely on the the type of agent used. Stinging sensation or hypersensitivity to the enzyme or any other components applied are both causes of concern with this method or wound debridement. [21] There are many FDA approved drugs on the market that act as topical debriding agents. These chemicals help speed up the wound healing process by destroying foreign

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[14] *Tissue viability*

[15] Williams, D., and S. Enoch. "Effect of Sharp Debridement Using Curette on Recalcitrant Nonhealing Venous Leg Ulcers: A Concurrently Controlled, Prospective Cohort Study." *Wound Repair and Regeneration* 13.2 (2005): 131-37.*Web of Science*. Web. 3 Jan. 2015.

[16] "Debridement Methods"

[17] "Debridement Methods"

[18] "Wound Bed Preparation." *Smith & Nephew*. N.p., n.d. Web. 05 Jan. 2015. <http://www.smith-nephew.com/professional/products/featured-products/wound-bed-preparation/background/debridement/>.

[19] Zenilman, J. "Chronic Venous Ulcers: A Comparative Effectiveness Review of Treatment Modalities [Internet]." *Agency for Healthcare Research and Quality* 13.14 (2013).*PubMed*. Web. 5 Jan. 2015.

[20] Valle MF, Maruthur NM, Wilson LM, et al. Comparative effectiveness of advanced wound dressings for patients with chronic venous leg ulcers: a systematic review. Wound Repair Regen. 2014;22(2):193-204.

[21] Enzymatic Wound Debridement

material and removing dead tissue when applied to the wound.[22] A common practice is to inject enzymes beneath the surface of the eschar of devitalized tissue. The fluid must be placed in the devitalized tissue region. Streptokinase and streptodornase, known as Varidase, are examples of enzymes commonly used to promote necrotic wound debridement. Streptokinase activates a fibrinolytic enzyme, breaking up thrombi, while streptodornase liquefies the dead cells allowing for irrigation to remove the liquefied material.[23] In a study done by F Smith in 2013, one trial found that enzyme-treated wounds were cleaned more quickly compared to other debridement methods. However, the researcher noted that the methodological quantity was poor and a better comparison of debridement methods should be published. [24] Another example of enzymatic debridement is RD Sinclair's study of proteolytic enzymes and their role in wound healing. Proteolytic enzymes are able to deteriorate the necrotic tissue that results from cell breakdown, present in wounds. Many of these types of enzymes are currently available for wound debridement. According to the study, proteolytic enzymes have the ability to regulate cell growth, to synthesize collagen, to eliminate dead tissue following inflammation, and to develop and remove perivascular fibrin cuffs (present in venous insufficiency and leg ulceration).[25]

More studies are needed to completely evaluate the effectiveness of enzymatic debridement. Problems known to be associated with enzymatic debridement are the fluid moving away from the required position, the need to change the dressings, and the error in injection site.[26] The effectiveness of enzymatic debridement has been compared using hydrogel which is often used in conjunction to help hydrate the wound. In a study by SJ Martin, hydrogel only and enzyme (Varidase)/hydrogel was compared in its ability to remove eschar. It was found that it took fewer days with the hydrogel only group, however results were not statistically significant.[27] In another study published in the Journal of Wound, Ostomy and Continence Nursing, researchers investigated the effectiveness of enzymatic debriding materials collagenase and papain-urea in wound healing by necrotic tissue removal. Results showed that collagenase, an enzyme debriding agent, was more effective than a placebo in necrotic tissue debridement for pressure ulcers, leg ulcers, and partial-thickness burn wounds. Results also suggested that enzyme debridement could replace or be used in conjunction with surgical methods. In conclusion, by debriding both slough and eschar, enzymatic debriding agents may be used in necrotic tissue removal in cases of ulcers and partial-thickness wounds. It is important to note that enzymatic agents can often be a primary method of debridement, especially when sharp wound debridement can lead to serious consequences, for example in bleeding disorder cases. As stated before, combination therapy is also often used in wound debridement. Previous clinical research has suggested the use of both surgical and enzymatic debridement in patients with chronic or non-healing wounds. Autolytic debridement may also be used with these methods. With the application of enzymes, there is also a variety of dressings needed to take into consideration such as gauze, thin foams, and transparent film. Similar factors that affect enzyme choice also impact the type of dressing that should be used.[28]

In burn wounds, selective enzymatic debridement has been studied for its ability to preserve spontaneous epithelialisation potential and decrease the possibility of injury caused by sharp or surgical debridement.[29] In the past, enzymatic debriding agents needed long and repeated exposures and often required additional surgical intervention. This repeated application process using dressings created the

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[22] "Topical Debriding Agents." *Drugs.com*. N.p., 2014. Web. 28 Dec. 2014. <http://www.drugs.com/drug-class/topical-debriding-agents.html>.

[23] *Tissue viability*

[24] Smith F, Dryburgh N, Donaldson J, Mitchell M. Debridement for surgical wounds. Cochrane Database Syst Rev. 2013;9:CD006214.

[25] Sinclair RD, Ryan TJ. Proteolytic enzymes in wound healing: the role of enzymatic debridement. Australas J Dermatol. 1994;35(1):35-41.

[26] *Tissue viability*

[27] Martin SJ, Corrado OJ, Kay EA. Enzymatic debridement for necrotic wounds. J Wound Care. 1996;5(7):310-1.

[28] Enzymatic Wound Debridement

[29] Yuval Krieger, Alexander Bogdanov-Berezovsky, Reuven Gurfinkel, Eldad Silberstein, Amiram Sagi, Lior Rosenberg, Efficacy of enzymatic debridement of deeply burned hands, Burns, Volume 38, Issue 1, February 2012, Pages 108-112, ISSN 0305-4179, http://dx.doi.org/10.1016/j.burns.2011.06.002.

huge possibility of infection. Researchers have identified the ideal debriding agent to be safe; selective, ability to remove necrotic tissue without affecting viable tissue; effective, removing entire eschar; rapid; simple and cost effective.[30] Enzymatic has been tested in burn patients and has shown variable results. Positives include a lower need for blood transfusion and quick necrotic tissue removal and thus allowing early skin grafting. However, a number of problems are associated with enzyme debriding. Different enzymes often times are needed for debridement of different types of burn wounds. Also, research has shown that enzyme preparation must occur in a moist environment to be effective. In addition, the problem of bleeding with an aggressive treatment of enzymes is still an issue. Ongoing research, however, is being devoted to enzymatic debridement rather than surgical in the treatment of wounds due to its possibility of higher selectivity.[31] In a 2012 clinical study using the selective enzymatic compound Debrase on deep hand burns, researchers found that using a selective enzymatic agent in debridement of deep-hand burns led to a decrease in perceived full-thickness wound area and skin-graft use. Debrase proves safe due to its inability to penetrate intact keratin, its limitation to act for a few hours, and its eschar specificity. This ability in enzyme debridement to have eschar specificity allows for accidental prolonged application that will not cause healthy tissue damage. No complications besides pain was found in this study. There was a significant decrease in the number of burn patients needed for an operative procedure compared to before enzymatic debriding agents were used. In other words, there was a statistically significant difference between the expected and actual number of hands needed for surgery. There was also a significant decrease in the wound are grafted in those who underwent skin grafting procedures.

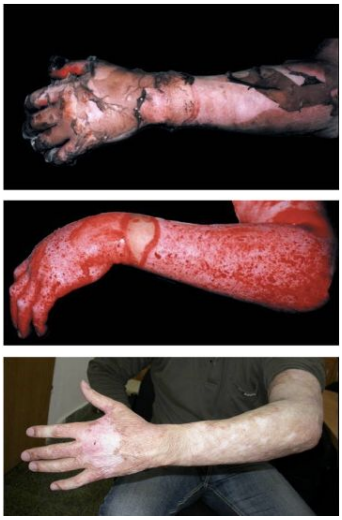

Figure 2 shows the process of Debrase enzyme debridement on deep flame burns on the hand. The study also showed that an enzymatically debrided wound bed has the ability to support skin grafts.[32]

Figure 2. First picture depicts the burns on Day 1 before treatment. Second picture depicts the clean derman bed on Day 1 after enzymatic debriding agent, Debrase, was applied. Third picture is the 9 year follow-up.[33]

Enzyme	Selected products
Collagenase	Santyl
Fibrinolysin/DNase	Elase[a]
Papain/urea	Accuzyme
	Ethezyme
	Gladase
	Kovia
Papain/urea/CCC	Panafil
	Ziox
Streptokinase/ streptodornase	Varidase[a]
Trypsin	Xenaderm
	Granulex

a Not available in the United States.

Overall, the enzymatic method should be performed on wounds prone to eschar formation and “friction-type” injuries. It is known to cause minimal damage to healthy tissue and is the best choice for home care patients.[34] Current enzymatic debriding agents on the market are depicted in Figure 3. Evidence for enzymatic treatment versus other methods has been lacking, and more research must be done to determine the efficacy of enzymes

ébridement

[redacted] otic tissue from burn wounds, Burns, Volume 26, Issue 3, 1 May 2000, Pages 207-222, ISSN 0305-4179, http://dx.doi.org/10.1016/S0305-4179(99)00117-5.

[32] Efficacy of enzymatic debridement of deeply burned hands

[33] Efficacy of enzymatic debridement of deeply burned hands

[34] “Debridement Methods”

compared to other debridement techniques.[35]

Figure 3. Enzymatic debriding agents commercially available.[36]

Biological Method

Maggots have the ability to ingest necrotic tissue, in particular soft necrotic tissue. The benefits of using this bio-debridement method is the selective debridement of dead tissue, the digestion of liquefied tissue, the antimicrobial properties, and the presence of growth-promoting maggot secretions. However, there is special protocols needed to be taken when dealing with larvae including a permit, a special dressing to confine this larvae, biological waste considerations, and patient cooperation.[37] A main reason why maggot therapy has found new popularity is due to the increasing complications with conventional treatment-resistant wounds and antibiotic resistance bacteria. Maggot therapy uses disinfected fly larvae to treat wounds and prevent infections by dissolving the necrotic tissue, killing bacteria and promoting wound healing. The larvae (the most commonly used is Lucilia sericata) has been found to show antibacterial properties against Gram-negative and Gram-positive bacteria, including MRSA. Examples of uses of maggot therapy to date include a variety of skin and soft tissue wounds such as ulcers (pressure ulcers, venous stasis ulcers, neurovascular ulcers) and traumatic wounds and burns.Through this review, maggot therapy can be effective for necrotic wounds and other cases where it is used in earlier stages of treatment should be reviewed.[38] Another advantage of maggot debridement technology is the fact that maggots have the ability to separate necrotic tissue from living tissue, showing 80 percent to 95 percent full debridement achieved. This information can hopefully be used to prevent unneeded amputation cases. In patients with deep wounds, septicemia, or life-threatening bacterial infection, can be a major concern that can be seen to be prevented by maggot debridement technology as well. In terms of discomfort and esthetics, majority of patients do not complain of any major discomfort besides the tickling or itching sensation. Approximately 20 to 25% of the patients with painful wounds were treated with analgesics due to pain. “MDT has been proven to be an effective method for cleaning chronic wounds and initiating granulation. It is a simple, efficient, well tolerated and cost-effective tool for the treatment of wounds and ulcers, which do not respond to conventional treatment and surgical intervention.”[39] Maggot therapy was performed on the treatment of chronic wounds and ulcers in patients in Israel. The result found that complete debridement was achieved in approximately 88 percent, while 7 percent had significant debridement, determining that maggot therapy is a rapid and effective treatment. The type of wound that this study focused on to perform maggot therapy is significant: large necrotic wounds resistant to conventional treatment and sensitive to surgical intervention.[40] A 2003 clinical study assessed the efficacy of maggot therapy specifically in diabetic foot ulcers that were unresponsive to conventional therapy. Results showed that maggot therapy had a higher growth of granulation tissue and greater wound healing rates, proving to be more effective and efficient than conventional care in nonhealing foot and leg ulcers.[41]

Mechanical Method

Methods termed mechanical, defined by the physical removal of debris from a wound, include wet-to-dry, irrigation, pulsatile lavage, and whirlpool therapy.The simplest form is the wet-to-dry technique

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[35] Falabella, Anna F. "Debridement and Wound Bed Preparation." *Dermatologic Therapy* 19.6 (2006): 317-25. *Wiley Online Library*. Web. 4 Jan. 2015.

[36] "Debridement and Wound Bed Preparation."

[37] “Debridement Methods”

[38] Falch BM, De weerd L, Sundsfjord A. [Maggot therapy in wound management]. Tidsskr Nor Laegeforen. 2009;129(18):1864-7.

[39] Mumcuoglu KY. Clinical applications for maggots in wound care. Am J Clin Dermatol. 2001;2(4):219-27.

[40] Mumcuoglu KY, Ingber A, Gilead L, et al. Maggot therapy for the treatment of intractable wounds. Int J Dermatol. 1999;38(8):623-7

[41] Sherman RA. Maggot therapy for treating diabetic foot ulcers unresponsive to conventional therapy. Diabetes Care. 2003;26(2):446-51.

but this method is time-intensive, costly, and often painful.[42] Once the dressing is removed from the wound, wet-to-dry dressings cause mechanical separation of the eschar from the wound. However, this method not only causes the patient extreme discomfort, but also may damage newly formed tissue.[43] The process of wet-to-dry dressing begins with a wet gauze dressing applied to the wound and laid to dry. Necrotic debris becomes embedded in the gauze applied and then the gauze is mechanically stripped from the wound bed. Granulating wounds should not be subject to this method as it will traumatize the new tissue.[44] Another mechanical method termed wound irrigation involves the use pressurized water to remove bacteria and necrotic debris from the wound. The downside is the possibility of pushing bacteria into healthy tissue accidentally. Whirlpool therapy, another form of powered irrigation, also is able to loosen and remove exudate, necrotic tissue, and debris. Mechanical methods are often suitable to be used with inflammatory wounds but not with sensitive granulation tissue wounds.[45] There are many commercial products available that provide the necessary pressure to irrigate the wound to remove exudate.[46] Saline or another cleansing agent is often used in addition to water to help cleanse the wound. This non-selective method, however, creates the problem of low pressure possibly being ineffective while high-pressure irrigation damaging healthy tissue.[47]

Hydrotherapy is used to ease pain during debridement treatments. Patients often rate pain during the process of burn wound debridement as severe to excruciating. In these cases, hydrotherapy is used to help alleviate the pain. Results have found that patients report significantly less pain when using a hydrotank, according to a 0 to 10 rating scale. Hydrotherapy has proven to be an effective nonpharmacologic pain reduction technique in the process of wound care.[48]

Comparative Method Studies

Ongoing research is targeted to optimizing the debridement method which includes multiple studies comparing all the methods listed above. Treatment of sources of dead cells including ulcers and burn wounds were studied over time to test debridement methods.

A 1999 non-experimental design study investigated the clinical efficacy of 4 debridement methods in ulcer care. Two enzymatic methods, collagenase and fibrinolysin, one autolytic method, and one type of mechanical method termed wet-to-dry dressings were tested for specific clinical outcomes. Using computer modeling, it was found that collagenase (70%) gave the highest likelihood of achieving a clean wound bed, followed by fibrinolysin (57%), autolysis (50%), and wet-to-dry dressings (30%). The collagenase treatment also resulted in the lowest hypothetical total cost, with the wet-to-dry dressings being the most expensive.[49] A 2013 clinical trial of pressure ulcer care in long-term care also confirmed that collagenase debridement was economically dominant compared to autolytic debridement. In other words, the collagenase debridement method was more effective at a lower total cost. The incapability to generalize to other hydrogel dressings, however, was noted.[50] A clinical study in 2005 focused on the effectiveness of an autolytic process and enzymatic process in the debridement of chronic leg ulcers. Wounds were treated with either TenderWet24, an autolytic degradation design, or Iruxol N (Santyl), an enzymatic treatment, and were evaluated based on amount of slough and area of healthy granulation. In the first two weeks, the autolytic degradation appeared more efficient. However, the study found that in

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[42] “Debridement Methods”

[43] “Wound Bed Preparation.”

[44] Falabella, Anna F. "Debridement and Wound Bed Preparation." *Dermatologic Therapy* 19.6 (2006): 317-25. *Wiley Online Library*. Web. 4 Jan. 2015.

[45] “Wound Bed Preparation.”

[46] “Debridement Methods”

[47] "Debridement and Wound Bed Preparation."

[48] Hoffman HG, Patterson DR, Seibel E, Soltani M, Jewett-leahy L, Sharar SR. Virtual reality pain control during burn wound debridement in the hydrotank. Clin J Pain. 2008;24(4):299-304.

[49] Mosher, Beverly A. "Outcomes of 4 Methods of Debridement Using a Decision Analysis Methodolgy." *Advances in Wound Care* 12.2 (1999): n. pag. *Advances in Skin and Wound Care*. American Professional Wound Care Association. Web. 02 Jan. 2015.

[50] Waycaster C, Milne CT. Clinical and economic benefit of enzymatic debridement of pressure ulcers compared to autolytic debridement with a hydrogel dressing. J Med Econ. 2013;16(7):976-86.

general, effectiveness between both treatments was not statistically different.[51] The efficacy of different type of dressings were also assessed in the care of pressure ulcers. Hydrogel, hydrocolloid, and saline solution-moistened dressings were compared against one another in wound healing rates. Results showed no statistical significance between them.[52] Many studies focus on the cost-effectiveness of these dressings as they show similar results in wound healing. Different wounds, however, may need different care. Clearly, ongoing research in this field must be done to find the optimal technique. Overall, other factors need to be considered with debridement methods. A simplified overview of the debridement methods is given here in Figure 4.[53]

Figure 4. Table comparing main wound debridement methods.[54]

Debridement method	Advantages	Disadvantages
Autolytic	• Easy to perform • Natural • Selective • Painless • Useful in wounds with minimal debris	• Slow process • Cannot be used in infected wounds
Chemical (proteolytic enzymes)	• Easy to perform • Selective • Painless • Useful in noninfected wounds where other methods are contraindicated	• May cause irritation of surrounding tissue • Slow process • Enzymes may be inactivated by the wound's pH or other topical agents being used • Need to cross-hatch eschar, if present, prior to application of enzyme
Mechanical	• Easy to perform • Faster than autolytic and chemical debridement • Useful in wounds with necrotic material and moderate to large amounts of exudate	• Nonselective • May remove viable tissue • May damage surrounding tissue.
Surgical (sharp)	• Immediate results • Selective • Indicated in ulcers with large amounts of necrosis and eschar	• Requires skilled clinician • May cause bleeding and pain • Need for analgesia
Biological (maggot therapy)	• Highly selective • Maggots produce antimicrobial factors	• Use is confined to selected cases

Discussion: Question of Wound Debrider

The consideration in a debrider device in wound debridement is its ability to differentiate between dead and viable tissue. Selective wound debridement methods known currently such as maggot therapy and surgical intervention both have the capability of differentiating between these tissues using enzyme secretions and appearance respectively. The question arises is what are the characteristic properties of dead cells that can be sensed by a device. As previously stated, clinical results have showed wounded cells have a decrease in ATP viability, increase in cytotoxicty, and in DNA damage compared to normal

[51] König M, Vanscheidt W, Augustin M, Kapp H. Enzymatic versus autolytic debridement of chronic leg ulcers: a prospective randomised trial. J Wound Care. 2005;14(7):320-3.
[52] Mulder GD, Altman M, Seeley JE, Tintle T. Prospective randomized study of the efficacy of hydrogel, hydrocolloid, and saline solution-moistened dressings on the management of pressure ulcers. Wound Repair Regen. 1993;1(4):213-8.
[53] "Debridement and Wound Bed Preparation."
[54] "Debridement and Wound Bed Preparation."

cells.[55] The next step from these results would be how to have a device sense these electrical or chemical changes that differentiate dead and viable cells. Dielectrophoresis (DEP) has been utilized and demonstrated in the detection of live and dead cells. A DEP microdevice has been shown to selectively separate and detect viable bacteria (by Suehiro et al.) and to separate live and heat-treated Listeria cells. The difference in the electrodynamics of viable and non-viable yeast cells was also extensively studied by Huang et al. through DEP methods. Docoslis et al. proposed a DEP microfluidic device that was able to selectively retain viable cells. In a 2009 study, researchers, studying in the bioelectric field, were able to develop two microfluidic devices that have the ability to selectively isolate live human leukemia cells from dead cells using their electrical "signatures." Results showed 100% selectivity between live and dead cells.[56] Dielectrophoresis is an advanced cell sorting method that creates a non-uniform electric field that separates and identifies particles and cells based on intrinsic properties such as size and electrical composition. The innovative method utilized in the 2009 study is termed contactless dielectrophoresis (cDEP) because electrodes are physically isolated from the sample, eliminating contamination possibilities, complexity and expensive fabrication possible in dielectrophoresis. [57] This is done by inserting electrodes on two sides of a microchannel that are apart from the conductive solution sample by thin insulating barriers. The process of contactless dielectrophoresis and its cell separation ability is shown in Figure 5. Applications using this have been focused on cancer cells and drug therapies.[58]

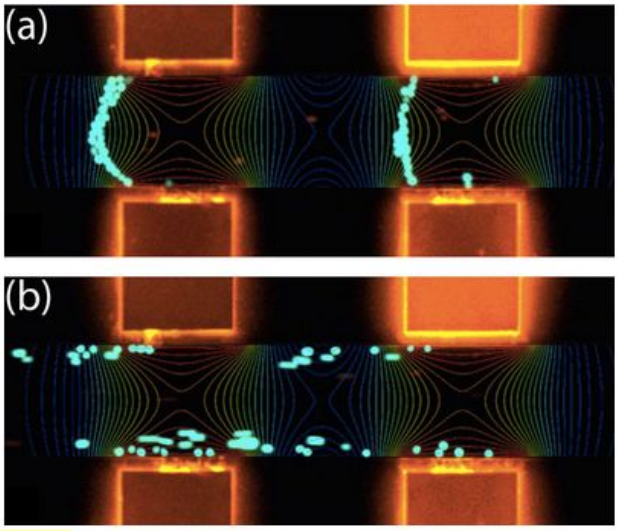

Figure 5. (a) After 30 seconds, live cells (green) are seen being trapped (due to a positive DEP force), while dead cells (red) pass by the trapping area. (b) Depicts the result when the power supply is turned off for comparison.[59]

This separation of live and dead cells is a crucial first step in the debriding technology on wounds since only dead cells must be removed and the highest amount of healthy, viable tissue should be retained. This type of DEP technology that can in the near future, be a fully automated lab-on chip system that has the ability to separate and identify cells based on intrinsic properties could be integrated in the wound debrider hypothetically.[60] From previous studies, electrical contact with wound may even stimulate wound healing. Studies have shown the effectiveness of electrical stimulation in

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[59] Contactless Dielectrophoresis (cDEP): A new technique for particle manipulation.

[60] Contactless Dielectrophoresis (cDEP): A new technique for particle manipulation.

advancing wound healing in the treatment of pressure ulcers.[61] A device that could differentiate the chemical differences between live and dead cells could also be integrated in the wound debrider technology.

In 2012, a wound debrider, Debrisoft, was put into clinical trials and tested in its effectiveness and safety in wound debridement. Researchers pointed out the limitations such as pain, time-intensiveness,selectivity, or accessibility in debridement options available on the market (these options are given in the review above). Using innovative monofilament fiber technology, Haemmerle et al. modified the gauze and dressings treatment to be more effective and tolerable. This fiber has a specific texture that gives it the ability to loosen and bind debris even with just a swipe on the wound surface. The fiber also has mechanical strength that prevents it from shedding when in contact with the wound and are chemically inert, blocking fluid uptake. In clinical trials, the debrider removed almost all debris: wound debris, slough, exudate, and necrotic material. It importantly also kept healthy granulation tissue and epithelialized tissue intact and unharmed. There was no pain recorded and the debrider is considered cost-effective. A surgeon blind assessment of the results from the debrider was deemed “very good.” Scanning electron microscopic analyses of the results show the fibers ability to pick up wound debris as shown in Figure 6.[62] This debrider with fiber technology shows the type of advances in wound care currently in progress. This lacks the selectivity needed in a conductive blade method.

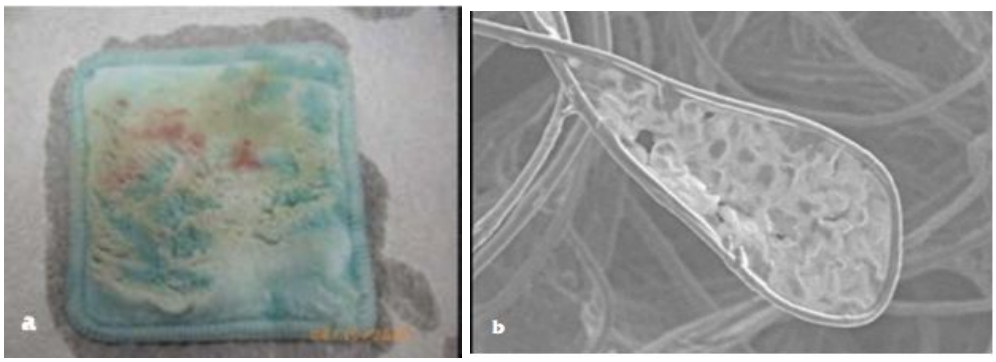

Figure 6. (a) Shows slough and other debris the debrider picked up. (b) x150 magnification of the fibers fixed together by removed material.[63]

Additional research must be done to understand the feasibility of a small cutting surface or blade that can sense tissue viability electrically or chemically. Devices using DEP and cDEP can be used to tell the difference between live and dead cells giving selectivity to wound debridement. The fiber technology of a wound debrider already tested gives a feasible way of picking up most of the debris from a wound giving effectiveness. In conclusion, further research must focus on ways to separate living and dead cells and an effective, safe, and painless method of debriding the dead cells off.

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[63] "The Wound Debrider: A New Monofilament Fibre Technology."