In vitro Evaluation of the Cleansing Effect of a Monofilament Fiber Debridement Pad Compared to Gauze Swabs

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Keywords

Wound cleansing · Gauze swabs · Mechanical wound debridement · Cleansing capacity

Abstract

Background: Removal of nonvital tissue is an accepted method to eradicate biofilms and to stimulate wound healing. Debridement using a monofilament polyester fiber pad has clinically been shown to be effective as well as pain and trauma free. **Methods:** For in vitro determination of the cleansing capacity of this product compared to gauze swabs, a wound debridement model was used with glass plates coated with a bovine serum albumin solution, stained with hematoxylin. Both products were moistened and fixed to a weight connected to a regulated motor and were then pulled over the holding device with the coated glass plate under standardized conditions (power = 0.067 N/cm², velocity = 1.6 cm/s). **Results:** At a low coating concentration (0.5%) both products were equally effective, but at a high concentration (1.5%) cleansing did not occur after 5 wipes. When wiping the plates 15 times, the debridement pad cleansed significantly ($p < 0.001$) better than gauze. When

consecutively wiping 4 coated plates with a single debridement pad or swab, the pad exhibited and maintained a significantly higher cleansing capacity while gauze quickly lost its effect. **Conclusion:** Our in vitro test results indicated a higher cleansing capacity of the debridement pad compared to gauze swabs.

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Introduction

The presence of necrotic or sloughy tissue is reported to delay wound healing [1]. Devitalized tissue acts as a physical barrier to healing and may impede normal matrix formation, angiogenesis, granulation tissue development and epidermal resurfacing [2]. Necrotic tissue or slough may mask or mimic signs of infection and may act as a proinflammatory stimulus or culture medium for microorganisms [3]. The removal of nonvital tissue, debridement, is accepted as a necessity to the management of wound biofilms, eradication of infection and to stimulate the physiological wound healing processes in the stalled wound [2]. Mechanical debridement is historical-

ly associated with the use of wet-to-dry gauze, which non-discriminatorily removes devitalized tissue, resulting in significant pain and damage to healthy tissue [4]. In a clinical study [5] mechanical wound cleansing and debridement using a monofilament polyester fiber product was shown to be effective, pain and trauma free (Fig. 1). The cleansing/debridement efficacy of this product has been evaluated in vitro and was compared to the effects of gauze swabs.

Materials and Methods

Materials

The monofilament polyester fiber debridement pad (Debrisoft®) was obtained from Lohmann & Rauscher GmbH and Co. BSA (bovine serum albumin) was purchased from Sigma-Aldrich (Germany) and hematoxylin solution (mod. Gill II) from Merck (Germany).

Examination of the Cleansing Efficacy Using the Wound Debridement Model

The wound debridement model used consists of glass plates (8 × 8 cm) coated either with a 0.5, 1.0 or 1.5% BSA solution, to imitate the wound slough, which is stained with hematoxylin. Glass plates were placed into a holding device (Fig. 2). Prior to their use, the wound debridement pad was moistened with 18 mL water while the gauze was wetted with 5 mL water. For application, both were fixed to the weight (Fig. 2), which is connected to a controllable motor, and were then pulled over the holding device with the coated glass plate under standardized conditions (power = 0.067 N/cm², velocity = 1.6 cm/s) for a total of 5 times. Plate images were obtained before and after treatment. All images were processed using ImageJ 1.45m (NIH, Bethesda, MD, USA).

Determination of the Cleansing Capacity Using the Wound Debridement Model

For determination of the cleansing capacity, the wound debridement model (Fig. 2) was used with glass plates (8 × 8 cm) coated with a 0.5% BSA solution stained with hematoxylin. Glass plates were placed successively into the holding device. The wound debridement pad was moistened with 18 mL water and the cotton gauze with 5 mL water prior to their use. Both were fixed to the weight connected to the controllable motor, and were then pulled once over the holding device with the coated glass plate under standardized conditions (power = 0.067 N/cm², velocity = 1.6 cm/s). One wound debridement pad or cotton gauze was used to clean 4 BSA-covered plates consecutively. Plate images were obtained before and after treatment. All images were processed using ImageJ 1.45m (NIH, Bethesda, MD, USA). Therefore, color images were converted to black-and-white binary images and saved as tif files. These files were then uploaded into the ImageJ 1.45m program, sharpened using the process tool and the threshold was adjusted using the image tool. Subsequently, images were analyzed using the particle tool from the analyze option in the ImageJ 1.45m program which yields the quantification of dark (BSA-covered) and light (cleansed) areas.

Fig. 1. Example of a venous leg ulcer patient. Debridement of the wound bed and periwound skin was performed with the monofilament fiber pad (courtesy and permission of N. Mustafi, Nord-west-Klinik, Frankfurt, Germany). **a** Situation before debridement. The wound bed is covered with slough, and crusts are present at the wound edges and periwound skin. **b** Situation after debridement. Both the wound bed and periwound skin were clean after 1 procedure of 3 min. **c** Debridement pad after a debridement session. Debris is contained in the pad.

Fig. 2. The wound debridement model: a glass plate with BSA cover is put into the holding device, and cotton gauze or wound debrider are attached to the weight. The weight is then pulled over the glass plate.

Fig. 3. Soaking of samples in an excess amount of distilled water, 5% BSA, or 10% BSA solution to determine the fluid-holding capacity.

Determination of the Fluid-Holding Capacity of Dry and Prewetted Samples

Samples were weighed previously to all tests performed (m_{dry1}). The fluid-holding capacity (FHC) of the samples was then analyzed by soaking the samples in an excess of (a) distilled water, (b) 5% BSA solution, or (c) 10% BSA solution for 5 min at room temperature (Fig. 3). The samples were carefully removed from the Petri dishes (Greiner Bioone, Germany) keeping them at a horizontal position, and the weight of the bathed samples was immediately determined (m_{wet1}). Then samples were transferred to a vertical position to drip off a possible excess of fluid, and then their weight was measured a second time (m_{wet2}). Subsequently, the samples were dried at 80°C for 4 h until a constant weight (m_{dry2}) was obtained. The FHC was calculated according to the following equations [6]:

$$\text{fluid-holding capacity (FHC}_1\text{)} [\text{mL/g pad}] = \frac{m_{wet1} [\text{g}] - m_{dry1} [\text{g}]}{\rho [\text{g/mL}] \times m_{dry1} [\text{g}]} \quad (1)$$

$$\text{fluid-holding capacity (FHC}_2\text{)} [\text{mL/g pad}] = \frac{m_{wet2} [\text{g}] - m_{dry1} [\text{g}]}{\rho [\text{g/mL}] \times m_{dry1} [\text{g}]} \quad (2)$$

with ρ (distilled water) = 1.00 g/mL, ρ (5% BSA solution) = 1.05 g/mL, and ρ (10% BSA solution) = 1.10 g/mL.

All images were processed using ImageJ 1.45m (NIH, Bethesda, MD, USA). Analysis was performed as described in the section Examination of the cleansing efficacy using the wound debridement model.

Analysis of the Protein Retention from BSA Solutions

The retention of protein from 5 and 10% BSA solutions during the tests for FHC after dripping off a possible excess of fluid in a vertical position was calculated according to the following equation:

$$\text{protein retention [g protein / g pad]} = \frac{m_{dry2} [\text{g}] - m_{dry1} [\text{g}]}{m_{dry1} [\text{g}]} \quad (3)$$

Statistical Analysis

Results on cleansing efficacy were obtained from independent measurements, and cleansing capacity was determined in triplicate. FHC experiments were performed 5 times. All values are expressed as means $\pm$ SD (standard deviation). One-way analysis of variance was carried out to determine statistical significances (Microsoft® Excel 2000). Differences were considered statistically significant at a level of $p < 0.05$.

Results

We investigated the performance of a debridement pad in vitro and compared it to conventional cotton gauze swabs that are clinically in use for mechanical debridement.

For the determination of its cleansing efficacy under standardized conditions the developed wound debridement model was used. It could be shown that the debridement pad exhibits a significantly higher cleansing efficacy at a moderate protein scaling (1% BSA) compared to cotton gauze (Fig. 4). At lower BSA concentrations (0.5%) the cleansing effect achieved was comparable. However, at a higher concentration of the protein coating (1.5%), neither cotton gauze nor the debridement pad was able to clean the glass plates. However, increasing the wiping duration from 5 to 15 times resulted in a significant increase ($p < 0.001$) in the cleansing efficacy of the debridement pad (Fig. 5).

Fig. 4. Cleansing efficacy of Debrisoft® compared to cotton gauze. Data are given as means $\pm$ SD.

Fig. 7. Comparison of the FHC of Debrisoft® and gauze pads in the horizontal position (FHC_1). Data are given as means $\pm$ SD.

Fig. 5. Effect of the increase in the wiping duration to 15 times on the cleansing efficacy of Debrisoft® compared to cotton gauze for 1.5% BSA-coated glass plates. Data are given as means $\pm$ SD.

Fig. 8. Comparison of the FHC of Debrisoft® and gauze pads in the vertical position (FHC_2). Data are given as means $\pm$ SD.

Fig. 6. Cleansing capacity of Debrisoft® compared to cotton gauze. Data are given as means $\pm$ SD.

Fig. 9. Comparison of the protein retention of Debrisoft® and gauze pads from 5% and 10% BSA solutions. Data are given as means $\pm$ SD.

To further test the cleansing/debridement capacity of the debridement pad and cotton gauze, 4 coated glass plates were consecutively wiped with a single debridement pad or cotton gauze swab. The debridement pad exhibited a significantly higher cleansing/debridement capacity which was further retained over wiping 4 BSA-coated glass plates while cotton gauze quickly lost its effect (Fig. 6). The physicochemical nature of the debridement pad may provide an advantage with regard to FHC and protein retention from BSA solutions, compared to conventional cotton gauze. As this is relevant for testing cleansing/debridement capacity we have determined these parameters, for the debridement pad and compared them to the results for the cotton gauze swabs. The FHC of pads was calculated for (a) keeping the pads in a horizontal position (FHC_1) and (b) after dripping off a possible excess of fluid in a vertical position (FHC_2). The FHC (in milliliters per gram pad) was determined for distilled water, 5% BSA solution, and 10% BSA solution. For cotton gauze, a significant decrease in the FHC_1 with increasing BSA concentration was observed (Fig. 7). In contrast, the FHC_1 of the debridement pads decreased only slightly with increasing BSA concentration. Figure 8 shows the FHC after dripping off a possible fluid excess in the vertical position (FHC_2). The FHC_2 of cotton gauze also significantly decreased with increasing protein concentration. In contrast, the absorption capacity of the debridement pads was found to significantly increase with higher protein concentrations. Protein retention of the debridement pads and gauze pads from 5 and 10% BSA solutions after dripping off an excess of fluid in a vertical position was analyzed. For both protein concentrations tested, a significantly higher retention of protein per gram pad was observed for the debridement pad compared to cotton gauze (Fig. 9).

Discussion

Complex wounds are often at risk for infection, especially when they are covered with necrotic and/or devitalized tissue [7]. Debridement is generally accepted as a necessary preparation for allowing formation of new tissue [8]. It decreases bacterial load [9], stimulates wound healing, and is therefore widely used as part of systematic wound management [10]. Current options for debridement include surgical, biosurgical, enzymatic, mechanical, and autolytic techniques [8, 11]. The choice of method depends on the general goals of patient care, the etiology and nature of the wound, and the devitalized tis-

sue [8, 11]. Other considerations include social and environmental factors, debridement frequency, access to skilled practitioners, complete patient assessment, and cost [1]. Rapid and effective wound debridement methods include sharp or surgical debridement, mechanical debridement, hydrosurgery, and ultrasonic therapy. Surgical debridement is the most expeditious method but may not always be feasible because of pain, bleeding potential, cost, professional/system regulations, and the lack of clinician expertise [11]. In contrast, emerging technologies using ultrasonic devices or hydrosurgery have been demonstrative wound bed preparation methods without the incumbent painful and traumatic scraping and cutting associated with sharp debridement [8]. However, they require costly equipment and specialized training. Mechanical debridement is historically associated with the use of wet-to-dry gauze, which nondiscriminatorily physically removes devitalized tissue from the wound, resulting in significant pain and damage to healthy tissue [4]. An effective method is required that can be handled by all wound care clinicians in all settings [12, 13]. It should be easy to perform, safe, and, importantly, comfortable for patients [5, 13]. In a clinical study the debridement pad was shown to effectively remove devitalized tissue [5]. The authors concluded that the results of the clinical evaluation indicate that the monofilament fiber product has the potential to replace several modes of debridement, based on its efficacy, short procedure, ease of use, and patient comfort [5]. Clinically it is not feasible to perform a standardized comparison on debridement methods. Necrotic and or sloughy stalled wounds present with different features and are difficult to standardize. Moreover, various wound types require different approaches to wound bed preparation. Due to its convincing debridement effects, the British NICE recommended the use of the debridement pad in acute and chronic wounds [14].

In our model, the increase in the BSA content mimics the different wound surfaces, from sloughy to a hard and thick deposit of dried wound exudate. Testing of the cleansing/debridement capacity using the model showed the ability of the pad to take up wound exudate and crusts from small up to large wound surfaces. FHC testing conducted supported the results on fluid uptake – originally developed for wound dressings but applicable for this situation by adaptation of the contact time. Although our *in vitro* study has limitations and only mimics clinical conditions for testing wound cleansing/debridement, we demonstrated a favorable cleansing/debridement efficacy of the debridement pad compared to gauze swabs under

standardized in vitro conditions. Furthermore, the high water-holding capacity of the debridement pad may be beneficial for taking up excess amounts of wound exudate and slough during the debridement procedure.

Conclusions

Our in vitro test results indicated a higher cleansing/debridement capacity of the debridement pad compared to gauze swabs when cleansing surfaces with a high concentration of protein coating, making it an attractive option for mechanical wound cleansing/debridement.

Statement of Ethics

This study was done in vitro and adhered to the guidelines for good laboratory practice.

Disclosure Statement

This work was supported by Lohmann & Rauscher GmbH & Co. KG, Rengsdorf, Germany. M.A. is an employee of Lohmann & Rauscher GmbH & Co. KG Germany. C.W., K.R., and U.H. received travel grants from Lohmann & Rauscher GmbH & Co. KG Germany, to participate at wound healing conferences. A.A. has been an investigator for Lohmann & Rauscher GmbH & Co. KG, Rengsdorf, Germany.

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