Ultrasound-Assisted Wound Debridement in Diabetic Foot Ulcer Treatment

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Among complications caused by diabetes mellitus, diabetic foot ulcer (DFU) is one of the most serious and costly. Diabetic foot syndrome is defined as the presence of infection, ulceration, or destruction of foot tissues associated with peripheral arterial disease (PAD) and neuropathy. The effectiveness of ultrasound-assisted wound (UAW) debridement is due to the cavitation and micro-streaming effects of ultrasound. Cavitation refers to the formation of oscillating gas microbubbles in a fluid medium; when it occurs, microbubbles expand, contract, and implode, allowing the removal of non-viable tissue and biofilms without damaging healthy tissue. UAW debridement shows higher healing rates, a greater percentage of wound area reduction, and similar healing times in patients with DFUs, but greater quality evidence is needed to confirm these findings. UAW debridement could be an effective alternative when traditional debridement techniques are not available or are contraindicated for use.

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1. Introduction

Among complications caused by diabetes mellitus, diabetic foot ulcer (DFU) is one of the most serious and costly [1]. Diabetic foot syndrome is defined as the presence of infection, ulceration, or destruction of foot tissues associated with peripheral arterial disease (PAD) and neuropathy [2]. Approximately 19–34% of diabetic patients will develop a DFU during their lifetime, leading to amputation of the affected limb [3][4]. Eighty-five percent of amputations in patients with diabetes will be preceded by the presence of a foot ulcer, reaching a mortality rate of seventy percent at five years after initial amputation [3][5].

Standard of care (SOC) in patients with DFU is based on infection control, use of pressure off-loading devices, PAD management, local wound care, metabolic control of diabetes, and treatment of co-morbidities [6]. Wound debridement is a fundamental part of the local treatment of ulcers and consists of removing devitalized tissue from the wound bed to obtain viable tissue to promote healing [7]. There are different types of debridement, including mechanical, sharp/surgical, autolytic, enzymatic, or biological debridement [8]. The International Working Group on the Diabetic Foot (IWGDF) recommends sharp/surgical debridement in preference to other techniques because it is the least expensive, fastest method of wound bed preparation and is available in all geographic areas [7][9]. Sharp/surgical debridement requires specific clinical skills as there is the potential for extensive damage to the wound bed with exposure of bone, joint tissue, or ligament [7].

Currently, in developed countries, it is estimated that approximately 50% of patients with diabetes and foot ulceration have PAD, and it is estimated that 65% of DFUs have an ischemic component; therefore, an effective alternative to traditional debridement techniques is ultrasound-assisted wound (UAW) debridement, which is useful when sharp/surgical debridement is contraindicated, such as in patients with poor vascular status [8][10][11].

There are two modalities of UAW debridement—contact and non-contact—which have identical effects on wound healing. The only difference between the two modalities is how ultrasound is applied: non-contact UAW delivers ultrasound energy to the wound bed through a fine mist of sterile saline applied at a distance between 5 and 15 mm from the wound [12][13].

The effectiveness of UAW debridement is due to the cavitation and micro-streaming effects of ultrasound. Cavitation refers to the formation of oscillating gas microbubbles in a fluid medium; when it occurs, microbubbles expand, contract, and implode, allowing the removal of non-viable tissue and biofilms without damaging healthy tissue [14][15][16]. Likewise, micro-streaming refers to the flow of interstitial fluids caused as a result of the vibration generated by the ultrasound device; this effect alters cell membrane permeability and second messenger activity, resulting in increased protein synthesis, mast cell degranulation, and increased growth factor production, which ultimately leads to neo-angiogenesis and fibroblast stimulation at the wound site [17][18].

Several studies have shown that UAW treatment favors granulation tissue formation in the wound bed, resulting in increased healing rates and reduced healing times of hard-to-heal wounds [12][19][20]. A case series published by Lázaro-Martinez et al. on the effect of UAW debridement in neuroischaemic DFUs showed a significant bacterial load reduction, independent of bacterial species. Bacterial load reduction was associated with improved clinical wound characteristics and a significant reduction in wound size [21]. A recent open-label randomized and controlled parallel clinical trial comparing UAW debridement versus surgical debridement in patients with DFU over a 6-week treatment period demonstrated a significant improvement in cell proliferation and reduction of bacterial load, resulting in a reduction in healing time with the use of UAW debridement [22].

2. Ultrasound-Assisted Wound Debridement in Diabetic Foot Ulcer Treatment

UAW debridement in patients with DFUs is associated with higher healing rates, a greater percentage of wound area reduction than placebo and SOC, and similar healing times between UAW debridement and control groups.

There are two modalities of UAW debridement: contact and non-contact. Both are based on the effect of cavitation and micro-streaming to remove non-viable tissue from the wound bed. As the name suggests, non-contact UAW debridement generates the same effect but with a lower intensity and without direct contact with the wound surface [23].

Although the healing rates favored the UAW group with OR at 2.22 (95% CI 0.96, 5.11), no statistically significant differences were observed concerning the control group (placebo and SOC).

SOC effect compared to UAW debridement on DFUs was reported in five studies [20][22][23][24][25]. The follow-up time of the studies ranged from 5 to 24 weeks, the frequency of debridement application varied from 1 to 3 times per week, and DFUs included were classified according to Wagner [26] and Texas [27] classifications. Only two of five studies analyzed reported on application time of UAW debridement; in the research conducted by Lázaro-Martínez et al. [22], only neuroischaemic DFUs were included, and application time of UAW debridement was 2–3 min/cm^2, whereas the RCT published by Amini et al. [20] included neuropathic and neuroischaemic DFUs and application time of UAW debridement was 1 min/cm^2.

Regarding studies comparing UAW debridement with SOC, three studies reported on the healing rate. Amini et al. [20] and Lázaro-Martínez et al. [22] showed that the healing rate was higher with UAW debridement than with SOC; 60% and 85.1%, respectively. In contrast, Michailidis et al. [23] found a higher healing rate in the SOC group than in the UAW debridement group (83.3% versus 62.5%).

In terms of healing time, UAW debridement appears to have similar healing times to the control group. These findings could be caused by the variability of DFUs included in the RCTs, as healing time will differ depending on the wound depth and presence or absence of infection or ischemia. Another factor to consider is the variability of DFUs classification systems used in the RCTs (Wagner [26] and Texas [27] classifications).

Healing time in studies compared to placebo was only reported by Ennis et al. [28], being shorter in the UAW debridement group than the placebo group (9.12 ± 0.58 versus 11.74 ± 0.22 weeks). In relation to healing time of DFUs in studies comparing UAW debridement versus SOC, Amini et al. [20] and Lázaro-Martínez et al. [22] showed that healing times were shorter with UAW debridement (8.8 ± 12 and 9.7 ± 3.8 weeks) than with SOC (11.6 ± 11.2 and 14.8 ± 12 weeks). Michailidis et al. [23] found that the time to healing was greater in the UAW debridement group than in the SOC group (29.4 ± 10.07 and 15.4 ± 6.1 weeks).

The results obtained in relation to healing rate and healing time carried out by Michailidis et al. [23] in favor of the SOC group could be related to the small sample size and with an application time of UAW debridement, which was not precisely determined.

In addition, the reduction of wound area was greater in patients with DFUs where UAW debridement was applied. The absence of statistically significant results can be explained by the existence of the wide variation in the application time for UAW debridement and the frequency of debridement treatments, ranging from once per week to three times per week. Regarding the application time of UAW debridement, scholars such as Amini et al. [20] established an application time of 1 min/cm^2, whereas in the research by Bajpai et al. [29], the application time was 15 min/cm^2. The great difference in application times and frequency of UAW debridement is due to the use of ultrasound devices with different modalities (contact or non-contact ultrasound devices).

3. Conclusions

Compared with placebo (sham device) and SOC, UAW debridement shows higher healing rates, a greater percentage of wound area reduction, and similar healing times in patients with DFUs, but greater quality evidence is needed to confirm these findings. UAW debridement could be an effective alternative when traditional debridement techniques are not available or are contraindicated for use.

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