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Original research article

Effective debridement with micro water jet technology (MWT): A retrospective clinical application observation of 90 patients with acute and chronic wounds

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ABSTRACT

Objective: This retrospective clinical application observation study shall demonstrate the effect of a wound debridement using micro water jet technology (MWT) as an efficient method promoting wound healing. The final goal is to accomplish a decrease in wound size (reepithelization) due to debridement with MWT. Through the application of MWT, the wound shall receive a healing stimulus. Besides the use of MWT, there are other water-based cleaning/rinsing systems available.

Method: From two wound care centers (Kantonsspital Obwalden, Spital Lachen), all data from patients treated with MWT and different types of wound, over a time period of 3 years, were retrospectively analyzed. All patients, except one, could be treated in an outpatient setting. Fewest of the patients did receive a local anesthetic. Included were all patients, independent from gender and age.

Results: The retrospective data analysis was carried out on 90 patients (46 m/44 f) with an average age of 68.5 years (17/93 years) and a total of 95 different wounds. 58 wounds were completely closed at exit from the wound care center within a median treatment time of 59 days (8.4 weeks). The average treatment time for all 95 wounds was 39 days (5.6 weeks) per wound at the end of debridement, the average wound size 6.1 cm^2. The reduction of healing time compared to traditional methods was approximately 30%.

Conclusion: The result of the retrospective data analysis on patients with predominantly chronic and persistent wounds shows that debriding with micro water jet technology is an efficient, tissue-preserving, precise and time-saving method for outpatient wound care – with excellent healing outcomes. Patient safety was high and we have seen no adverse effects. The MWT is comparable to other water jet-based cleaning/rinsing systems.

1. Introduction

1.1. General information

For chronic or poorly healing wounds, wound bed preparation is critical for the progress of healing [1]. One of the most important measures in wound treatment is effective wound debridement. The goal is to eliminate factors that inhibit healing (necroses, crusts, scabs, eschar, dead tissue, hyperkeratoses, foreign material and microorganisms, inflammatory and infectious foci, pus, exudate, hematomas, fibrinous coatings, biofilm [2], inflammatory cells, metalloproteases, and residues of, for example, ointments and old wound dressings, etc.). Debridement induces the functional process of tissue regeneration [3] and is a key medical intervention in the management of both acute and chronic, non-healing wounds [1]. Debridement induces transformation of a chronic wound into an acute stage, thereby stimulating the healing process afresh. It was demonstrated that more frequent debridement achieves better healing outcomes [4,5].

1.2. Chronic wounds

Normal wound healing is a highly complex process that proceeds over several phases. Schematically, the three phases (inflammatory, proliferation, and remodeling) proceed synchronously and with overlaps. For various reasons (see below), wound healing can be disrupted, resulting in a chronic or poorly healing wound. Wound healing in most cases then gets stuck in the inflammatory phase [6]. There is no uniform definition of when a wound is considered to be chronic. However, a wound can be considered chronic if it has not yet healed after 1–3 months [7–9]. Impaired wound healing is in most cases due to

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underlying systemic diseases, the main cause, in 90% of all wounds, being impaired vascular drainage, that is, chronic venous insufficiency with development of a venous leg ulcer. A somewhat less common cause is peripheral arterial occlusive disease (PAOD). Another important cause of impaired wound healing is excessive mechanical load on the tissue that can produce a pressure or decubitus ulcer. Lastly, metabolic, neural, or vascular causes may also be critical, such as diabetic foot syndrome [10,11]. Other reasons are less likely to be responsible for a chronic wound (skin diseases, tumors, etc.). In addition, systemic factors such as diabetes mellitus, age, sepsis, smoking, medications (corticosteroids, immunosuppressants), and radiotherapy also play an important role. An important factor that must be mentioned is the biofilm that forms within 2–4 days which can inhibit the wound healing process. It must be eliminated from the wound surface to allow healing to proceed. The best method for eliminating the biofilm is physical removal, that is, mechanical debridement [12].

2. Debridement methods

Wound debridement for wound bed preparation can be carried out using a number of methods: wet-to-dry debridement, paraffin gauze, gauze cleaning, mechanical surgery using a scalpel, curette, sharp spoon, monofilament polyester fiber pads or brushes; biosurgery using fly larvae and autolytic and absorbent dressings, or honey and enzymatic debridement with peptidases [13].

The use of a scalpel or curette in particular can be inaccurate and may penetrate too deeply and remove too much or too little tissue. Other more modern methods include the use of negative pressure wound therapy (NPWT), ultrasound, shock waves, and hydrosurgery. The last three methods act directly on the wound and are therefore referred to as direct debridement technologies (DDT) [1].

2.1. Hydrosurgery

An efficient method of wound debridement is hydrosurgery. It has been shown that wound bed preparation using hydrosurgery is faster and more precise and can be carried out with less tissue damage than other mechanical methods [14]. Hydrotherapy achieves wound cleaning, pressure irrigation, and hydromassage of the tissue [15]. Experiments have shown that only high-pressure cleaning of a wound is able to achieve a significant reduction in the microbial load [16]. One highly effective method of mechanical cleaning is the use of high-pressure micro water jet technology (MWT) in which a fluid pump generates a high hydraulic pressure on a surgical fluid and a micro water jet is precisely directed onto a wound through a nozzle. NaCl, Ringer's solution, or an antiseptic solution (e.g., polyhexanide and the like) can be used as the sterile fluid.

With MWT, the water jet is fed with pressure through a tube connected to the main device to a non-return nozzle that generates a very fine water jet. The pressure that has been set is equal to the pressure prevailing before the point of entry into the nozzle. To evaluate various systems with equivalent abrasive effects on tissue (wounds) and for comparison with other methods, physical examinations were carried out.

As a result, the concept and the calculation formula (Fig. 1) for the jet push pressure (Fig. 2) were defined. The investigation showed that although the different systems operate with different physical parameters such as pressure, flow volume, distances, etc. they are comparable in terms of the jet push pressure and thus the abrasive effect on the wound [17].

$$JPP = \frac{8}{\pi} \frac{PA_{\text{düse}} \sin^2(\alpha)}{\left(\frac{L}{2}\tan(2\beta) + D_{\text{düse}}\right)^2}$$

Fig. 1. Formula to calculate the jet push pressure: α = jet angle; ß = jet spread angle; P = pressure; A = area; L = jet length; D = diameter of the nozzle.

2.2. Effect on the tissue

An animal study of rats with iatrogenically induced wounds examined the effect of treatment with different operating pressures (150 bar vs. 200 bar), different distances between the nozzle and the wounds (150 mm vs. 200 mm), and different angles of incidence of the jet on the wound (45° vs. 90°). The MWT treatment with the abovementioned parameters did not induce any additional tissue trauma or cause degenerative or necrotic damage to the tissue [18].

In another animal study of 6 rats the iatrogenically induced wounds were tested with different nozzle distances from the wound surface (100/150/200 mm) and different operating pressures (100, 150, 200, and 250 bar) but only at an angle of 90°. The results were evaluated using histological specimens. A water jet at a short distance of 100 mm, regardless of the pressure used, was associated with significant local swelling, air bubbles in the subcutaneous tissue (subcutaneous emphysema), and destruction of the wound bed. In contrast, in the deeper part of the skeletal muscle only minimal changes were observed compared to the untreated wounds or wounds that were treated from a greater distance [19] (Fig. 3).

2.3. Technical description and procedure

The mobile MWT device is prepared and undergoes a functional check each day using a standard procedure. It can be operated using the associated compressor or via a wall connection with compressed air. The standard setting for the water jet pressure is 150 bar. The water jet is ejected (Fig. 4) through a sterile single-use nozzle after passing through a re-usable high pressure line with a handpiece. The surgical fluid is connected directly to the device.

The jet is initially aimed at the wound from a distance of about 20–30 cm and at an angle of about 30°–45°. In clinical application, the distance between the nozzle and the wound should not be less than 15 cm. The parameters pressure, distance between the nozzle and the wound surface, and the impact angle of the water jet are used to ensure that the debridement is accurately controlled, precise, and gentle. By using a meandering path of the jet over the tissue, tissue is removed until extremely fine bleeding develops (Fig. 5). The aerosol formed after contact with the tissue is collected in protective tenting. Both patient and therapist wear a face mask.

An initial test jet is sprayed onto the patient's hand so that he or she can get a feel for the force of the jet. If the patient feels pain during the treatment, an analgesic is administered and/or the wound area is locally anesthetized (e.g., using lidocaine gel). After debridement, a standard wound dressing appropriate for the local situation is applied.

The indications for using MWT include all wounds that require debridement. The method is also effective in the case of acute wounds with a high level of contamination. The indication is basically determined by the treating physician or a competent expert (e.g., wound experts).

Hydrosurgery is contraindicated for malignant wounds, open body cavity injuries (e.g., open thorax injury, open abdominal injury), or open grade IIIC fractures (as defined by Gustilo and Anderson), or open grade III fractures (as defined by Tscherne and Oestern [20]) with exposed vessels, and near eyes, ears, or nose [15]. In patients with uncontrolled hypertension and patients on anticoagulation therapy or acetylsalicylic acid medication, MWT is associated with a higher risk, but is not contraindicated in principle [21]. If stronger bleeding occurs, compression is initially carried out and an alginate or a hemostyptic agent is applied. In the event of stronger bleeding or visible open vascular stumps, a ligature or perforating suture is applied.

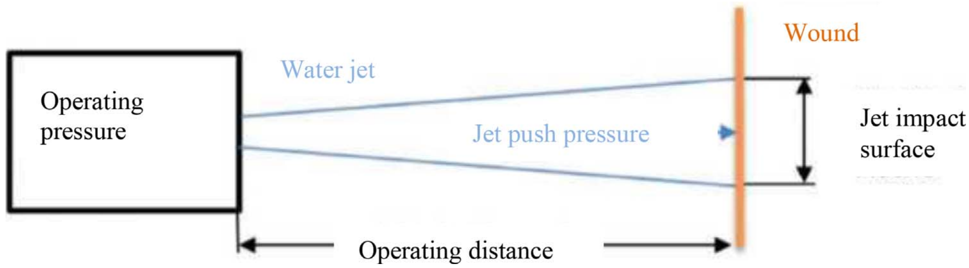

Fig. 2. Schematic diagram of the various concepts used to determine the jet push pressure.

3. Method

In this application observation a retrospective document analysis of the treatment records of the use of an MWT device for debridement of wounds was carried out. All treatments apart from one were carried out in an outpatient setting in the outpatient wound clinics of the Cantonal Hospital Obwalden and the Lachen Hospital. Overall, 90 patients with a total of 95 wounds were evaluated. Over a treatment period of 3 years, results were consecutively recorded for all patients of all ages and both sexes who had wounds of any type such as chronic, acute, or traumatic that required debridement and which had a wide range of levels of contamination. The wound had to have a minimal size of 0.2 cm^2. For all treatments, the date of the procedure, the type of wound, the wound area in cm^2 (measured by planimetry), the degree of epithelialization, the proportion of granulation tissue, the materials used, and any special features were recorded. The wound developments were regularly documented by photographs. All patients gave their consent, initially orally, later also in writing. Patients who declined to give their consent as well as those who did not comply, those patients for whom significant amounts of data were missing (gaps in the record keeping), and those who terminated ongoing treatment for unexplained reasons were excluded from the study. The endpoint for the observation was the formation of new epithelial tissue in the sense of a reduction in the wound area. The microbial load of the wounds during the treatment was not examined. No control group was included. For the debridement, a MWT device (Debritom™, Medaxis, CH-6340 Baar) was used

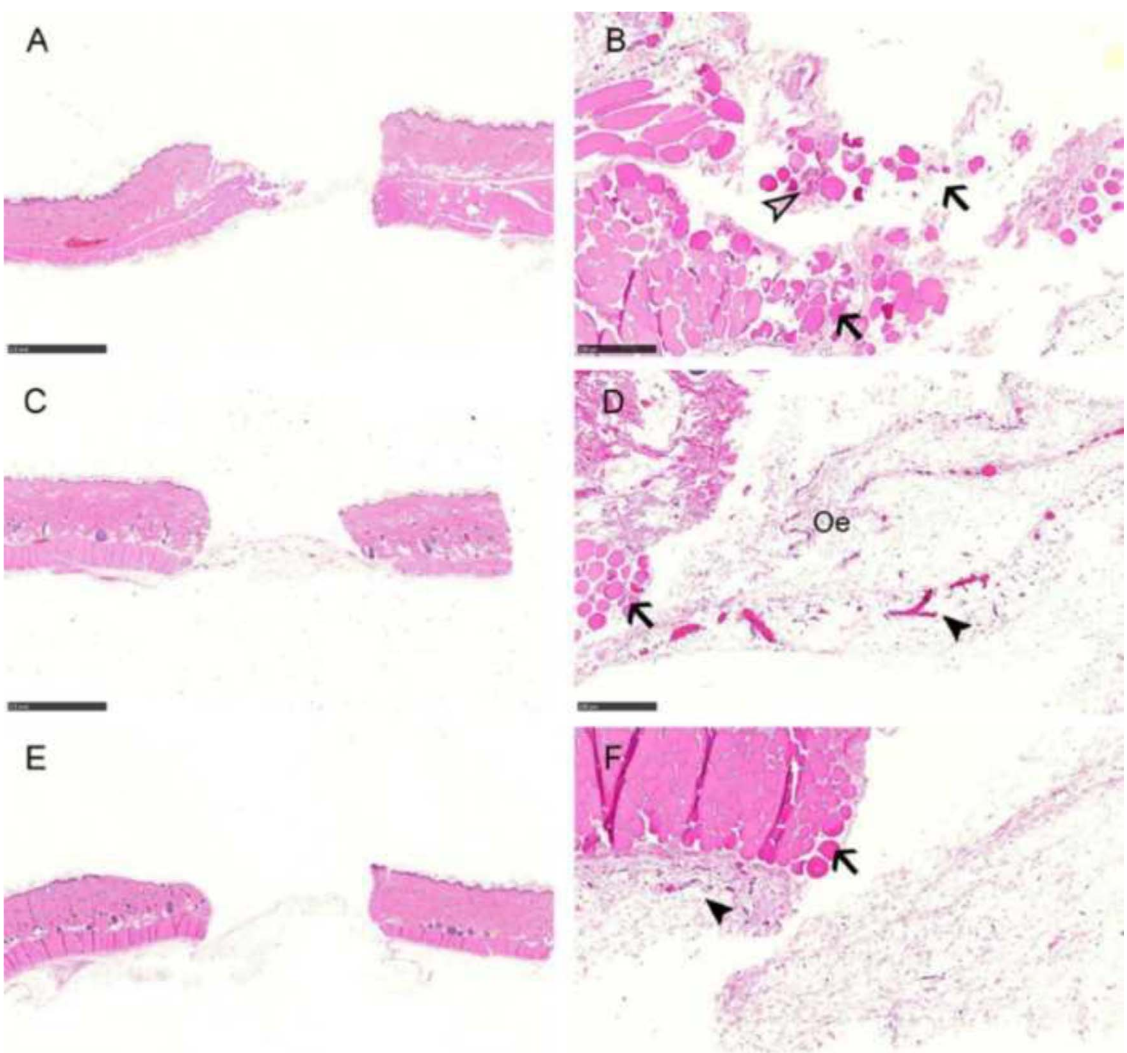

Fig. 3. Tissue changes associated with water jet application with 150 bar at different distances: From a distance of 100 mm (A and B: test animal 1), from 150 mm (C and D: test animal 2), and from 200 mm (E and F: test animal 3). Degenerated muscle fibers (- >) in the skeletal musculature, hyperemia (▶), edema (Oe), and bleeding (Δ).

Fig. 4. Handpiece with emitted micro water jet.

Fig. 5. Micro water jet impacting a wound.

(Fig. 6).

4. Results

The retrospective data analysis of MWT treatment records covered a period of 3 years (35.9 months) between November 2012 and November 2015. Of the original 92 patients, 2 were excluded; one patient refused to give consent and another was excluded for a lack of compliance. In the Cantonal Hospital Obwalden, 79 patients with a total of 82 wounds were treated while in the Lachen Hospital 11 patients with a total of 13 wounds were treated. The evaluations were carried out for 90 consecutive patients (46 male, 44 female) with a total of 95 wounds; 5 of the 90 index patients had 2 wounds each. The mean age of the patients was 68.5 years (17–93 years).

The majority of the wounds were chronic wounds (63%).

Fig. 6. MWT device. The irrigation solution is connected on the left side. The handpiece with the nozzle is lying on the table.

Specifically, the wounds treated (Fig. 7) included 26 venous leg ulcers (27.3%), 5 arterial leg ulcers (5.4%), 5 mixed leg ulcers (5.4%), 12 DFS (diabetic foot syndrome) (12.6%), 20 surgical wounds (21.0%), 15 traumatic wounds (15.5%), 12 miscellaneous wounds due to other causes (infection, open gouty tophus, dermatological problems, etc.) (12.6%). The wounds were located at the following sites: 43 on the lower leg (45.2%), 34 on the foot (35.8%), 1 on the chest (1%), 4 on the arm (4.2%), 1 on the hand (1%), 2 on the abdomen (2.1%), 1 on the back (1%), 1 in the axilla (1%), and 8 in the sacral region (8.4%). In the case of 46 of the 95 wounds, it was known that they had been present for an average of 86.1 days (12.3 weeks; 1–720 days). The median of the initial wound sizes before the first debridement was 10.5 cm^2 (0.2 cm^2–515 cm^2). Over the period investigated, a total of 653 wound treatments with MWT were carried out, which corresponds to a mean of 6.8 debridements per wound (1–65).

The treatments lasted between 1 and 22 min depending on the wound size and the level of contamination. The median treatment duration with MWT for all 95 wounds was 39.2 days (5.6 weeks) per wound (1–809 days). 58 wounds (of 95 wounds; 61%) were completely healed at the end of the treatment in a median period of 59 days (3–580 days), which corresponds to 8.4 weeks. The patients with the 37 wounds that were not completely healed when they left the outpatient wound clinic were treated further in other institutions (old people's home, nursing home, primary care physician, home-based care).

Overall, for the 95 wounds a reduction in the wound area from a mean of 25.2 cm^2 to a mean of 6.1 cm^2 was achieved over the median treatment period of 39.2 days (wound area reduction of 75.8%). In one patient with a large wound area on the foot of 515 cm^2 that had undergone several previous operations, it was not possible to reduce the wound area despite regular use of MWT; however, the chronic infection was able to be eliminated using the device (several example patients are shown in Figs. 8–12).

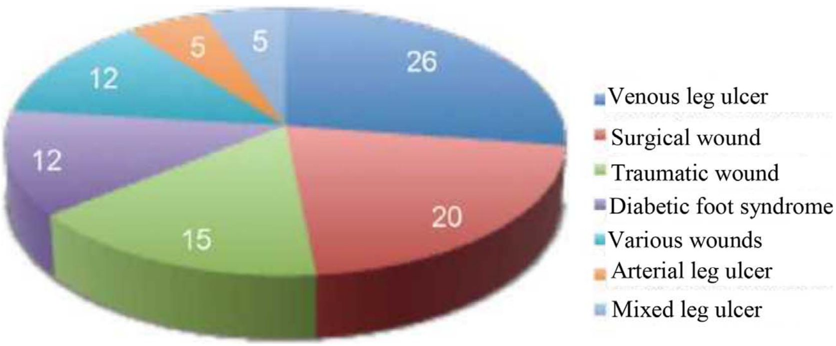

Fig. 7. Distribution of the various types of wound in the study. 63% of the wounds were chronic and 37% were acute wounds.

5. Discussion

The aim of the retrospective data analysis was to investigate the methodological efficiency of micro water jet technology for debriding wounds. In our outpatient wound clinics, MWT has long been used as a standard debridement method for a wide range of wound types. The median treatment time for 58 wounds (61% of the 95 wounds) that were treated with MWT and healed completely was 59 days per wound (8.4 weeks). This corresponds to about a 30% reduction in the total healing time compared to conventional surgical debridement methods combined with a standard therapy (moist wound management, compression) for which a healing time of 3–6 months is normally expected [22–25,27–29]. In other controlled trials specifically looking at leg ulcers that used systematic compression therapy and standard wound debridement, 71% of the ulcers healed only after 24 weeks [26]. The remaining 37 wounds that were not yet completely healed at the end of the treatment exhibited progressive reduction in the wound area and the formation of fresh granulation tissue. For this reason, the patients were referred back to the original treating institutions. Overall, for the 95 wounds a reduction in the wound area of 75.8% was achieved over the treatment period even though this included several intractable and hardly treatable wounds.

The shortening of the wound healing process is apparent, particularly if one considers that for half the patients (46) the wounds had already been present for an average of 86.1 days (12.3 weeks) at the start of the MWT treatment and had not been successfully treated. The duration of a single treatment with MWT per wound of 1–22 min corresponds to the experiences of other authors who use MWT (5–30 min) [15,22,27]. In one randomized controlled trial, a mean time of 33.9 min was indicated for conventional debridement, which is significantly longer than hydrosurgical debridement with a mean time of 14.2 min [28]. The debridement can be carried out with no or only minimal pain which can be eliminated by simple local measures. The consumption of rinsing fluid of 100 mL–200 mL per treatment is extremely economical. Although there is little literature on MWT, our observations corresponded to those made quite some time ago by other authors who use MWT. In all applications, a very wide range of wounds were likewise treated [15,21,22,29,30].

Other similar hydrosurgical debridement systems are known such as the Versajet™ system (Smith & Nephew), Interpulse (Stryker), PulseCare

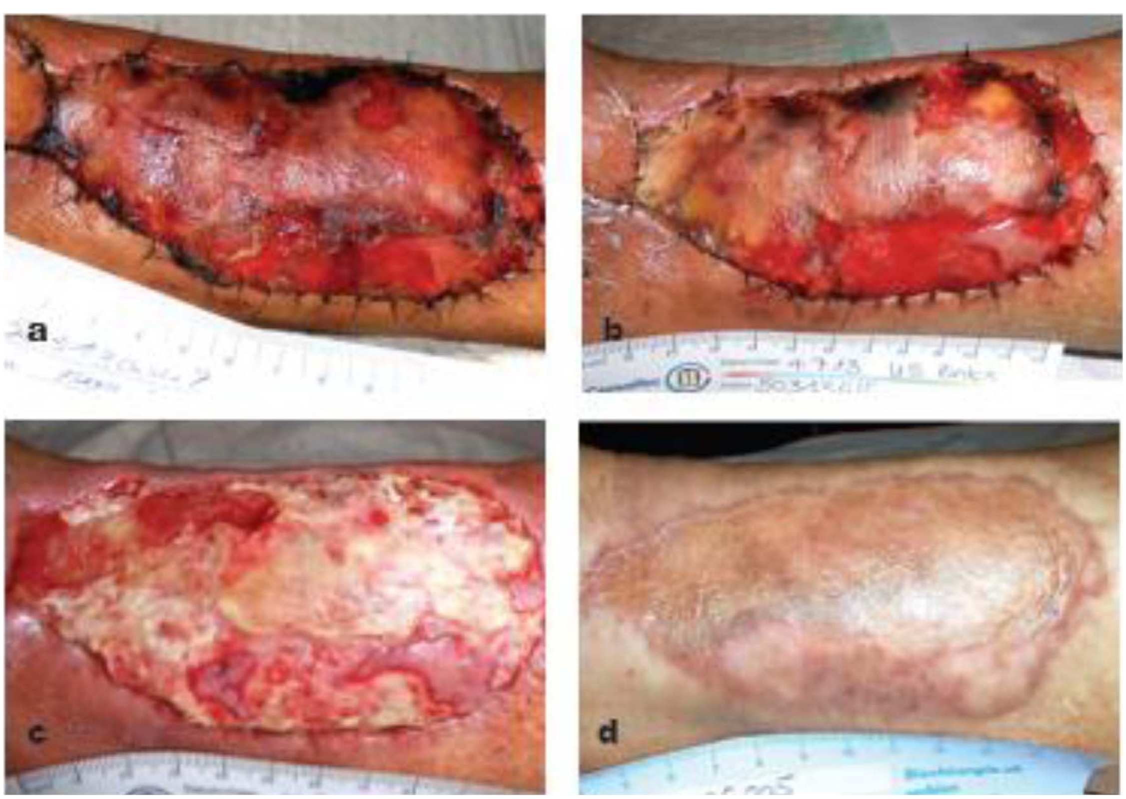

Fig. 8. Example patient: healing course of a pedicled flap on the lower leg that became necrotic after surgery due to circulatory disorders. The necrotic layers were regularly debrided in several sittings using the MWT device until new granulation tissue and epithelium had formed with a good final result.

Fig. 9. Example patient: A lower leg ulcer. Temporary increase in the wound area after the first debridement. Followed by good stimulus and rapid healing progress.

Fig. 10. Example patient: Infection following a flap graft on the left hand. Wound debridement with MWT. Duration of the healing process shown above: 11 weeks.

Fig. 11. Example patient: Traumatic skin necroses on the thorax caused by rotating wheels of a mower. After initial surgical debridement, regular wound cleaning with MWT.

Fig. 12. Example patient: An ulcer on the left lower leg. Wound bed preparation with MWT.

Closed Pulse Irrigation™ (CPI) (PulseCare Medical™), Pulsavac Plus System (Zimmer), Jetox (DeRoyal). A direct clinical comparison of the various hydrosurgery methods is difficult because each one exerts a different water jet push pressure on the tissue. Thus, for MWT the water pressure at the nozzle exit is 2175–2900 psi (pounds per square inch) while for the Versajet it is up to 15,000 psi and for the InterPulse it is up to 15 psi [17]. Nevertheless, the efficiency of a system in terms of the debridement can be compared with the corresponding properties and effects of the other systems because what is critical is not the nozzle outlet pressure but rather ultimately the energy/force that is exerted on the wound (abrasive forces).

There is extensive literature available on the Versajet Hydrosurgery System, often in connection with burns [31–37], as well as about treatments of other wounds (skin necroses, before and after skin grafts, ulcers, explosion injuries, and various wounds with healing disorders) [28,38–45]. Almost all Versajet applications must be carried out in the operating theater and under anesthesia. Most of the patients were hospitalized for this purpose or the treatments were carried out during hospitalization. The cost efficiency of the systems was only investigated in a few studies. In one previously mentioned study by Liu et al., one patient group that underwent conventional therapy was compared to a hydrosurgery group, the conventional group being hospitalized for a median of 38 days and the hydrosurgery group being hospitalized for 39 days for the wound treatment. The mean total costs (surgical procedure and hospitalization) varied between US$39,940 and US$44,290 with no significant differences between the two groups [28]. Even though we are unable to provide any precise comparison figures, the costs for outpatient-applied MWT are much less than such sums. The treatment times for the Versajet Hydrosurgery System, where indicated, were between 5.8 and 15.5 min and are thus slightly less than the time needed for treatments with MWT (1–22 min) [28,42–45]. Considerably lower costs are associated overall with MWT because, as mentioned above, the technique does not require hospitalization, operating theater use, or anesthesia.

On the other hand, the precision of the debridement achieved with the two systems is equally good and can generally be carried out more precisely than with a scalpel or curette. MWT was also associated with less scar formation and fewer re-infections compared to conventional surgical debridement [15,29].

A number of other studies evaluated different hydrosurgery systems such as pressurized irrigation, pulsatile lavage, pulse lavage, and power-pulsed lavage. These can all be referred to as 'low-pressure' water jet systems because the pressures exerted by the water jets are only 4–15 psi. Pressure values below 4 psi (0.28 bar) do not achieve a cleaning effect [46]. The fluid consumption of 1–3 L per application for these systems is also considerably higher than for MWT [22,25,47–50].

MWT enables optimal wound bed preparation. Treatment and healing times can be greatly reduced along with a generally desired cost reduction thanks to rapid outpatient hydrosurgical wound debridement. There is a high level of patient satisfaction and very few complaint symptoms due to treatment. No adverse effects or complications have been identified to date. Handling by nursing staff and physicians is easy and uncomplicated and only requires a brief training phase.

One drawback of MWT is its inability to treat wound cavities that have undermined wound edges where the water jet cannot be directed; deep wound beds can, however, be directly reached. A rather minimal drawback is the size of the device which, once set up, is available for the entire day, and is then no more laborious than other methods. Despite the size, the device can be moved without considerable effort. On the other hand, the device is too expensive for wound therapists who only carry out few debridements. The reimbursement of the materials and the service is quite good in Switzerland and rapidly offsets the initially high purchase costs. MWT has been successfully used for many years in a number of hospitals and institutions but is not as well known as other systems because of the little literature that is available.

6. Summary

The use of MWT to carry out wound debridement is an effective, ergonomic, and economically sound method and can therefore be considered evident. For patients it is a safe and gentle technique that can be carried out as an exclusively outpatient procedure. Multiple but short application times ultimately lead to a reduced healing time for a wound compared to other standard therapies. MWT is on a par with other hydrosurgery methods. Additional, preferably randomized, prospective studies with larger patient numbers would be desirable in order to more thoroughly confirm the effectiveness of MWT as would be a more detailed investigations of the microbial load before and after the treatment. MWT meets the requirements for a high-performance debridement method.

Conflict of interest

Dr. med. M. Reber works as an independent consultant for Medaxis.

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