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Versatility of Negative Pressure Wound Dressings in Plastic Surgery

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Abstract

Negative wound dressing, also known as Vacuum-assisted closure (VAC) dressings, have become a staple for most plastic surgeons when managing difficult wounds. But nowadays, the scope of VAC dressings has broadened and includes burn wounds, open fracture wounds, radiation wounds, post-surgical wounds, abdominal wounds and post-traumatic complex wounds. This review discusses the mechanism of action of VAC, applications, pros and cons of this technique and finally, the future directions and research that must be done to refine this technique.

Keywords: Vacuum-assisted closure, Wound healing, Wound shrinkage, Negative pressure wound therapy, complex wounds, Microdeformational wound therapy.

Introduction

The technique of negative pressure wound therapy was first introduced by Argenta et al. (1997) for the healing of chronic wounds[1] and, since then, its scope has broadened considerably to include the healing of open fracture wounds[2], burn wounds[3], pressure ulcers[4], post-surgical wound complications[5], post-traumatic complex wounds[6], abdominal wounds[7] and radiation ulcers[8].

NPWT affects wound healing by four basic mechanisms - macro deformation, micro deformation, fluid removal, and alteration of the wound environment. Various secondary mechanisms are described in the literature (including neurogenesis, angiogenesis, modulation of inflammation, and alterations in bioburden).[2] This review article aims to provide a comprehensive review of the literature on NPWT, its applications in plastic surgery, and the future of this emerging technology in healing difficult wounds.

Discussion

The use of VAC dressings in the healing of chronic and difficult to heal wounds is well established and has provided a viable alternative option to the reconstructive surgeon. The basic mechanisms through which this modality works have been described in the literature and are worth recapitulating; it includes four primary mechanisms: macro deformation, micro deformation, fluid removal, and alteration of the wound environment. Macrodeformation is a phenomenon that causes the foam to collapse due to the negative pressure effect of suction, resulting in wound shrinkage. The resultant deformational forces draw the wound edges closer, expediting wound healing.[9] Negative pressure of 125 mm of Hg can reduce the volume of the VAC sponge by almost 80% resulting in significant wound contraction. However, the extent of contractability is largely dependent on wound deformability.[10-12] Microdeformation involves mechanical forces such as compression and tension from the foam, shear and hydrostatic forces from the extracellular fluid, and the effect of gravity that are transmitted all over the wound via the extracellular matrix. Microdeformation occurs at the microscopic level due to the interplay between these forces that affect the cytoskeleton. These forces activate a signaling cascade that upregulates granulation tissue healing and promotes accelerated wound healing. Microdeformation causes localized tissue hypoxia that causes increased vascularity and ingrowth of new vessels (neovascularization) toward the wound.[13] NPWT is believed to remove fluid from the wound via two mechanisms. First, VAC reduces the burden on the lymphatic system by directly removing fluid from the wound. Second, it gradually induces an increase in the density of lymphatics at the wound edges.[14] Finally, VAC alters the wound environment by removing electrolytes and proteins along with the fluid. This, in turn, stabilizes osmotic and oncotic gradients at the wound surface (Fig. 1).

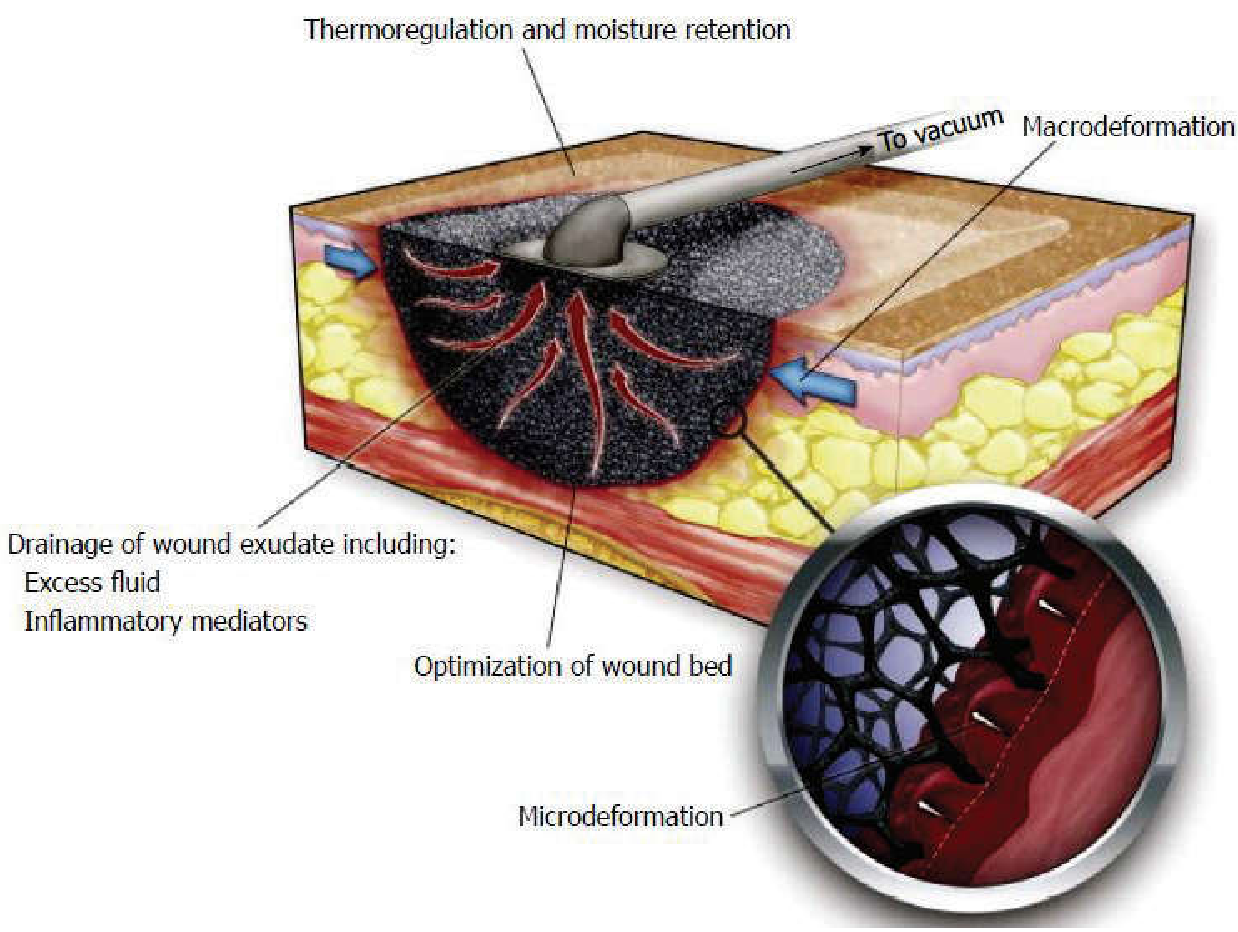

Fig. 1: The primary mechanisms of microdeformational wound therapy: (1) Macrodeformation; (2) Microdeformation (3) Fluid removal; and (4) Alteration of the wound environment.[2] Reproduced from, Huang C, Leavitt T, Bayer LR, Orgill DP. Effect of negative pressure wound therapy on wound healing. CurrProbl Surg 2014; 51: 301-331. Copyright 2016 by Elsevier.

The secondary effects of VAC therapy include: Neurogenesis due to upregulation of neurotrophin nerve growth factor, substance P, and calcitonin gene-related peptide leading to enhanced neural growth and neuropeptide expression[15]. VAC therapy can promote haemostasis as the negative suction pressure can occlude blood vessels mechanically, reducing bleeding from the wound surface. Second, the negative pressure induced by VAC strongly apposes the dressing to the wound surface, favouring clot formation[16]. NPWT maximizes angiogenesis and tissue perfusion with increased microvessel density[17]. NPWT activates the wound healing process by inducing inflammation with increased cellularity of wound exudate with elevated erythrocytes and leukocytes, increased gene expression of leukocyte chemoattractants, such as CXCL5 and IL-8, while removing harmful products of inflammation such as infiltrating leukocytes, cytokines, and matrix metalloproteinases[18]. VAC therapy promotes granulation tissue formation, cell proliferation, and blood vessel sprouting[19]. It has been postulated that VAC therapy leads to a decreased bacterial colonization in the wound due to the mechanical effect of suction, and the enhanced neovascularization; increased blood flow builds up tissue resistance by increasing oxygen tissue levels in the wound.[20]

Clinical uses of NPWT

1. Management of open wounds: NPWT has been used to expedite the healing process of chronic non-healing ulcers (e.g., chronic diabetic wounds, vascular ulcers, neuropathic ulcers, pressure sores)[21].
2. Complex surgical wounds: VAC therapy has been used to fortify the closure of complex surgical wounds and skin graft immobilization as a tie-over bolster dressing. The advantage of the incisional VAC (iVAC) therapy is to enhance wound healing due to strict immobilization, enhanced vascularity and healing with the prevention of surgical site infections[22].
3. NPWT in burns: VAC therapy has been shown to improve the vascularity of burn wounds[23]. It has also been used to bolster the adherence of dermal substitutes in the healing of burn wounds and in the long term improves the elasticity of such healed burn scars[24]. It acts mainly to decrease wound exudate, and bacterial load and expedites wound healing. VAC therapy is also indicated in full-thickness burns (third and fourth-degree burns) to favour the formation of granulation thereby ensuring a good take of skin graft resurfacing[25].
4. Open fractures: NPWT has been used in difficult wounds with exposed bone and open joints, where it keeps the wound moist, and prevents desiccation and bacterial contamination. The wound healing process in such wounds is also accelerated with VAC therapy.
5. Deep infected wounds (body cavities: abdominal, thorax/sternotomy wounds): NPWT, when used in deep wounds, was found to decrease bacterial load, inhibit infection induced tissue necrosis, and induce early initiation of granulation tissue formation.[21,26,27]
6. Skin graft immobilization: NPWT is used in STSGs in the place of a tie-over bolster, which is traditionally used to immobilize the graft. NPWT stabilizes the graft, drains excess fluids, and promotes better contact for graft incorporation enhancing vascularization.[28,29] NPWT has successfully been used in degloving injuries to immobilize skin grafts, or as an adjuvant treatment with a dermal matrix (Fig. 2).[30]
7. Postoperative salvage of flaps: NPWT has been shown to decrease the risk of reoperation in cases of congested lower extremity pedicle and free flaps by decreasing venous insufficiency and tissue oedema, promoting granulation and, hence, preventing further flap necrosis.[31]

Newer Modalities/Variations of VAC

1. Silver incorporated VAC dressing: Various bioactive factors have been incorporated in NPWT to enhance efficacy. Silver was added to the coating of the PU foam to decrease the bacterial load in the wound. In complex infected wounds, silver dressings placed beneath the negative pressure dressings resulted in a decrease in the bacterial load[32].
2. Instillation therapy is the injection of fluid, such as normal saline, into the wound through a port on the NPWT connecting tube to enhance wound healing. This technique has been successfully applied in chronic wounds to reduce bacterial concentrations in the wound before split skin grafting (SSG). In continuous-instillation NPWT, a second port is connected to the continuous drip system,

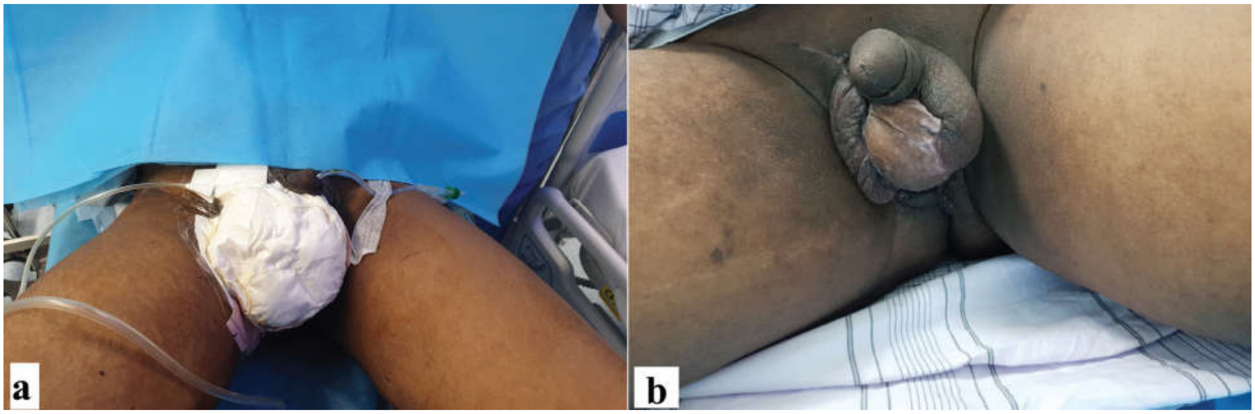

Fig. 2a: VAC dressing used for skin graft immobilization over a difficult site of the body (scrotum). 2b: The final result after 3 months showed a full take of the skin graft.

which can allow continuous irrigation of a fluid, for example, antibiotic solution, to decrease the time required for wound healing[33,34].

A new form of NPWT with instillation and dwell time (NPWTi-d) has been developed and promoted to heal complex, infected wounds associated with decreased vascularity. This system NPWTi-d (V.A.C. VeraFlo™ Therapy; 3M + KCI, San Antonio, TX) involves using a reticulated open-cell foam dressing with the transparent airtight film dressing connected to the VAC suction machine. Then, normal saline is instilled until the foam is saturated for a one-second dwell time, followed by six hours of continuous negative pressure (−125 mm Hg). The one-second dwell time simulates frequent wound irrigation, which avoids the need to soak the foam for longer periods (Fig. 3).[35]

3. Incisional VAC therapy (iVAC)/ closed incision negative pressure therapy (ciNPT): The literature supporting the use of NPWT over clean incisions has mixed results.

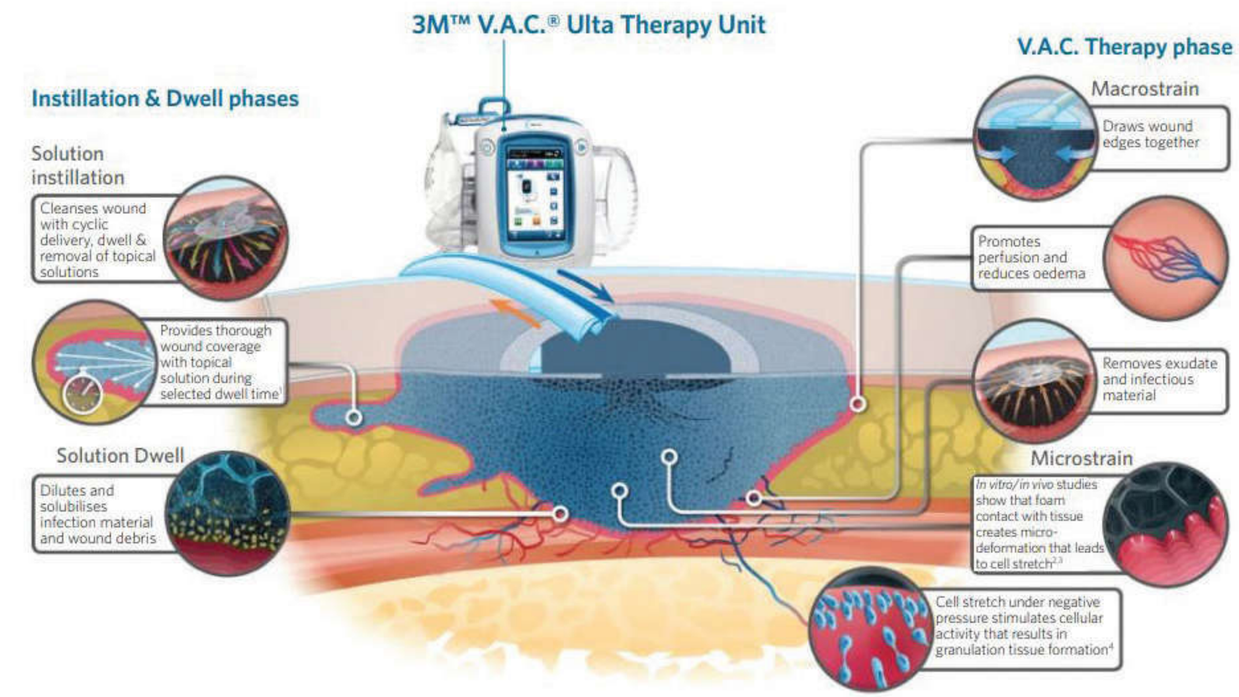

Fig. 3: Instillation and dwell time (NPWTi-d) VAC therapy with the Veraflo system. NPWTi-d combines NPWT with the addition of wound cleansing with topical wound solutions. Reproduced from, Rycerz AM, Slack P, McNulty AK. Distribution assessment comparing continuous and periodic wound instillation in conjunction with negative pressure wound therapy using an agar-based model. Int Wound J. 2013 Apr;10(2):214-20.

Decreased rates of seroma, as well as haematoma formation, have also been reported in post-bariatric patients receiving incisional NPWT. VAC applied to closed incisions also decreases the risk of infection[36,37].

Periincisional lateral stress is reduced by approximately 50% following NPWT application and the directions of these stress vectors mimicked the distribution found in intact tissue. Evidence from this research has supported the development of systems such as Prevena™ Incision Management System (KCI, San Antonio, TX) which is specifically designed to be used in incisional wounds[38].

Future Directions & Research

The optimum pressure for VAC therapy is still yet to be comprehensively studied, and in the literature, the accepted suction pressure ranges from 50-150 mm Hg. Lower pressure (50-75 mm Hg) are best used in circumferential wounds, painful chronic wounds and in those cases where NPWT is used as a dressing for free flap immobilization. Higher pressures (150 mmHg and greater) are used for large compartmental and exudative, infective wounds[3,39].

The optimal cycling regime for VAC is yet to be comprehensively studied. Another area that can be studied is the development of an ultraportable, mini-VAC machine that allows the patient unlimited degrees of freedom to carry on with his/her daily activities without disruption. Future multicenter randomized controlled studies comparing the different materials, suction pressure, types of VAC therapy and instillation of fluids, will help us evaluate this technique better and optimize its usage in the management of difficult wounds and perhaps expand its horizons further.

Conclusions

VAC therapy/NPWT has revolutionized the management of difficult surgical wounds and is now an established alternative when other options have been exhausted. Its use has expanded to include the management of almost every type of surgical and non-surgical wounds. However, the overall evidence regarding this emerging technology is still lacking despite its popularity. Future High-level research trials must be carried out to establish the ideal and optimal parameters of its use so that its effectiveness and efficiency can be further enhanced.

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Conflict of Interest: None

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