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# Negative Pressure Wound Therapy: Mechanisms of Action and Clinical Applications - A Narrative Review

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**Abstract** **Review Article**

Negative pressure wound therapy (NPWT) has become an important component of modern wound management since its introduction in the 1990s. By applying controlled subatmospheric pressure to the wound surface, NPWT modifies the mechanical and biological environment of the wound and promotes tissue repair. Its effects are mediated through several complementary mechanisms, including macrodeformation, microdeformation, removal of wound exudate and inflammatory mediators, reduction of edema, and modulation of the local microenvironment. NPWT has progressively expanded beyond conventional treatment of open wounds and is now used in a wide range of clinical situations, including diabetic foot wounds, pressure injuries, traumatic and postoperative wounds, skin grafts, complex soft-tissue defects, and closed surgical incisions. Technological developments have also led to instillation systems, single-use devices, and other specialized interfaces. Although substantial clinical evidence supports its use in selected wounds, outcomes remain dependent on appropriate patient selection, adequate wound-bed preparation, vascular status, infection control, and correct application of the therapy. This review summarizes the principal mechanisms of action of NPWT, its main clinical applications, currently available modalities, and important contraindications and precautions, with particular emphasis on its role in plastic and reconstructive surgery.

**Keywords:** Negative pressure wound therapy; vacuum-assisted closure; wound healing; diabetic foot; skin graft; pressure injury; reconstructive surgery.

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## INTRODUCTION

Negative pressure wound therapy (NPWT), also referred to as vacuum-assisted wound closure or vacuum-assisted closure (VAC), was introduced into modern clinical practice during the early 1990s and subsequently popularized by Argenta and Morykwas. Since then, the technique has progressively become an established adjunct in the management of acute, chronic, traumatic, postoperative, and complex wounds.

The conventional NPWT system consists of a wound-contact interface, commonly an open-cell foam, covered by a semi-occlusive adhesive drape and connected to a tubing and collection system through a negative-pressure pump. The application of controlled subatmospheric pressure modifies the physical environment of the wound and induces a series of mechanical and biological responses that can promote wound contraction, exudate removal, granulation tissue formation, and progression toward wound closure.

The mechanisms underlying NPWT are increasingly understood as a combination of macroscopic and microscopic mechanical effects rather than as a single biological pathway. Recent mechanobiological research has further highlighted the importance of tissue deformation and the way mechanical strain is transmitted from the dressing interface to the underlying wound tissue.

Over the last three decades, the technology has evolved considerably. In addition to conventional NPWT for open wounds, currently available approaches include NPWT for closed surgical incisions, NPWT with instillation and dwell time, portable and single-use systems, and applications designed specifically to support skin graft fixation.

The aim of this review is to summarize the principal mechanisms of action of NPWT, describe its major clinical applications and technological variants, and discuss the main precautions and contraindications relevant to clinical practice.

**1. Mechanisms of action:**

The therapeutic effects of NPWT are multifactorial. Four major mechanisms are commonly described: macrodeformation, microdeformation, fluid removal, and stabilization of the wound environment.

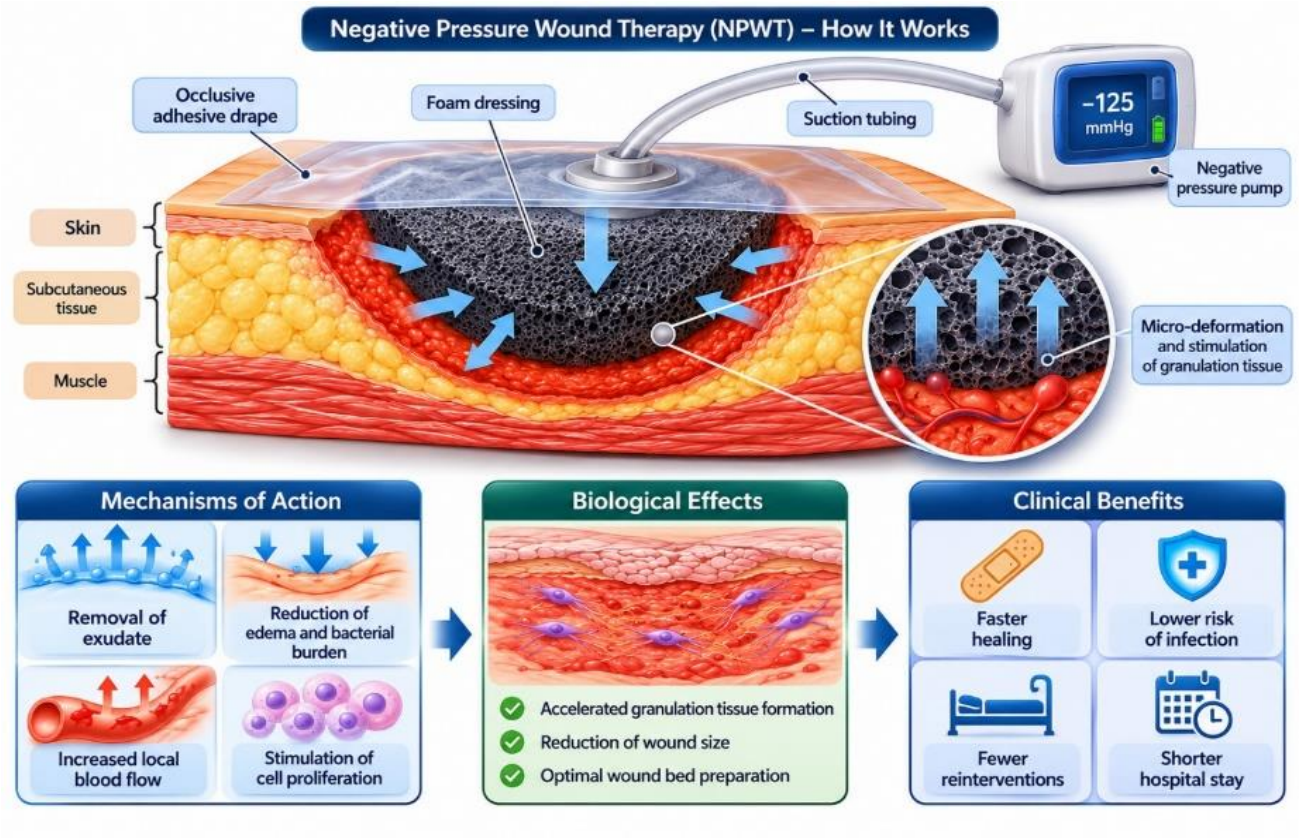



**Figure 1: Mechanisms of action of negative pressure wound therapy.**
Conceptual representation of the principal macroscopic and microscopic mechanisms involved in NPWT.

**1.1. Macrodeformation**

Macrodeformation refers to the visible contraction of the wound produced by the application of negative pressure. The dressing is drawn toward the wound bed, resulting in approximation of the wound edges and reduction of the wound surface area.

This mechanical effect may contribute directly to wound closure while also improving the contact between the wound-contact material and the wound bed. The degree of macrodeformation depends on wound geometry, tissue compliance, dressing characteristics, and the negative-pressure level applied.

**1.2. Fluid removal and reduction of edema**

Continuous removal of wound exudate is another important component of NPWT. By evacuating excess fluid, NPWT can reduce local edema and potentially improve the tissue environment for cellular activity and oxygen diffusion.

The removal of exudate may also decrease the accumulation of inflammatory mediators and proteolytic enzymes that can contribute to a chronic inflammatory wound environment. However, the precise biological contribution of these mechanisms remains an area of ongoing investigation.

**1.3. Microdeformation and mechanotransduction**

Microdeformation occurs at the interface between the wound-contact material and the wound bed. The application of negative pressure generates mechanical forces that deform the superficial tissue.

These mechanical stimuli may activate mechanotransduction pathways, promoting cellular proliferation, fibroblast activity, extracellular matrix remodeling, and angiogenic responses. Experimental and clinical research increasingly supports the concept that these mechanical effects are central to the biological activity of NPWT.

Rather than considering microdeformation simply as a consequence of suction, current mechanobiological models suggest that the magnitude and distribution of tissue strain are influenced by the characteristics of the dressing interface and wound geometry. This may help explain why different NPWT systems can produce different clinical effects.

### 1.4. Stabilization of the wound environment

The semi-occlusive dressing creates a relatively controlled wound environment by limiting external contamination and maintaining close contact between the dressing and the wound.

The reduction in dressing manipulation may also decrease mechanical disruption of newly formed tissue. Depending on the wound type and clinical situation, dressing changes are commonly performed every 48–72 hours, although the interval should be individualized according to the wound, level of exudate, infection status, and device used.

## 2. Different modalities of NPWT:

The developpent of NPWT has resulted in several modalities adapted to specific clinical situations.

### 2.1. Conventional NPWT

Conventional NPWT is primarily used for open wounds requiring temporary wound-bed management. It consists of a wound-contact interface, an occlusive drape, tubing, a collection canister, and a negative-pressure source.

It may be applied using continuous or intermittent suction depending on the clinical objective, wound characteristics, and device used. Appropriate wound-bed preparation, including removal of devitalized tissue and control of infection, is essential before initiating therapy.

### 2.2. Closed-incision NPWT

Negative pressure can also be applied over primarily closed surgical incisions. This approach, commonly referred to as closed-incision NPWT (ciNPWT), aims to reduce postoperative complications in selected high-risk wounds.

Its proposed benefits include reduction of edema, stabilization of the incision, reduction of lateral mechanical stress, and management of superficial exudate. The technique has become increasingly used in selected surgical populations, although its efficacy varies according to the type of surgery and patient risk profile.

### 2.3. NPWT with instillation and dwell time

NPWT with instillation and dwell time (NPWTi-d) combines negative pressure with intermittent instillation of a topical solution followed by a predetermined dwell period before suction is reapplied.

This approach was developed particularly for wounds with substantial exudate, slough, or bacterial burden. However, the addition of instillation should not be considered universally superior to conventional NPWT. In a randomized trial involving diabetic foot infections, NPWT with irrigation did not demonstrate significant improvements in healing or other clinical outcomes compared with standard NPWT. Therefore, NPWTi-d should be considered selectively rather than routinely.

### 2.4. NPWT associated with dermal substitutes

NPWT can be combined with dermal regeneration matrices in selected complex wounds with exposed tendon or bone. The rationale is to use the dermal substitute to provide a temporary scaffold while NPWT stabilizes the matrix, controls exudate, and promotes the formation of a vascularized wound bed suitable for subsequent skin grafting.

A retrospective study of wounds with tendon or bone exposure reported a high rate of successful subsequent coverage following combined artificial dermis and NPWT, followed by split-thickness skin grafting. This approach may provide an alternative to more complex flap reconstruction in selected patients.

## 3. Clinical applications:

NPWT has been investigated in a wide range of wound types. Its clinical effectiveness varies according to wound etiology, patient selection, vascular status, infection control, and the specific NPWT protocol.

### 3.1. Diabetic foot wounds

Diabetic foot wounds are among the most extensively studied indications for NPWT.

In a multicenter randomized controlled trial involving 342 patients with diabetic foot ulcers, complete wound closure was achieved in 43.2% of patients treated with NPWT compared with 28.9% with advanced moist wound therapy. NPWT was also associated with fewer secondary amputations.

Importantly, NPWT has also demonstrated benefit specifically following partial foot amputation. In a multicenter randomized trial involving 162 patients with partial diabetic foot amputations up to the transmetatarsal level and adequate perfusion, 56% of wounds treated with NPWT healed compared with 39% with standard moist wound therapy. NPWT was also associated with faster granulation and faster complete wound closure.

These findings support the use of NPWT as an adjunct in appropriately selected postoperative diabetic foot wounds, particularly after adequate debridement and when vascular perfusion is sufficient.

### 3.2. Pressure injuries

NPWT may be useful in selected advanced pressure injuries, particularly after adequate debridement and when direct closure or flap reconstruction is not immediately feasible. Its principal role is often to reduce wound dimensions, control exudate, and promote the development of a healthy granulating wound bed before definitive reconstruction.

In the management of pressure injuries, NPWT should therefore generally be considered part of a broader treatment strategy that includes pressure redistribution, nutritional optimization, infection management, and appropriate surgical debridement.

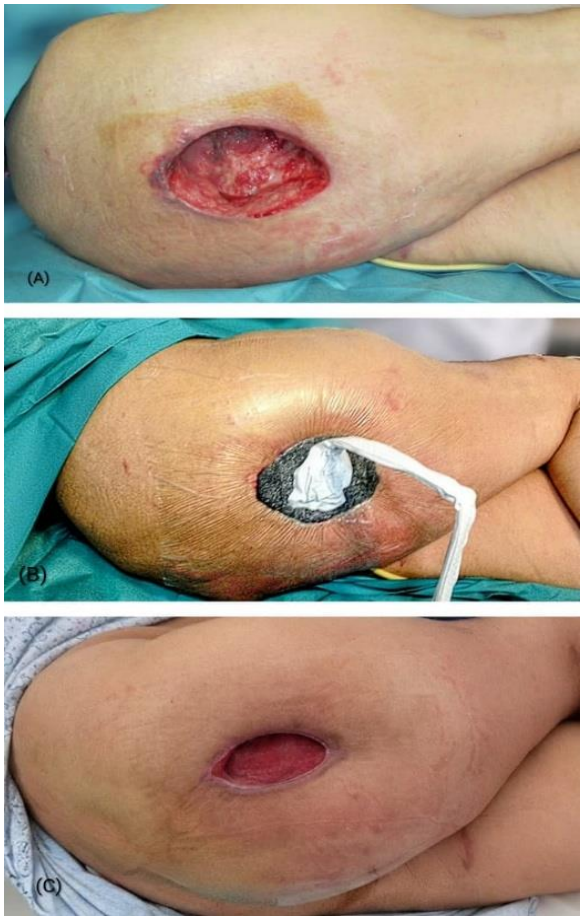



**Figure 2: NPWT for a trochanteric pressure injury, Clinical illustration from our department**

**A)** Initial appearance of the trochanteric pressure injury following surgical debridement. **(B)** NPWT application. **(C)** Progressive wound contraction and improvement in the quality of the wound bed.

### 3.3. Chronic wounds and wound-bed preparation

NPWT can be used as a temporary strategy to optimize the wound bed before definitive closure.

The ability to control exudate and promote granulation may be particularly useful in wounds that are not yet suitable for skin grafting or flap coverage. Recent evidence also supports NPWT as a useful adjunct in preparing diabetic foot wounds for subsequent split-thickness skin grafting. A randomized study reported faster preparation for grafting and improved graft survival in patients treated with NPWT compared with conventional moist dressings.

### 3.4. Skin grafts

One of the most relevant applications in plastic surgery is the use of NPWT as a bolster dressing following split-thickness skin grafting. By providing uniform pressure across the graft, NPWT can improve graft immobilization, reduce fluid accumulation beneath the graft, and potentially decrease shear forces and hematoma or seroma formation.

A systematic review and meta-analysis of randomized controlled trials demonstrated that NPWT improved skin-graft take compared with conventional dressings and reduced the need for reoperation.

More recently, a 2025 systematic review and meta-analysis including 16 randomized controlled trials further evaluated the benefits of NPWT in skin grafting, providing additional support for its role as an adjunct to improve graft outcomes.

This application is particularly relevant in irregular anatomical areas or wounds where conventional bolster dressings may provide insufficient immobilization.

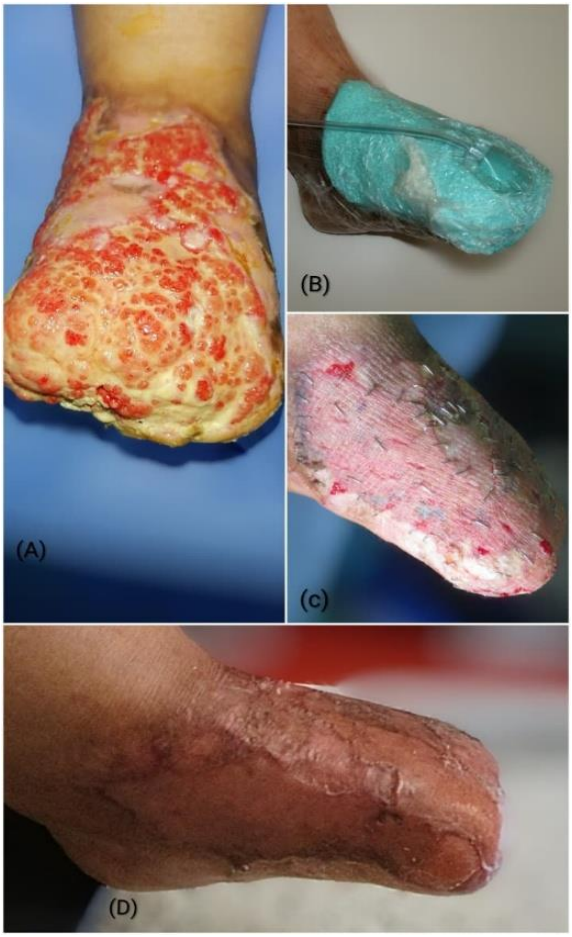



**Figure 3: NPWT-assisted skin graft fixation following transmetatarsal amputation in a diabetic foot, Clinical illustration from our department**

**(**A) Delayed wound healing following debridement and transmetatarsal amputation. (B) Split-thickness skin graft applied to the wound and secured using NPWT. (C) Early postoperative appearance showing satisfactory graft adherence and progressive healing. (D) Three-month follow-up demonstrating complete graft take and full epithelialization, with complete healing of the foot.

### 3.5. Complex traumatic and postoperative wounds

NPWT is widely used as a temporary wound-management strategy following trauma, open fractures, extensive soft-tissue loss, and complicated surgical wounds. In these situations, the objective is not necessarily definitive closure but rather optimization of the wound bed while reconstruction is planned or staged.

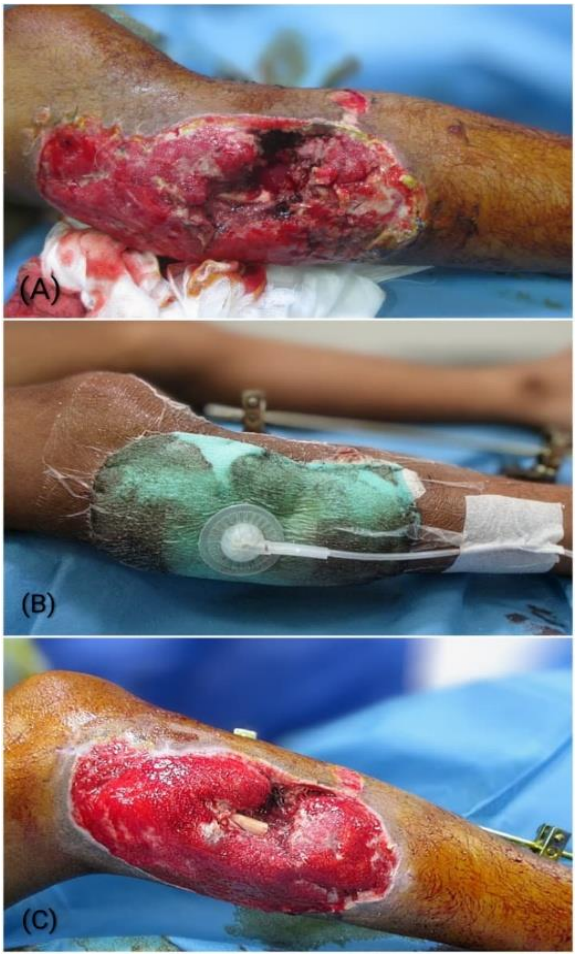



**Figure 4: NPWT in the management of a complex lower-leg wound, Clinical illustration from our department**
**(A)** Wound following initial surgical debridement in a patient with an open tibial fracture and soft-tissue loss. **(B)** Application of NPWT associated with external fixation. **(C)** Two-week follow-up showing a healthy granulating wound bed, improved vascularized tissue coverage, absence of clinical infection, and reduction in the area of exposed bone.

## 4. Contraindications and precautions

Although NPWT is generally well tolerated, appropriate patient and wound selection is essential.

### 4.1. Inadequately debrided wounds

Devitalized tissue, uncontrolled necrosis, and untreated infection should be addressed before NPWT is initiated. NPWT should not be regarded as a substitute for adequate surgical debridement.

### 4.2. Exposed vital structures

Direct contact between the negative-pressure interface and exposed major vessels, vascular grafts, nerves, organs, or other vulnerable structures may result in serious complications, including bleeding, erosion, fistula formation, or tissue injury.

When such structures are exposed, an appropriate protective interface or adequate tissue coverage should be established before NPWT is applied.

### 4.3. Malignancy

Active malignancy within the wound is generally considered a contraindication to routine NPWT because of concerns regarding bleeding and the potential effects of mechanical stimulation on tumor tissue.

### 4.4. Ischemic wounds

Adequate perfusion is essential for successful wound healing. In ischemic wounds, vascular assessment and, when appropriate, revascularization should precede NPWT. This is particularly important in diabetic foot wounds, where peripheral arterial disease can significantly compromise healing.

### 4.5. Bleeding risk

Bleeding is an uncommon but potentially serious complication of NPWT. Particular caution is required in patients with vascular abnormalities, coagulopathy, anticoagulation, or wounds adjacent to major vessels. Other reported complications include pain, skin injury related to adhesive removal, maceration, retained foam, and, rarely, fistula formation or severe infection.

## 5. NPWT in contemporary reconstructive surgery

The role of NPWT has progressively shifted from simple wound drainage toward a broader concept of wound-bed optimization and reconstruction planning.

In reconstructive surgery, NPWT may be used as a bridge between debridement and definitive coverage. It can reduce wound dimensions, promote granulation tissue, control exudate, and create a more favorable recipient bed for subsequent skin grafting or flap coverage.

The technology has also become increasingly diversified, with portable systems and specialized interfaces allowing its use in outpatient settings and anatomically difficult locations. Recent reviews emphasize that the clinical evidence remains heterogeneous, with outcomes dependent on wound type, dressing configuration, pressure settings, treatment duration, and patient characteristics.

Consequently, NPWT should be viewed as an adjunct to comprehensive wound management rather than an isolated treatment.

## 6. CONCLUSION

Negative pressure wound therapy has become an important tool in modern wound management and

reconstructive surgery. Its effects result from a combination of macrodeformation, microdeformation, fluid removal, and modulation of the wound environment.

Its clinical applications now extend from diabetic foot wounds and pressure injuries to traumatic and postoperative wounds, skin graft fixation, complex tissue defects, and closed surgical incisions. Evidence from randomized trials and recent systematic reviews supports its use in selected diabetic foot wounds and as an adjunct to skin grafting.

Nevertheless, NPWT should be prescribed within a structured wound-management strategy. Adequate debridement, vascular assessment, infection control, nutritional optimization, and appropriate reconstruction remain fundamental prerequisites for successful healing.

Future developments are likely to focus on increasingly individualized NPWT protocols, portable systems, improved wound interfaces, instillation technologies, and a better understanding of the mechanobiological mechanisms governing tissue response.

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