Abstract: Negative pressure wound therapy (NPWT) with reticulated open-cell foam (ROCF) dressings (ROCF, V.A.C.® GranuFoam™ Dressing, KCI USA, Inc, San Antonio, TX) creates a healing environment that removes wound exudates, reduces edema, and promotes perfusion and granulation tissue formation. Controlled instillation of saline during NPWT (NPWTi) may further enhance healing by facilitating automatic and contained volumetric wound irrigation and cleansing. A new ROCF dressing (ROCF-V, V.A.C. VeraFlo™ Dressing, KCI USA, Inc, San Antonio, TX) has been developed for use with NPWTi; benchtop and in vivo tests compared the properties and performance of both ROCF-G and ROCF-V. Pore size and density (contributors to microdeformation) are similar for both ROCF-G and ROCF-V, while mechanical testing demonstrates ROCF-V is stronger than ROCF-G under both tensile and tear loading. ROCF-V surface energy is higher than ROCF-G, making ROCF-V less hydrophobic. Under wet conditions ROCF-V wicks more fluid and shows less pressure drop than ROCF-G, suggesting ROCF-V may be better suited for NPWTi. After 7 days of therapy in a porcine full-thickness excisional wound model, NPWTi with ROCF-V resulted in a 43% increase ($P < 0.05$) in granulation tissue thickness compared to NPWT with ROCF-G. These data suggest NPWTi with ROCF-V creates a wound healing environment that provides enhanced granulation tissue formation compared to standard NPWT with ROCF-G.
ther promote wound healing by enhancing exudate and debris removal, maintaining a clean wound through integration of wound irrigation, as a component of therapy.\(^5,6\) NPWTi helps improve bioburden management by allowing for hydro-debridement and providing volumetric control of irrigant delivery for accurate dosing of antimicrobial or antiseptic solutions.\(^6\) NPWTi may also be used to improve pain management through delivery of analgesic solutions directly to the wound bed.\(^7\) Finally, porcine testing has shown that NPWTi can accelerate wound fill and increase collagen deposition in granulation tissue compared to standard NPWT.\(^8\)

A new therapy system (V.A.C. ULTRA™ Therapy System; KCI USA, Inc, San Antonio, TX) has been developed to deliver both NPWT (V.A.C.\(^6\)) and NPWTi (V.A.C. VeraFlo™ Therapy, KCI USA, Inc, San Antonio, TX). This system uses a single pad that delivers both negative pressure and irrigation solution, decreasing setup time and reducing the likelihood of leaks. The NPWTi system also has updated leak management with more robust computer algorithms that respond to indications of leaks or blockages. Furthermore, the drape adhesive material withstands exposure to many topical irrigation solutions, including those specifically suggested for use with the system (unpublished data). A new, modified ROCF dressing ([ROCF-V], V.A.C. VeraFlo™ Dressing, KCI USA, Inc, San Antonio, TX) has also been developed for use with NPWTi. Compared to ROCF-G, ROCF V is designed to facilitate enhanced fluid distribution and removal when the dressing is used with NPWTi.

This manuscript compares the properties of ROCF-V to ROCF-G using standard techniques. The pore size and structure of the foams were evaluated using scanning electron microscopy and the mechanical properties were measured under tension, compression, and tear loading. Surface energies were measured to determine the relative hydrophobicity of the dressings and their ability to distribute fluids was assessed. Additionally, pressure distribution profiles were determined under wet and dry conditions. Finally, the new therapy system and dressing (NPWTi with ROCF-V) were compared to an existing therapy system and dressing (NPWT with ROCF-G) using a porcine wound model. Overall, these data show that NPWTi with ROCF-V is a system optimized to provide the benefits of instillation therapy.

**Methods**

**Two ROCF dressings were tested.** ROCF-G is a polyether-based polyurethane foam designed for use with NPWT. ROCF-V is a polyester-based polyurethane foam designed for use with NPWTi. Prior to all testing, foams were sterilized using gamma irradiation (25–50 kGy), consistent with the commercially available versions of the products.

**Scanning electron microscopy.** Scanning electron microscopy images were collected using an EVO-LS10 Environmental Scanning Electron Microscope (Carl Zeiss Nano Technology Systems, Oberkochen, Germany). Images were taken in variable pressure mode, allowing for imaging of nonconductive samples without a metal coating. A 100-µm variable pressure aperture was used and the typical beam current was approximately 400 pA with an EHT (extra high tension) beam voltage setting of 20 kV. Images were acquired using a 5-quadrant backscatter detector with a working distance of 7 mm–9 mm. Pore sizes were semiquantitatively estimated using the scale bar on the scanning electron micrographs.

**Evaluation of Material Strength**

ROCF dressings were tested according to ASTM D3574-08 Standard Test Methods for Flexible Cellular Materials - Slab, Bonded, and Molded Urethane Foams. All mechanical testing was performed using an electromechanical test frame (Instron 5540 Series, Norwood, MA) with a 500 N load cell (Instron 2530-416, Norwood, MA). ROCF dressings were mechanically tested under both dry and wet conditions. Dry ROCF dressings were tested as is. Wet dressings were conditioned in 0.9% sodium chloride irrigation solution (Baxter, Deerfield, IL) at 37°C for 16 hours and then dried prior to testing. Data were analyzed for statistical significance using one-way ANOVA followed by the Tukey-Kramer method.

**Tensile testing.** Dressings were precut into dog bone shapes (total 140 mm x 15 mm thick; with 25 mm width x 38 mm length grip dimensions and 13 mm width x 35 mm length gauge dimensions). Dressings were loaded under tension at a uniform rate of 500 mm/min ± 50 mm/min and the stress at failure was measured.

**Tear testing.** Dressings were pre-cut to rectangular blocks (25 mm square x 150 mm long, with a 15 mm long pant leg split at one end, cut down the center of one end

**Key Points**

- NPWT with controlled fluid instillation (NPWTi) may further promote wound healing by enhancing exudate and debris removal, maintaining a clean wound through integration of wound irrigation, as a component of therapy.
of the specimen). Dressings were loaded under tension at a uniform rate of 500 mm/min ± 50 mm/min until at least a 50 mm length was torn. The maximum force was measured.

**Compression force deflection (CFD) testing.** Dressings were pre-cut to square blocks (50 mm by 50 mm x 25 mm thickness). The dressings were pre-flexed twice to 75%–80% of the original thickness at a rate of 250 mm/min ± 25 mm/min and then allowed to rest for a period of 6 minutes ± 1 minute. The specimens were then compressed to a pressure of 140 Pa, at which time the thickness of the specimens was measured; the specimens were then compressed to 50% of this thickness at a rate of 50 mm/min ± 5 mm/min and allowed to rest for 60 seconds (s) ± 3 s. The force was measured following this rest period.

**Surface energy measurements.** A precision calibrated wetting tension solutions kit (Accu Dyne Test; Diversified Enterprises, Claremont, NH) was used according to the manufacturer instructions to measure the surface energy of the ROCF dressings. Briefly, a 10 µL to 20 µL drop of the wetting tension solution was released by pipette onto a clean and level surface of the foam. Presence of the drop as a stable bead on the foam indicated the surface energy of the dressing was less than the surface tension of the solution, while spreading of the drop into the dressing indicated the surface energy of the foam was greater than the surface tension of the solution. Testing progressed in increments of 2 dynes/cm from low surface tension solutions through high surface tension solutions until spontaneous spreading of the drop was observed. The surface energy of the foam was estimated to be the liquid surface tension at which the transition between beading and dispersion occurred. A minimum of three sample points of equivalent location was tested for each dressing.

**Fluid distribution.** ROCF-G and ROCF-V dressings were pre-cut (51 mm width x 51 mm length x 15 mm thick), placed between two transparent plates, and compressed 65% to 5.3 mm thickness. This assembly was then immersed in a clear plastic reservoir containing 15 mm of saline (Figure 1). The samples were removed from the fluid reservoir after 6-, 15-, or 30-minute exposure times, weighed, and the amount of saline wicked by each dressing determined. The procedure was repeated 5 times. Data were analyzed for statistical significance using two-way ANOVA followed by the Bonferroni post-test for each time point.

**Pressure distribution.** ROCF-G and ROCF-V dressings were pre-cut to an irregular shape (area 84 cm²) to approximate the dimensions of a wound. Each dressing was applied to a surface with pressure transducers (Frescale Semiconductor, Austin, TX) integrated into the surface with 51 mm grid separation (Figure 2). V.A.C.® Drape was used to secure the ROCF dressing to the surface and either a SensaT.R.A.C.™ Pad or V.A.C. VeraT.R.A.C.™ Pad

![Figure 1. Experimental setup for the fluid distribution experiment showing the front view (left) and side view (right).](image-url)
(KCI USA, Inc, San Antonio, TX) was applied to the end of a bridge according to the manufacturer instructions; the 150 mm long by 25 mm wide ROCF bridge was applied to simulate typical wound dressing application in diabetic foot or pressure ulcers where clinicians typically bridge the SensaT.R.A.C. Pad away from these wounds to decrease pressure points. Pressure measurements were captured at locations within the foam at a sampling rate of 1 Hz while either NPWT or NPWTi was applied. The difference between the pressure set at the pump and pressure measured within the dressing, referred to as the pressure drop, was calculated. Testing was repeated 5 times for each dressing. Data were analyzed for statistical significance using one-way ANOVA followed by the Tukey-Kramer method.

**NPWT testing.** A SensaT.R.A.C.™ Pad and tubing set were used for NPWT testing. The tubing set was connected to a V.A.C. ATS® Therapy System (KCI USA, Inc, San Antonio, TX) set at -125 mmHg continuous therapy to deliver NPWT. Negative pressure was applied for 2 minutes and then released for 1 minute to pre-condition the foam. Negative pressure was applied again for 2 minutes during which the pressure transducers were activated to measure the actual negative pressure being delivered at discrete points in the ROCF-G or ROCF-V dressing.

**NPWTi testing.** A V.A.C. VeraT.R.A.C.™ Pad and tubing set, which allow for delivery of negative pressure and fluid instillation through the same tube set, was used for NPWTi testing. The tubing set was connected to a prototype V.A.C. ULTA™ Therapy System to deliver NPWTi, and the therapy unit programmed to deliver 100 mL of deionized water to the ROCF dressing followed by -125 mmHg continuous therapy. As with the NPWT testing, negative pressure was applied for 2 minutes and then released for 1 minute to pre-condition the foam. Negative pressure was applied again for 2 minutes during which the pressure transducers were activated to measure the actual negative pressure being delivered at discrete points in the ROCF-G or ROCF-V dressing.

**Granulation response in vivo.** The granulation tissue response to NPWT (with ROCF-G dressing) and NPWTi (with ROCF-V dressing) was evaluated in an in vivo model under a protocol approved by the Institutional Animal Care and Use Committee (IACUC) at the test facility. Twelve adult female domestic swine (weighing approximately 60 kg–70 kg) were used.

**Surgical procedures.** Anesthesia was induced with tiletamine plus zolazepam and xylazine and maintained during procedures with isoflurane inhalant anesthetic. Heart rate, blood pressure, body temperature, respiratory rate, and tidal volume were monitored during procedures. A pair of round, 5 cm diameter dorsal excisional wounds were surgically created on either side of the spine using a scalpel, with the full thickness of tissue down to the muscle fascia (including the epidermis, dermis, and the subdermal and subcutaneous fat layers) removed. Light
pressure was applied to stop bleeding and wounds gently wiped clean with saline moistened gauze.

**Application of dressings and NPWT or NPWTi.** One wound on each animal received NPWT with ROCF-G (NPWT/ROCF-G), and one wound on each animal received NPWTi with ROCF-V (NPWTi/ROCF-V). Dressings were pre-cut into disks 5 cm diameter by 1.5 cm thickness and pre-sterilized. Therapy parameters are summarized in Table 1.

In NPWT/ROCF-G treated wounds, ROCF-G dressing was applied to the wound. Following the manufacturer’s instructions for use, the wound with dressing was then covered with V.A.C.® Drape, a small hole was made in the drape, and a T.R.A.C.™ Pad applied. The T.R.A.C.™ Pad was connected to a V.A.C.® ATS Therapy System set to deliver continuous therapy at -125 mmHg. Dressings were changed on days 3 and 5 post surgery, and animals were euthanized after 7 days of therapy.

In NPWTi/ROCF-V treated wounds, ROCF-V dressing was applied to the wound. Following manufacturer instructions for use, the wound with dressing was then covered with V.A.C.® Drape, two small holes were made in the drape, and a T.R.A.C.™ Pad and an instillation pad were applied to each hole. The T.R.A.C.™ Pad and the instillation pad were connected to a prototype V.A.C. ULTA™ Therapy System programmed to deliver continuous negative pressure therapy at -125 mmHg, and sterile normal saline was instilled every 2.5 hours (approximately 10 cycles/day) with a 5-minute soak time. Dressings were changed on days 3 and 5 post-surgery, and animals were euthanized after 7 days of therapy.

**Tissue collection and histology.** Immediately following euthanasia, wound tissue was collected en bloc to include surrounding unwounded tissue and underlying muscle. Tissues were fixed in 10% neutral buffered formalin, processed for paraffin embedment, sectioned to 4-μm thickness, and stained with hematoxylin and eosin or Masson’s trichrome. Granulation tissue thickness (from the base of the wound to the surface of the granulation tissue) was measured at 2 mm increments across the entire cross-section of the wound and the increments averaged together to determine the average thickness for each wound. Edema and inflammation were qualitatively evaluated by a board certified pathologist for each wound using the following scale: 0 = none observed, 1 = minimal, 2 = moderate, 3 = marked, and 4 = severe.

**Statistical Analysis**

For granulation tissue thickness measurements, the Shapiro-Wilk test revealed the dataset to be normally distributed, so a paired-difference t test was performed. Edema and inflammation scores were considered to be categorical variables with multinomial distributions, re-

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**Table 1. Therapy parameters.**

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Dressing</th>
<th>Negative pressure</th>
<th>Instillation cycles</th>
<th>Instillation solution</th>
<th>Instillation solution soak time</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPWT</td>
<td>ROCF-G</td>
<td>-125 mmHg</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>NPWTi</td>
<td>ROCF-V</td>
<td>-125 mmHg</td>
<td>Every 2.5 hours (approx. 10 cycles/day)</td>
<td>Saline</td>
<td>5 minutes</td>
</tr>
</tbody>
</table>
Results

Scanning electron microscopy. Scanning electron micrographs revealed similar pore size and structure for both ROCF-G and ROCF-V (Figure 3). Both foam dressings have 3-D symmetrical cellular geometry and pore size consistent with previous reported pore size values of 400 µm to 600 µm for ROCF-G.9

Evaluation of mechanical properties. A summary of the mechanical testing results can be found in Table 2. Under both tensile loading and tear testing, ROCF-G and ROCF-V was found to be stronger under dry conditions compared to wet conditions ($P < 0.05$). Wetted ROCF-V was stronger than ROCF-G under both wet and dry conditions ($P < 0.05$). Compression force deflection testing similarly revealed a decrease in compressive stiffness of both dressings under wet compared to dry conditions ($P < 0.05$). The compression force deflection of wetted ROCF-G was approximately 6% less than wetted ROCF-V; although statistically significant ($P < 0.05$), this difference is considered to be minor.

Surface energy. Surface energy of ROCF-G was estimated to be $31 \pm 0$ dyn/cm while the surface energy of ROCF-V was estimated to be $37 \pm 0$ dyn/cm, suggesting ROCF-V is slightly less hydrophobic than ROCF-G.

Fluid distribution. Analysis revealed that ROCF-V distributed more fluid than ROCF-G under similar conditions (Figure 4), with ROCF-V pulling more saline from the reservoir than ROCF-G at 5, 10, and 30 minutes after immersion ($P < 0.05$). Furthermore fluid movement for ROCF-G reached equilibrium sooner than ROCF-V. Given the increased surface energy of ROCF-V, it is believed that its improved fluid distribution ability compared to ROCF-G is due to its decreased hydrophobicity.

Pressure distribution. The pressure distribution profiles of ROCF-G and ROCF-V under NPWT and NPWTi are presented in Figure 5, while the average pressure drop under each condition is presented in Table 3. The pressure drop is the difference between the pressure setting at the

Table 2. Summary of mechanical properties of ROCF-G and ROCF-V under dry and wet conditions ($n = 5$ samples tested per condition).

<table>
<thead>
<tr>
<th>Condition</th>
<th>ROCF-G</th>
<th>ROCF-V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry</td>
<td>Wet</td>
</tr>
<tr>
<td>Tensile (kPa)</td>
<td>Mean</td>
<td>95.44</td>
</tr>
<tr>
<td></td>
<td>Standard deviation</td>
<td>5.17</td>
</tr>
<tr>
<td>Tear (N/m)</td>
<td>Mean</td>
<td>741.78</td>
</tr>
<tr>
<td></td>
<td>Standard deviation</td>
<td>12.83</td>
</tr>
<tr>
<td>CFD (kPa)</td>
<td>Mean</td>
<td>3.45</td>
</tr>
<tr>
<td></td>
<td>Standard deviation</td>
<td>0.06</td>
</tr>
</tbody>
</table>

CFD = compression force deflection

Figure 4. Time course of fluid distribution of saline throughout ROCF-G and ROCF-V, showing that more fluid is distributed in ROCF-V compared to ROCF-G at 5, 10, and 30 minutes after immersion ($P < 0.05$). Data ($n = 5$ per group) represented as mean ± standard deviation.
therapy unit and the actual pressure at the dressing. A small pressure drop is preferred. Both ROCF-G and ROCF-V dressings distributed pressure evenly when NPWT was applied with minimal pressure drop (5 mmHg or less), suggesting that a consistent pressure would be delivered throughout a wound when NPWT is applied to either dressing. However when NPWTi was applied, there was a greater pressure drop recorded for ROCF-G compared to ROCF-V ($P < 0.05$). This suggests that ROCF-V may distribute negative pressure more consistently throughout a wound than ROCF-G when NPWTi is applied. These results may be attributable to the improved fluid handling ability of ROCF-V and suggest that fluid pooling may have occurred with ROCF-G.

**Granulation response in vivo.** Histological evaluation of the granulation tissue response after 7 days of therapy revealed a substantial increase in granulation tissue thickness in wounds treated with NPWTi/ROCF-V compared to wounds treated with NPWT/ROCF-G (Figure 6). Granulation tissue thickness in NPWTi/ROCF-V treated wounds averaged 4.82 mm (± 0.42 mm) while wounds treated with NPWT/ROCF-G averaged only 3.38 mm (± 0.55 mm). This statistically significant difference ($P < 0.05$) amounts to a 43% increase in granulation tissue in NPWTi/ROCF-V treated wounds compared to NPWT/ROCF-G treated wounds (Table 4, Figure 7).

**Table 3.** The average pressure drop across the dressings under different therapies. Pressures are shown as mean ± standard deviation.

<table>
<thead>
<tr>
<th>Therapy</th>
<th>ROCF-G</th>
<th>ROCF-V</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPWT (dry)</td>
<td>4.7 mmHg ± 0.2 mmHg</td>
<td>0 mmHg ± 0.3 mmHg</td>
</tr>
<tr>
<td>NPWTi (wet)</td>
<td>16.2 mmHg ± 4.4 mmHg</td>
<td>6.8 mmHg ± 2.9 mmHg</td>
</tr>
</tbody>
</table>

**Figure 6.** Masson’s trichrome stained tissue sections showing the difference in granulation tissue thickness between NPWT/ROCF-G treated wounds (left) and NPWTi/ROCF-V treated wounds (right) following 7 days of therapy. Therapy settings: NPWT = -125 mmHg; NPWTi = -125 mmHg, saline instillation every 2.5 hours with 5-minute soak.
Qualitative scoring of edema showed minimal edema in most wounds and no statistical difference between treatment groups (Table 4). Similarly, scoring of inflammation showed minimal to moderate edema in most wounds and no statistical difference between treatment groups (Table 4).

**Discussion**

NPWT/ROCF-G was first introduced in the mid-1990s.\textsuperscript{10,11} More than a decade of research, including *in vitro* and *in vivo* models, computer simulations, and clinical case studies, has improved the understanding of the mechanisms of action of NPWT. Next generation devices are being developed that exploit these mechanisms. An enhanced therapy option is NPWTi, which adds automated and contained volumetric wound irrigation and fluid removal phases between negative pressure cycles. As presented here, a new dressing has been developed for NPWTi; ROCF-V retains the pore size and structure of ROCF-G but has improved mechanical properties and decreased hydrophobicity. In this porcine wound-healing model, the new NPWTi/ROCF-V system increased granulation tissue formation compared to the traditional NPWT/ROCF-G system.

The mechanical properties of ROCF dressings are important for several reasons. Both the tensile integrity of the dressings and their ability to withstand tearing have implications for their ease of removal. Most polyurethanes exhibit some hydrolytic degradation in the presence of moisture and both ROCF dressings showed some decrease in tensile and tear strength after exposure to saline. Additionally, moisture infusion into the polymer may cause a plasticizing effect that results in softening of the foam. ROCF-V, however, is stronger than ROCF-G under both wet and dry conditions, suggesting ROCF-V may be easier to remove than ROCF-G when substantial granulation tissue is present.

Compression force deflection, a measure of stiffness, indicates the ability of a ROCF dressing to resist compression. As negative pressure is applied in an NPWT system, the foam dressing will partially collapse within the wound, reducing the volume of the wound by approximating its edges. At 125 mmHg, ROCF dressings collapse sufficiently to produce this volume reduction\textsuperscript{12} while resisting complete compression. Resisting complete compression maintains the open cell structure within the

### Table 4. Histological edema and inflammation scores of NPWT/ROCF-G treated wounds compared to NPWTi/ROCF-V treated wounds, shown as mean ± standard error of the mean (n = 12). The P values for the statistical comparisons reveal the differences are not significantly different. Therapy settings: NPWT = -125 mmHg; NPWTi = -125 mmHg, saline instillation every 2.5 hours with 5-minute soak.

<table>
<thead>
<tr>
<th></th>
<th>NPWT/ROCF-G</th>
<th>NPWTi/ROCF-V</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granulation tissue thickness (mm)</td>
<td>3.38 ± 0.55</td>
<td>4.82 ± 0.42</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Edema score</td>
<td>1.17 ± 0.25</td>
<td>0.83 ± 0.18</td>
<td>&gt; 0.05</td>
</tr>
<tr>
<td>Inflammation score</td>
<td>1.54 ± 0.23</td>
<td>1.71 ± 0.18</td>
<td>&gt; 0.05</td>
</tr>
</tbody>
</table>

**Figure 7.** The measured granulation tissue thickness of NPWT/ROCF-G treated wounds compared to NPWTi/ROCF-V treated wounds, shown as mean ± standard error of the mean. (n = 12 per group, *P < 0.05). Therapy settings: NPWT = -125 mmHg; NPWTi = -125 mmHg, saline instillation every 2.5 hours with 5-minute soak.

**Keypoints**

- In this porcine wound-healing model, the new NPWTi/ROCF-V system increased granulation tissue formation compared to the traditional NPWT/ROCF-G system.
- As hydrophobicity decreases, the affinity of the dressing for fluid increases, thus ROCF-V compared to ROCF-G may enable more even delivery of instilled fluids to the wound bed.

Qualitative scoring of edema showed minimal edema in most wounds and no statistical difference between treatment groups (Table 4). Similarly, scoring of inflammation showed minimal to moderate edema in most wounds and no statistical difference between treatment groups (Table 4).
dressing, allowing it to manifold pressures throughout the entirety of the wound (unpublished results). Because the cells remain open, the dressings mitigate edema with less likelihood for clogging.

ROCF pore size, structure, and stiffness contribute to the generation of mechanical strain, and thus mechanical forces, at the cellular level when tissues are treated with NPWT or NPWTi. Sensory cells, including those involved in touch and hearing, have long been known to respond to mechanical forces. More recently the concept of mechanotransduction has been accepted, suggesting that many other cell types biologically respond to mechanical forces, at the cellular level when tissues are treated with NPWT or NPWTi. Sensory cells, including those involved in touch and hearing, have long been known to respond to mechanical forces. More recently the concept of mechanotransduction has been accepted, suggesting that many other cell types biologically respond to mechanical stimuli. In vitro, fibroblasts exposed to mechanical strains exhibit changes in cell growth, proliferation, chemotaxis, cellular energetics, growth factor production, extracellular matrix production, and extracellular matrix remodeling. In wound healing in vitro, the ability of NPWT to stimulate cell proliferation compared to controls has been attributed to the ability of NPWT with ROCF dressings to mechanically stimulate the wound.

The decreased hydrophobic properties of ROCF-V contribute to the effectiveness of NPWTi. As hydrophobicity decreases, the affinity of the dressing for fluid increases, thus ROCF-V compared to ROCF-G may enable more even delivery of instilled fluids to the wound bed. As shown in the fluid distribution experiment, the decreased hydrophobic properties may also enhance the removal of these instilled fluids and also wound exudates from the wound bed. This increased affinity for fluids may also pull fluid away from the wound edges and into the foam, reducing the strain on the drape seal around the wound edge and potentially reducing the incidence of leaks. Additionally, the improved fluid handling ability of ROCF-V was evidenced in the pressure distribution experiment, as the increased pressure drop when NPWTi was applied to ROCF-G was likely due to fluid pooling within or beneath the dressing. These data suggest ROCF-V may distribute negative pressure more consistently throughout a wound than ROCF-G when NPWTi is applied.

The instillation of fluids is enhanced by the decreased hydrophobic properties of ROCF-V and helps maintain a moist wound environment that facilitates wound healing. Furthermore, clinicians suggest that instillation of saline solution prior to a dressing change allows for easier ROCF dressing removal and reduces associated pain.

Mechanical debridement techniques, sharp or otherwise, are employed to clean wounds of necrotic tissue, fibrinous slough, and bacteria and are typically followed by wound irrigation to flush out remaining debris. NPWTi may be more effective than traditional wound irrigation or lavage techniques because it allows for automated frequent instillation of fluid throughout the treatment period. The semiocclusive drape that seals the wound to deliver negative pressure also serves to contain the wound irrigation solutions, potentially reducing the likelihood of cross-contamination of patients, clinicians, and their surroundings. The drape also serves as an impermeable barrier that protects the wound from exogenous pathogens and helps maintain a clean wound environment.

Porcine skin is anatomically similar to humans, and wound healing in swine is characterized by granulation and is suggested to be the most relevant for studying human wound healing. NPWT creates a favorable environment for the granulation response, and the preclinical data presented herein suggest that NPWTi may even further enhance granulation tissue formation. As mentioned previously, the reduced hydrophobicity of the ROCF-V dressing improves fluid distribution, suggesting that periodic wound cleansing offered by NPWTi with ROCF-V may better remove wound exudates than other therapies. These exudates contain inflammatory cytokines, reactive oxygen species, and proteolytic enzymes that may have deleterious effects if they are present in excess. The results of this experimental model are especially promising, and future studies may be conducted to determine the effects of instillation therapy settings (such as instillation cycles and soak times), dressing selection, and other parameters on wound healing. It is expected that clinical use will confirm the effects of NPWTi on granulation tissue formation.

**Conclusion**

Negative pressure wound therapy with controlled instillation of fluids (NPWTi) is the next generation of nega-
tive pressure therapy. A new therapy system (V.A.C. ULTA™ Therapy System) has been developed that delivers NPWTi and consists of two components: the therapy unit and the specialized ROCF-V wound dressing. The system provides discrete wound irrigation and fluid removal phases between negative pressure cycles and simplifies wound cleansing by allowing for automated and contained volumetric wound lavage. The new ROCF-V dressing has modified hydrophobic and mechanical properties compared to the existing ROCF-G dressing, enhancing fluid delivery and removal while potentially reducing the likelihood of tearing or particle retention at dressing changes. This study also shows NPWTi with ROCF-V to be effective in a non-infected porcine wound model, resulting in more granulation tissue than standard NPWT with ROCF-G; these results should be confirmed in human studies. The benefits of proper wound cleansing are widely accepted, and this paper introduces a new technique for cleansing and treating wounds that may also have a positive effect on granulation tissue formation.

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