Does Tissue Response to Fuzzy Wale Elastic Compression Therapy include Cell Micro Deformation, Optimizing Cell Mechano Transduction Signaling to Nuclear DNA to Upregulate Gene Expression and Synthesis of Proteins Required for Healing?

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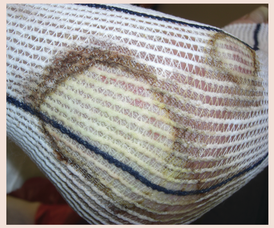
Profoundly Ischemic Foot Responds to Fuzzy Wale Compression as the Wound Contact Layer with Dramatic Early Wound Bed Progress

Rx day #0: 55 yo F vasculopath with aortic occlusion below renal arteries, S/P L BKA, no doppler signals below R knee consistent with profound R leg ischemia. Pt refused R BKA. Photo is after 3 days of NPWT, which was discontinued due to maceration and inflammation beneath polyethylene. Fuzzy wale elastic compression stockinet was selected as a wound contact layer in an attempt to control 6mm ankle edema and skin maceration.

Rx day# ~45: Dramatic wound bed progress, neo epithelization, healthy new normal appearing skin at wound margins and bleeding, which all suggest improved perfusion. Fuzzy wales deliver static Newtonian force creating furrows in the skin, we posit turbulent flow in 7μm arteries beneath these furrows stimulates release of nitric oxide (NO) that vasodilates downstream patent arteries in ~80% of skin surface between wales. Robust healing of wound surface and healing without scar in peri wound skin in a profoundly ischemic R leg with no audible doppler signals below R popliteal artery. How is this possible - almost certainly wales enhance NO generation.



Rx Day~ #3: Fuzzy wale elastic compression stockinet was the wound contact and the compression layer for the full thickness ischemic wound with edema and maceration response was dramatic.

Rx Day #100: These were the first wounds we treated using EdemaWear as the wound contact layer - Wound Bed Progress was dramatic. (Schultz)(Sibbald)

Fuzzy wale compression stockinet* acts as an effective physiologic mandril to deliver therapeutic static Newtonian force: tissue in the base of furrows beneath fuzzy wale experience compression tissue in the sidewalls experience tension, creating *tissue deformation* the ideal conditions for *mechano transduction pathways* to signal DNA to upregulate gene expression and synthesize myriad proteins required for healing. Open cell foam is the physiologic mandril of delivering Static Newtonian force in NPWT fuzzy wale elastic compression therapy stockinet creates a faux shearling pile interface with tissue, a physiologic mandril that delivers Positive Pressure Wound Therapy© (PPWT) S. Ehmann.

Discharged on Day #193:
Profoundly ischemic full thickness mixed wound 'miraculously' (crucifix) healing without scar—a bedside clinical sign of regenerative healing which occurs when stem cells flourish.

Regenerative healing is commonly seen with NPWT, Ehmann (2022) made the observation that robust regenerative healing seen with EdemaWear®* is the result of Positive Pressure Wound Therapy (PPWT). Elastic textile compression via fuzzy wales* creates furrows in 20% of the wound surface what is seen with NPWT. We posit PPWT from fuzzy wale compression delivers three unique physiologic therapies:

1) enhanced skin perfusion - (probable upregulation of Nitric Oxide?),

2) rapid edema control,

3) tissues experiencing micro deformation in furrows beneath fuzzy wales send mechano transduction signals to their DNA to upregulate gene expression and synthesize the myriad proteins required to heal the wound.

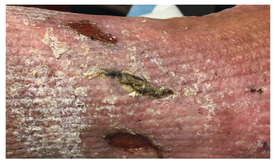
Aristotle reported textile compression healed leg ulcers in 400 BC at temple of Asclepius by priest practitioners. We posit fuzzy wale elastic compression* introduces a third dimension, furrows in skin that appears to dramatically increase three physiologic functions of textile compression therapy.

Fuzzy Wale Compression Stockinet as a Contact Layer Delivers Dramatic Early Wound Bed Progress in a Refractory VLU Present 48 Months

Rx Day #0: Intensely painful weeping bilateral venous stasis dermatitis with nonhealing refractory mixed etiology wound. Patient followed in a wound clinic ~ 48 months. Compression therapy was not tolerated due to pain. Observe wound edges epibioly and cobblestone edema changes. Compression with fuzzy wale stockinet started on this day. (Photo © Marta Ostler, Sheridan Wyoming)

Rx Day ~ #8, 3rd Clinic Visit: Wound bed progress is dramatic. Tissue beneath fuzzy wale stockinet experiences compression that forms parallel furrow while skin and subcutaneous fat between furrows experience tension (think "stretch"), these conditions create tissue "micro deformation," which optimizes mechano transduction signaling to local cell DNA, upregulating gene expression to synthesize proteins needed for the final 3 stages of wound healing. Tissue micro deformation is believed to be one mechanism of NPWT. We posit that Aristotle's documentation of swaddling of lower extremity wounds with linen wraps represents the first therapeutic tissue micro deformation. (Photo © Marta Ostler)

RX Day~ #40: Dramatic healing the VLU surface attests the effectiveness of fuzzy wale elastic compression stockinet* delivering static Newtonian force to tissue under the wales, creating furrows in subcutaneous fat and granulation tissue in ~ 20% of the skin surface. The term Positive Pressure Wound Therapy was coined by Ehmann. (Ehmann 2022)** (Photo © Marta Ostler)



Day #106: Observe large area of recently regenerated peri-wound epithelium appears robust beneath cornrow furrows. Layered compression therapy, in absence of exudate, now consists of just EdemaWear and crepe wrap to keep dressing from falling. Discharge planning was started at this visit: daily leg elevation, frequent calf plantar flexion, and lifelong EdemaWear is recommended to prevent ulcer recurrence. (Photo © Marta Ostler)

* EdemaWear® Elastic Compression Stockinet, Compression Dynamics LLC, Omaha, Nebraska 68102

NPWT Creates Tissue Micro Deformation Delivering Static Force with Open Cell Foam, a Physiologic Mandrel

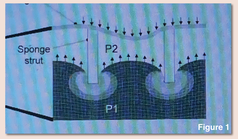


Figure 1: Illustration shows the forces delivered by a single cell of NPWT open cell foam under sub atmospheric air pressure. The open cell foam wall (strut) is sucked down to compress the wound surface that it touches. Simultaneously, tissue in the center of the foam cell is sucked up, creating tenson, illustrated by artist with black arrows.

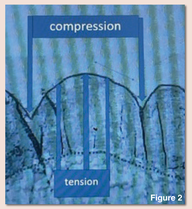
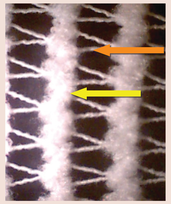


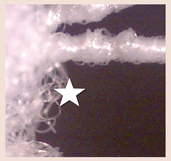
Figure 2: Histology at tissue/foam interface of mammal granulation tissue: Simultaneous compression and tension (blue arrows) create cell micro deformation, a term coined by Orgill (2007). The open cell foam wall (strut in diagram) is sucked down to compress the wound surface that it touches, simultaneously tissue in the center of the foam cell is sucked up, creating tenson, illustrated by artist with blue arrows. (Saxena 2004) Ehmann coined the term Positive Pressure Wound Therapy (PPWT) to describe wound surface and stasis dermatitis results of fuzzy wale elastic compression stockinet that she observed. (Ehmann 2022) We posit that PPWT is in part, a mechanism of traditional limb swaddling introduced by Greek healers of antiquity.

Fuzzy Wales Act as a Physiologic Mandrel to Create Tissue Micro Deformation

Vertical fuzzy wales (~7X power – marked with **yellow arrow**) have a fractal pile like texture that acts as a physiologic mandril to deliver static force to tissue via with dimensions similar in magnitude to the open cells in the black polymer foam mandril used in Negative Pressure Wound Therapy. Static force, when delivered via an appropriate contact **mandrel** creates adjacent areas of tissue tension and tissue compression resulting in tissue micro deformation (TMD). Mechanical transduction signals from TMD upregulates local gene expression to synthesize myriad protein required to reverse stasis dermatitis and heal wounds. Horizontal spandex yarns (marked with the **orange arrow**) under tension span ~80% of the limb surface that is not under compression between the wales that deliver static elastic force to create furrows in subcutaneous fat as edema and extra cellular fluid enter patent lymphatic collection vessels and flow down a pressure gradient toward the heart. (Photo EdemaWear® Stockinet © David Coberly Council Bluffs, Iowa)



Fuzzy wale elastic compression stockinet* (*photo* 20X power) is warp knitted with yarn composed of 5 spiderweb thin strands of nylon that are not spun, not attached to each other, and individual fibers can be seen (marked with **white star**) in photograph above. Vertical wales deliver a fractal, 'faux shearling pile' interface with skin and wound granulation tissue. We posit that fuzzy wales act as a physiologic mandril with a microscopic fractal surface similar to the tiny individual open cells in polymer foam effective for NPWT, (both deliver static force to tissue create local tissue micro deformation). Micro deformation creates tissue conditions required for mechano transduction signaling of local cell DNA, turning on gene expression to synthesize proteins required to reverse stasis dermatitis and heal wounds. (Photo EdemaWear® Stockinet © David Coberly)



Introduction
Enhancing Wound Bed Preparation (WBP), (Schultz) (Sibbald) guides evidence based bedside leg ulcer management advancements: textile compression, Aristotle 365 BCE, moist wound care, aggressive debridement, and recently Negative Pressure Wound Therapy. Argenta observed a remarkable triad of NPWT effects: ..."96% of the wounds responded favourably stating that the technique led to the removal of *chronic oedema, increased blood flow and increased granulation tissue."(Argenta '97). In NPWT, individual oval* polyurethane foam cells act as a tiny physiologic mandril delivering static Newtonian force to small volumes of granulation tissue that experience *compression* under the oval polyurethane cell wall edge and *tension* in the center of each open foam cell as a result of being sucked into the foam sphere resulting in Cell Micro Deformation of wound surface tissue. This tissue transmits effective mechano transduction signals to the local Cell DNA upregulating gene expression to synthesize the myriad proteins required during four stages of wound healing, see figures 1 & 2. (Saxena) (Orgill) (Novak)

Methods
Clear close-up photos with detailed captions document Wound Bed Preparation and healing outcomes in two real world cases of nonhealing refractory VLU/mixed leg wounds outliers treated with fuzzy wale compression stockinet in intimate contact with the peri wound skin and ulcer granulation tissue.

Results
Photos reveal early wound epiboly resolution, exuberant inflammatory granulation tissue abatement, peri wound stasis dermatitis clearing, and reepithelization along cornrow furrows that form beneath fuzzy wales.

Discussion
We posit that fuzzy wale compression stockinet* as a wound contact layer is an effective physiologic mandrel, delivering static Newtonian force from spandex elastomer to skin and wound tissue in furrows that form beneath fuzzy wales. Therapeutic static Newtonian force common to both NPWT and to fuzzy elastic textile compression therapy delivers the Argenta triad, "removal of chronic oedema, increased blood flow and increased granulation tissue." (Argenta '97) Unique to fuzzy wale textile compression is rapid clearing of peri wound stasis dermatitis (recall NPWT foam disrupts intact skin) and healing of chronic mixed wounds, prompting the term PPWT. (Ehmann) (Winkler). Is Aristotle smiling; further study is underway.

References
Schultz G, Sibbald G, Wound bed preparation: a systematic approach to wound management. Wound Repair and Regeneration 2003; 11:1–28

Sibbald G. et al. Special Considerations in Wound Bed Preparation: An Update. Advances in Skin & Wound Care, September 2011 – [PDF] (researchgate.net) (www.WoundCareJournal.com)

Argenta, L. et.al. Vacuum-assisted closure: a new method for wound control and treatment: clinical experience. Annals of Plastic Surgery, 1997 journals.lww.com

Saxena, V. et al. Vacuum-Assisted Closure: Micro deformations of Wounds and Cell Proliferation, Plastic and Reconstructive Surgery October 2004, Volume 114, Issue 5, 1086-1096.

Orgill, D. et al. The Mechanism of Action of the Vacuum-Assisted Closure Device, Plastic and Reconstructive Surgery: September 2008, Volume 122, Issue 3, 786-797.

Novak, A, et al. The evidence-based principles of negative pressure wound therapy in trauma & orthopedics. Open Orthop J. 2014 Jun 27;8:168-77. doi: 10.2174/1874325001408010168. PMID: 25067971; PMCID: PMC4110388.

Ehmann S. Fazzari E, Fuzzy Wale Compression (FWC) Stockinet Delivers Positive Pressure Wound Therapy (PPWT) 2022 Science Poster SAWC Link accessed 5 30 23. https://compressiondynamics.com/wp-content/uploads/2022/06/PosterFuzzy-Wale-Compression-FWC-Stockinet-Delivers-Positive-Pressure-Wound-Therapy-PPWTEhmann-Fazzari-Erikson-OstlerSAWC-Spring-2022.pdf

Winkler, M. Does Fuzzy Wale Elastic Compression Therapy Deliver Positive Pressure Wound Therapy, PPWT? Bedside Observations of Refractory Wound Responses to textile Compression with a Third Dimension - a Non-Flat Surface. 2022 SAWC Science Poster Link accessed 5 30 23 https://compressiondynamics.com/wp-content/uploads/2023/02/PosterThree-Dimensional-Elastic-Compression-Therapy-Positive-Pressure-Wound-Therapy.pdf

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