Strain and Frictional Work Experienced by Prophylactic Heel Dressings: A Finite Element Analysis

Elinor Dhesi[1], Ciara Cassidy[1], Euan Motion[1], Runi Brownhill[1]
[1]Science & Research Group, Advanced Wound Management R&D, Smith+Nephew, Hull, UK

Introduction

- Previous *in vitro* and *in silico* studies have shown that prophylactic dressings with slidable, unbonded internal layers can substantially reduce strain transferred into underlying soft tissues.[1,2]
- To extend this understanding, this study evaluates how an unbonded, frictionally sliding dressing (UD*) (**Figure** 1) redistributes strain and dissipated energy during combined compression and shear, compared with a bonded dressing (BD†).

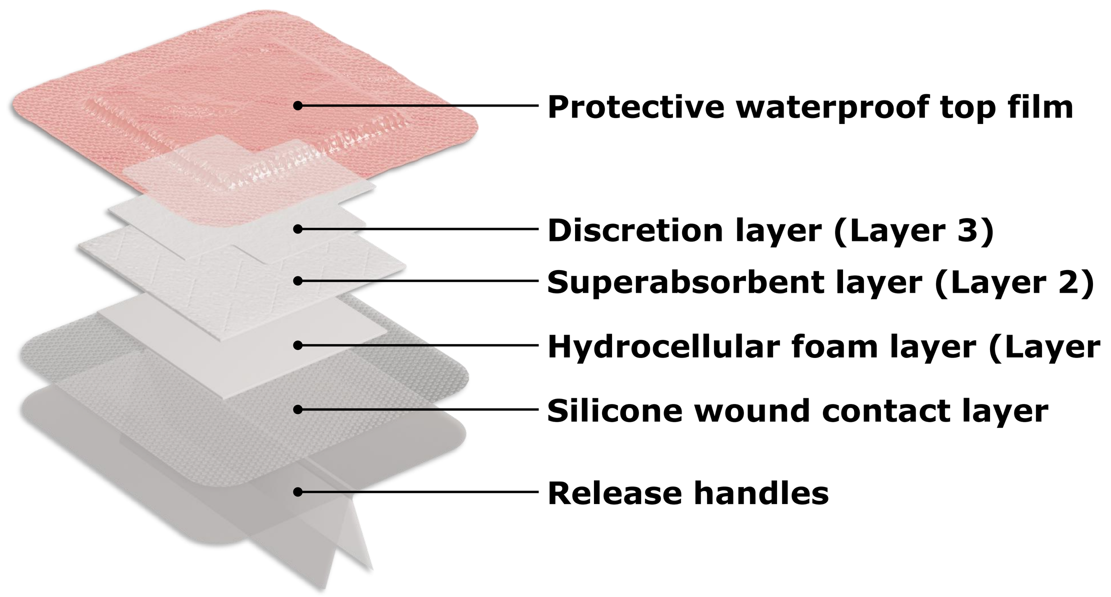

Figure 1. Unbonded Dressing* architectures. UD* includes unbonded slidable layers; interfaces between discretion layer, superabsorber and foam are unbonded.

Study Aim

- To evaluate how the unbonded sliding layers in UD* redistribute mechanical load compared to BD† by quantifying interlayer strain behaviour and frictional energy dissipation within a finite element heel model.

Methodology

- A 3D heel model was generated from MRI data in Simpleware W-2024.12, with both dressings constructed in SOLIDWORKS, 2022 to cover a region of interest beneath the calcaneus.
- Skin and adipose were modeled using hyperelastic Neo-Hookean materials and the calcaneus, Achilles tendon, and support were linear elastic. Dressing layers were simplified to pad layers only, which were modelled as linear elastic through benchtop characterisation, with UD* layers assigned unique stiffness values and BD† layers sharing a bulk modulus due to the pad layers being fully bonded.
- The assembly was loaded with 4 mm compression followed by 3.5 mm horizontal shear at the calcaneus, representative of bed-based heel loading during patient repositioning.

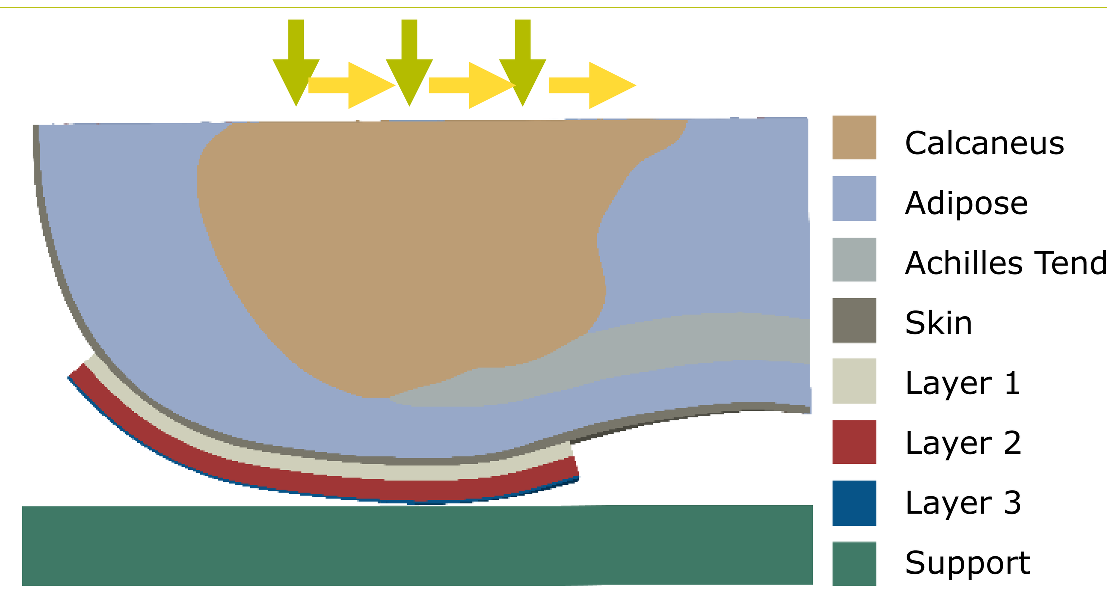

Figure 2. Segmented heel geometry and applied loading conditions, layers representative of UD*. Green arrows indication compression, yellow arrows indicate shear.

Methodology cont.

- UD* was modeled with frictional sliding contacts between pad layers and BD† with fully bonded internal layers. Both dressings were tied to the skin and assigned the same friction coefficient at the dressing–support interface.
- The heel and dressing layers were meshed using tetrahedral hybrid elements to model near-incompressible soft tissues and the support surface used hexahedral elements. A mesh convergence study identified 0.7 mm as the optimal element size for dressing layers and 0.9mm for heel tissue.

Results

- UD* shows elevated strain in Layer 1, which is absorbed by the material and rapidly dissipated through sliding interfaces, resulting in a sharp strain drop between layers (**Figure 3**). This behaviour demonstrates UD*'s ability to localise deformation within the dressing rather than transmitting it to the soft tissue. BD† exhibits a more uniform strain profile, indicating limited interlayer redistribution and reduced ability to buffer deformation in underlying tissues (**Figure 3**).

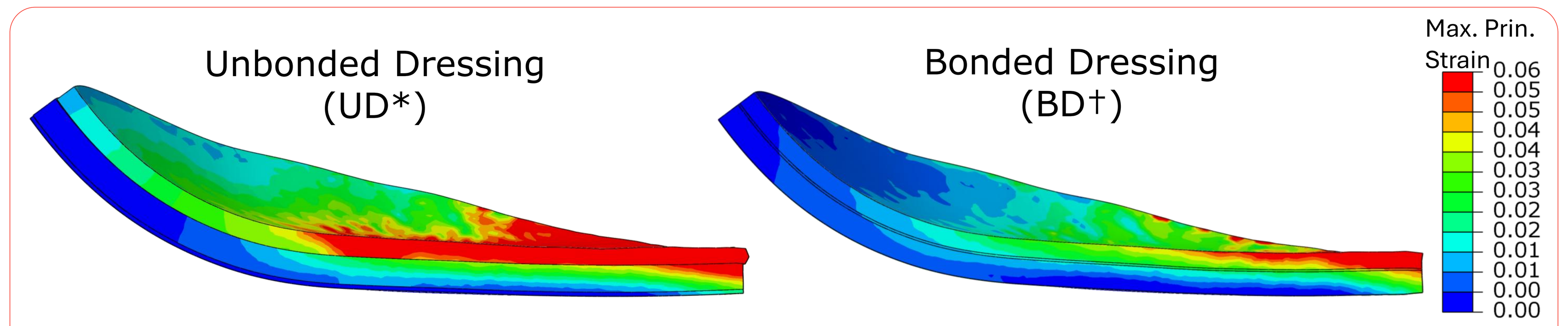

Figure 3. Cross-sectional contour plots showing maximum principal strain occurring within the dressing layers.

- Cumulative percentage element volume vs strain curves were generated ($\Delta\varepsilon = 0.001$). Area under the curve (AUC) calculations showed that UD* dissipated substantially more strain between contiguous layers: 73% (Layer 1→2) and 69% (Layer 2→3), compared to BD†'s 28% and 33%, confirming 2–2.6-fold greater strain redistribution in UD* (**Figure 4**).

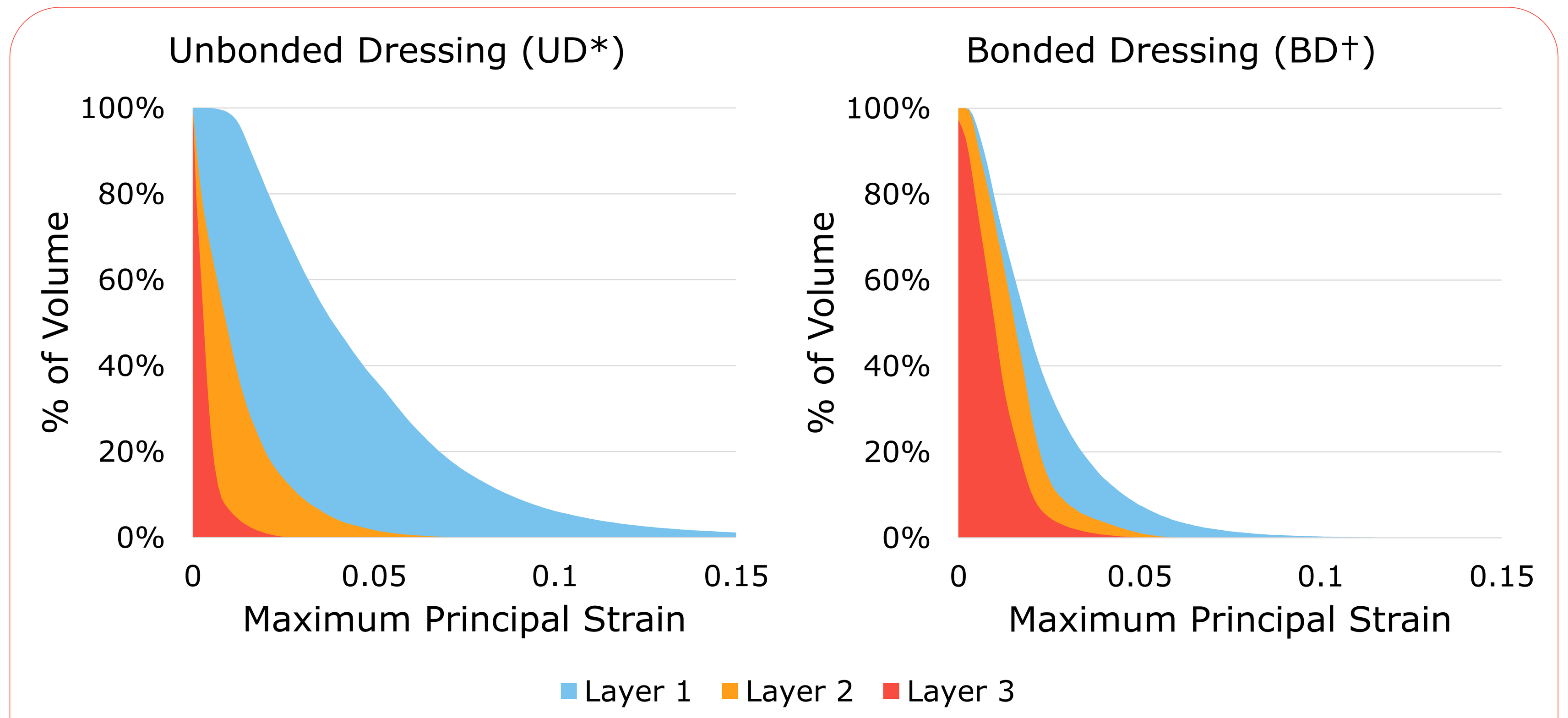

Figure 4. Cumulative percentage of dressing exposure to strain under combined compression and shear loading.

Results cont.

- To complement the volumetric strain distribution, the deltas in % of elements experiencing strain comparing contiguous layers is also reported, showing the element-weighted distribution data follows the same trend as the volume-weighted (**Table 1**).

Table 1. Percentage deltas in strain experienced by contiguous layers in the different dressings.

	% Elements Δ Layer 1→2	% Elements Δ Layer 2→3	% Volume Δ Layer 1→2	% Volume Δ Layer 2→3
UD*	74.00%	67.74%	73.33%	69.07%
BD†	23.43%	32.39%	28.32%	33.39%
UD*/BD†	3.16	2.09	2.59	2.07

- Frictional work was calculated over the displacement path to assess energy dissipation during compression and shear loading. UD* dissipated 0.0203 mJ of mechanical energy through frictional work, a 6.15-fold increase over BD† which dissipated 0.0033 mJ (**Figure 5**).

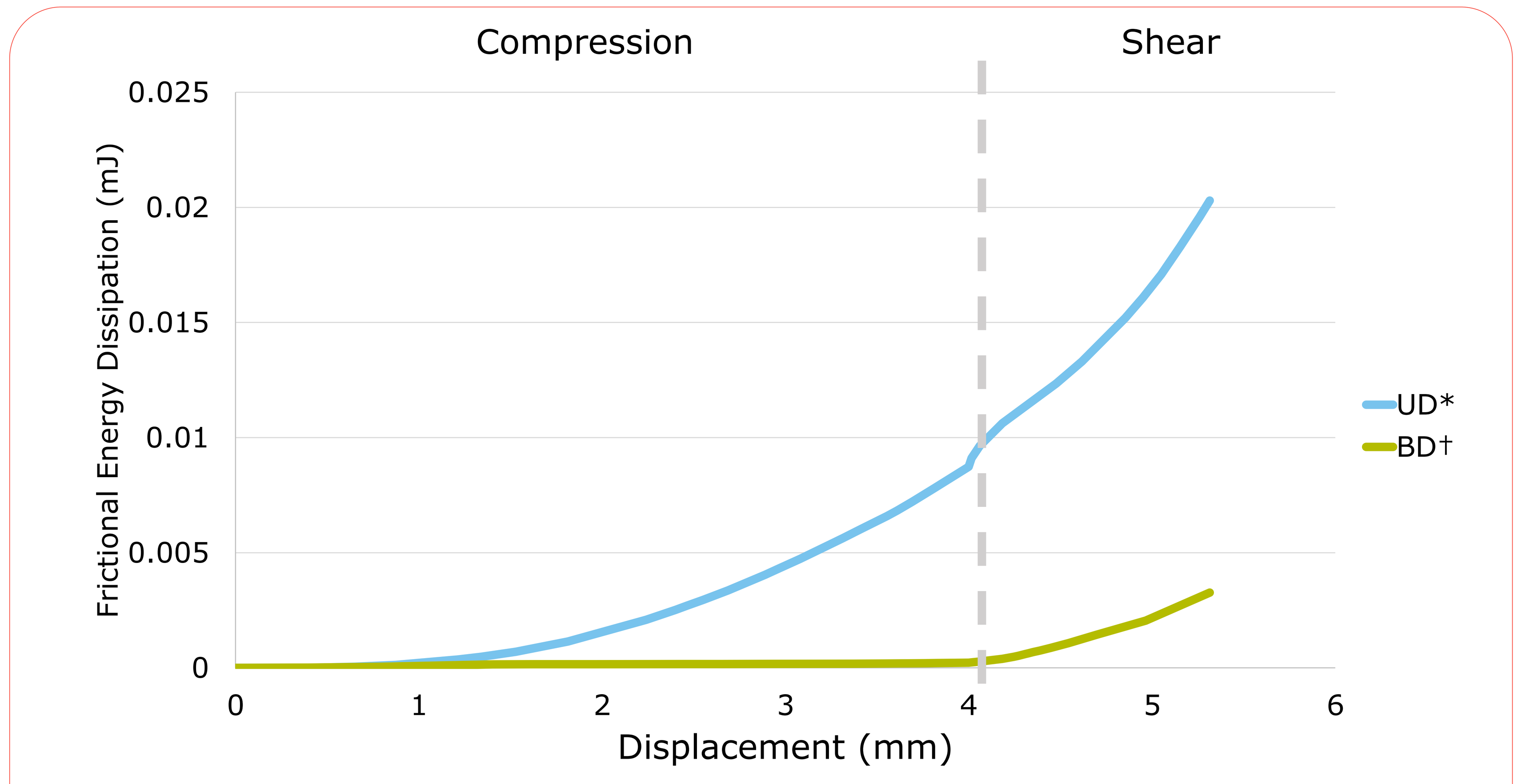

Figure 5. Energy dissipation via frictional work (mJ) against displacement magnitude (mm). Dashed line represents transition from compression to compression and shear loading.

Conclusions

- This study demonstrates that dressing architecture strongly influences how mechanical loads are managed during heel compression and shear. Consistent with previous *in vitro* and *in silico* data[1,2], the unbonded dressing (UD*) showed a markedly superior ability to internalise deformation through its slidable layers compared with the bonded dressing (BD†).
- UD* redistributed 2–3-fold more strain between layers and concentrated deformation in its Layer 1, clearly visible in the contour plots. The much higher frictional work (~5-fold) in UD* confirms that it can dissipate far more energy through unbonded layer frictional sliding.
- Together, these findings indicate that unbonded multilayer dressings provide more effective mechanical buffering, absorbing and redistributing strain within the dressing rather than the soft tissue. This supports the concept that sliding-layer architectures can enhance soft tissue protection and may contribute meaningfully to pressure injury prevention during patient repositioning.

References: 1. Marché C *et al*. Int Wound J. 2024 Apr;21(4):e14871. **2.** Orlova D *et al*. Int Wound J. 2025 Oct;22(10):e70764.
Acknowledgements: We thank Harriet Talbott, Michael Laughton, Sarah Crossland, and Louise France (University of Hull) for the creation of the initial heel FEA model.

Presented at the Symposium on Advanced Wound Care (SAWC) Spring, April 8-12, 2026, Charlotte, NC, USA

*ALLEVYN◊ COMPLETE CARE dressing, Smith & Nephew.

†Mepilex™ Border Dressing, Molnlycke.

Wound Management, Smith & Nephew Medical Ltd, 101 Hessle Road, Hull, HU3 2BN, UK.