Engineering an Optimal Dressing to Prevent Pressure Ulcers

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Pressure ulcers affect 2.5+ million people annually in the U.S., contributing to 60,000+ deaths and $26+ billion in healthcare costs. Current prevention methods remain inadequate. Preventive dressings are a promising approach, but prior designs focused on single-layer or single-material designs. This study developed and optimized a novel 5-layer composite dressing. Three material options per layer yielded 243 combinations, requiring testing 2,916 dressings across 4 conditions (pressure, shear, moisture, and adhesion) with 3 trials each (1,458 hours). The Taguchi Design of Experiments (DOE) method reduced testing to 324 dressings (162 hours). Results revealed an optimal design: silicone mesh wound contact, alginate absorbent core, non-adherent gauze spacer, surgical paper tape adhesive, and foil backing. ANOVA identified the wound contact layer (47.9%; $F=15.3$, $p<0.001$) and absorbent layer (17.1%; $F=5.5$, $p=0.016$) as statistically significant drivers of performance variation. Separately, a Python-trained machine learning ridge regression model indicated interlayer interactions explained 17.3% of performance variability. Validation testing confirmed superior performance versus 4 commercial dressings, exceeding the top-performing comparator with statistically significant improvements in pressure resistance (81.3%; $t=-7.65$, $p<0.001$), shear resistance (27.0%; $t=2.37$, $p=0.02$), and moisture regulation (32.8%; $t=-5.92$, $p<0.001$). The optimized low-cost dressing designed in the study has the potential to transform the pressure ulcer prevention paradigm.

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