

ThermaAid: A Closed-Loop Isothermal Bandage for Chronic Wounds- Accelerating Simulated Wound Closure via Active Thermal Regulation and Flexible Additive Manufacturing

Arora, Ayan (School: Signature School)

Globally, a limb is amputated every 20 seconds due to complications from diabetes. Over 18 million people suffer from chronic diabetic wounds, caused by impaired circulation and reduced wound-bed temperatures. Current wound dressings do not address this thermal deficit, which significantly delays essential cellular repair. I engineered a low-cost, closed-loop, isothermal smart bandage capable of maintaining optimal wound-bed temperature ($38.0^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$) and tested it using a gelatin-based simulated skin model. My device, ThermaAid, is a flexible, 3D-printed bandage made from bio-safe TPU. It incorporates a polyimide film heater, a digital temperature sensor, and an ATtiny85 microcontroller running control logic. I evaluated device efficacy against two traditional passive dressings using a gelatin-based hydrogel skin model with standardized 6mm defects. To mimic an impaired diabetic environment, I performed trials at a reduced ambient temperature of 24°C . Over a 4-day period, I quantified daily wound closure using ImageJ software ($n=3$ per condition) and continuously logged temperature and moisture retention. The active isothermal system consistently maintained the target therapeutic temperature ($38.0^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$) without dangerous thermal overshoot. During the trial, the active system achieved an 18.8% reduction in simulated wound size, with an accelerated closure rate 3.5 times that observed in the unheated control (5.5%). Results indicate that maintaining elevated, stable wound-bed temperatures is associated with faster closure rates. This 3D-printed prototype demonstrates that accessible, low-voltage hardware can safely deliver precise thermal management. ThermaAid shows promise in improving healing outcomes for chronic diabetic wounds and reducing amputation rates.

Awards Won:

