

Accelerating Perfusion in Chronic and Diabetic Wounds

A Closed-Loop Isothermal Regulation System via a Flexible Additively Manufactured Matrix

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Q1: Engineering Goal & Problem Statement

Engineering Goal:

Design and validate a low-cost, closed-loop smart bandage maintaining a stable, isothermal (38.0°C) wound-bed environment to accelerate healing while ensuring patient safety.

Target Specifications:

- **Precision:** Maintain 38.0°C ± 0.5°C
- **Safety:** Prevent temperatures 40°C+
- **Form:** Flexible, 3D-printed using bio-safe TPU
- **Cost:** Bill of Materials under \$15 per unit
- **Validation:** Measurable via gelatin model

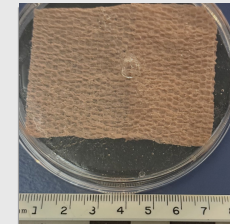


CAD Model of Housing
Created by Ayan Arora using Fusion360

Q2: Design Process & Challenges Overcome

Process:

- Iteratively built hardware
- Created wound models with 6mm puncture
- Compared device against control over four days monitoring closure, temperature, and moisture levels



Gelatin model with scale, prepared for daily analysis via ImageJ. (Photo: Ayan Arora)

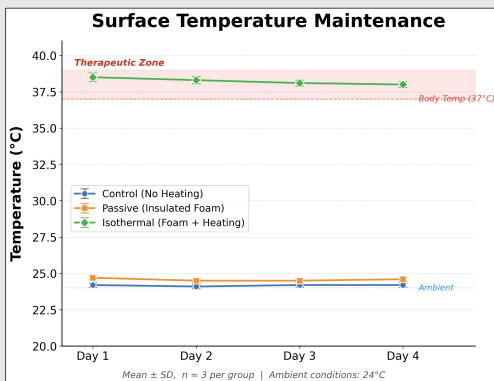


Thermometer confirming successful temperature maintenance (Photo: Ayan Arora)

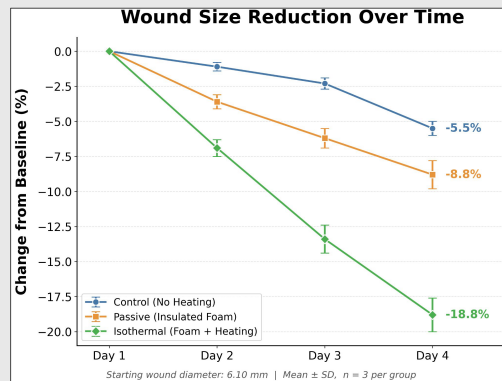
Challenges Experienced and Overcome:

- **Thermal Runaway:** Replaced unstable 4.2W heater with a 1W film to enable a safe climb to 38.0°C.
- **Substrate Degradation:** Corrected wound model melting by iteratively increasing hydrogel concentration.
- **Non-Uniform Dissipation:** Added high-density foam insulation to eliminate hot spots for uniform distribution.

Q3: Data Analysis & Results



Maintained target temperature within ±0.5°C
Graph created by Ayan Arora using Google Sheets



18.8% reduction in wound area by Day 4
Graph created by Ayan Arora using Google Sheets

Overall Healing Efficacy

Over 4-day trial, the device drove an **18.8% total reduction** in wound size, accelerating simulated healing by **3.5x** compared to the unheated control group.

Q4: Interpretation & Conclusions

Clinical Feasibility & Future Optimization:

Prototype met all engineering targets: Flexible, low-cost (>\$15), closed-loop, capable of precise temp. regulation (38.0°C).

The device optimizes conditions for cellular perfusion and enzyme activity, which are often compromised in diabetic cold wounds.



Final Prototype
Built by Ayan Arora

Next-Generation Iterations:

- Expand testing to living tissue models
- Conducting longer-duration experiments (beyond 4 days)
- Integrate Bluetooth for remote clinical monitoring
- Transition to a flexible PCB for bandage profile & comfort