

Differentiate Healing, Non-Healing, and Infectious Diabetic Foot Ulcers Using a Smartphone-based Thermal Scanner

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INTRODUCTION

- **Early detection and prevention of Diabetic Foot Ulcers (DFUs)** is a global unmet problem.
- **Visual Inspection** is the **gold standard** for assessing DFUs.
- **Thermal Imaging (TI)** can be used to **objectively assess the healing status of DFUs & to predict infections & amputations.**

OBJECTIVE

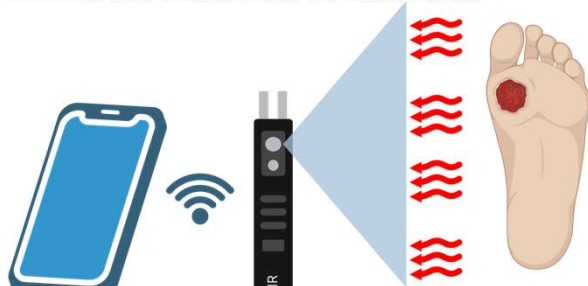
Assess the wound healing process in different manifestations of DFUs by monitoring the inflammation-related variations in temperature by using thermal imaging.

METHODS

Participants: 17 DFU participants with different healing conditions
Clinical Treatment: 6 Weeks of scalpel debridement treatment; IRB-approved study (FIU IRB-18-0025).

Imaging Technology: A commercial wireless handheld smartphone-based thermal imaging scanner (FLIR ONE EDGE Pro)
Data Processing and Analysis: Thermal maps of three independent cases were used to classify if the DFUs were healing, stalled healing (or non-healing), and infected.

Outcome: Thermal distributions were calculated for three different zones in the foot area to differentiate the clinical cases.



FLIR ONE EDGE Pro
 Wireless & smartphone-compatible
Accuracy: +/- 5°C
Thermal resolution: 160x120
 Field of View: 54° x 42°

ACKNOWLEDGEMENTS

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DATA PROCESSING AND ANALYSIS

Stefan-Boltzmann Law

$$W = \epsilon \sigma T^4$$

$W \rightarrow$ Radiated power per area unit of the body (W/m^2)

$\epsilon \rightarrow$ Emissivity ($\epsilon = 0.98$ for human body)

$\sigma \rightarrow$ Boltzmann Constant ($3 \times 10^8 m/s$)

$T \rightarrow$ Temperature from the radiator (K)



Acquired Image Stack

FLIR Thermal Studio

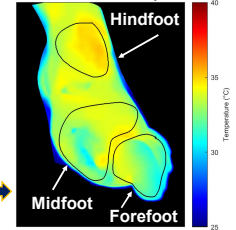
White Light Image

Infrared Image

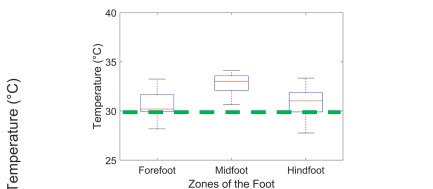
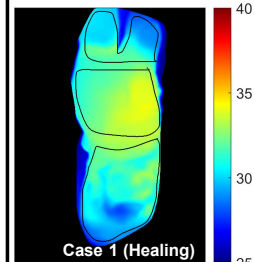
MATLAB®

Rescale, Segmentation & Area Selection

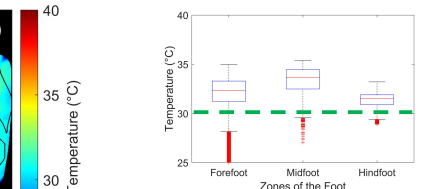
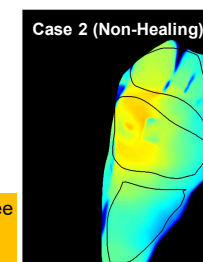
Thermal Map



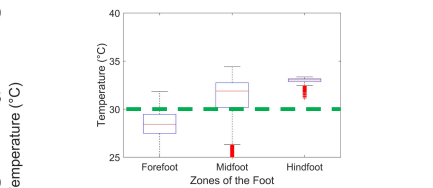
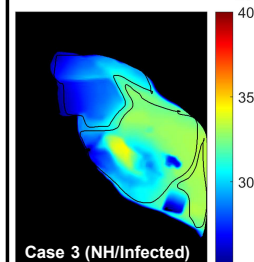
RESULTS AND DISCUSSION: Can TI differentiate between DFU cases? Only the infected cases show a drop below 30 °C



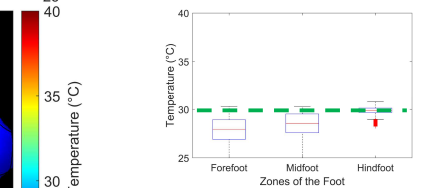
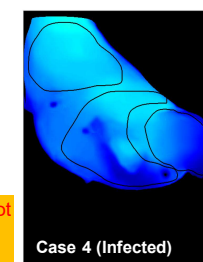
- Temperatures between 30-35 °C for the three areas in the foot
- Homogeneous thermal areas



- Temperatures between 30-35 °C for the three areas in the foot
- Contrasted area in the midfoot zone (DFU)

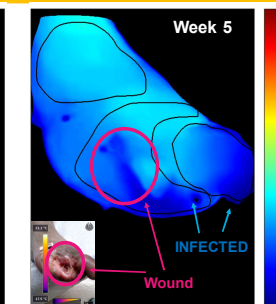
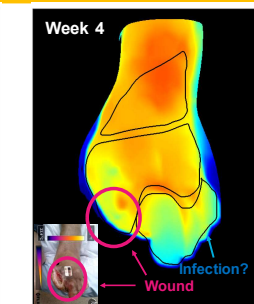
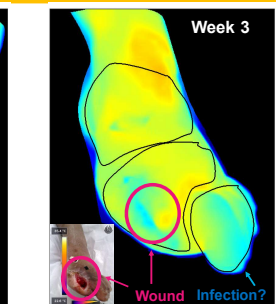
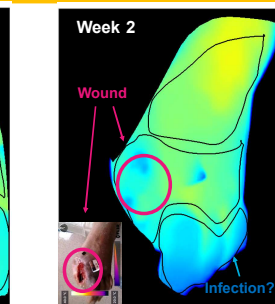
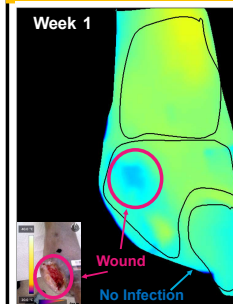


- Temperatures below 30 °C for the forefoot and midfoot
- Indicators of infection. Led to amputation



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RESULTS AND DISCUSSION: TI be used to predict infections? Yes, TI can detect early signs of infection across the weeks



- The forefoot showed a drop in temperatures across weeks – possible early signs of infection. This was clinically apparent during week-5; leading to amputation. The infection wasn't clinically diagnosed nor detected in the white light images in weeks 1-4, but thermal maps could possibly predict.