Three Dimensions of Wound Healing: AI-Assisted Planimetric, Volumetric, and Clinimetric Assessment of Chronic Wounds

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Introduction

Objective assessment and monitoring of chronic wound evolution are critical for optimizing treatment administration and improving patient outcomes. Prior work has explored automated wound and pressure ulcer measurement using classical machine learning methods [1]. This technical validation study investigates the potential of AI-driven image analysis to objectively track wound area, volume, and tissue composition from smartphone images. Together, these measures offer a framework for objective, longitudinal wound monitoring to support clinical decision-making.

Results

The CNN-based wound segmentation model achieved an F1-score of 0.83 and an Intersection over Union (IoU) of 0.72, demonstrating reliable automated delineation of wound boundaries and enabling accurate wound surface area measurements.

For tissue composition analysis, the Random Forest classifier achieved an overall classification accuracy of 0.97 across nine annotated tissue classes. The model enabled robust pixel-wise tissue characterization, providing quantitative assessment of healthy and pathological tissue proportions within the wound bed.

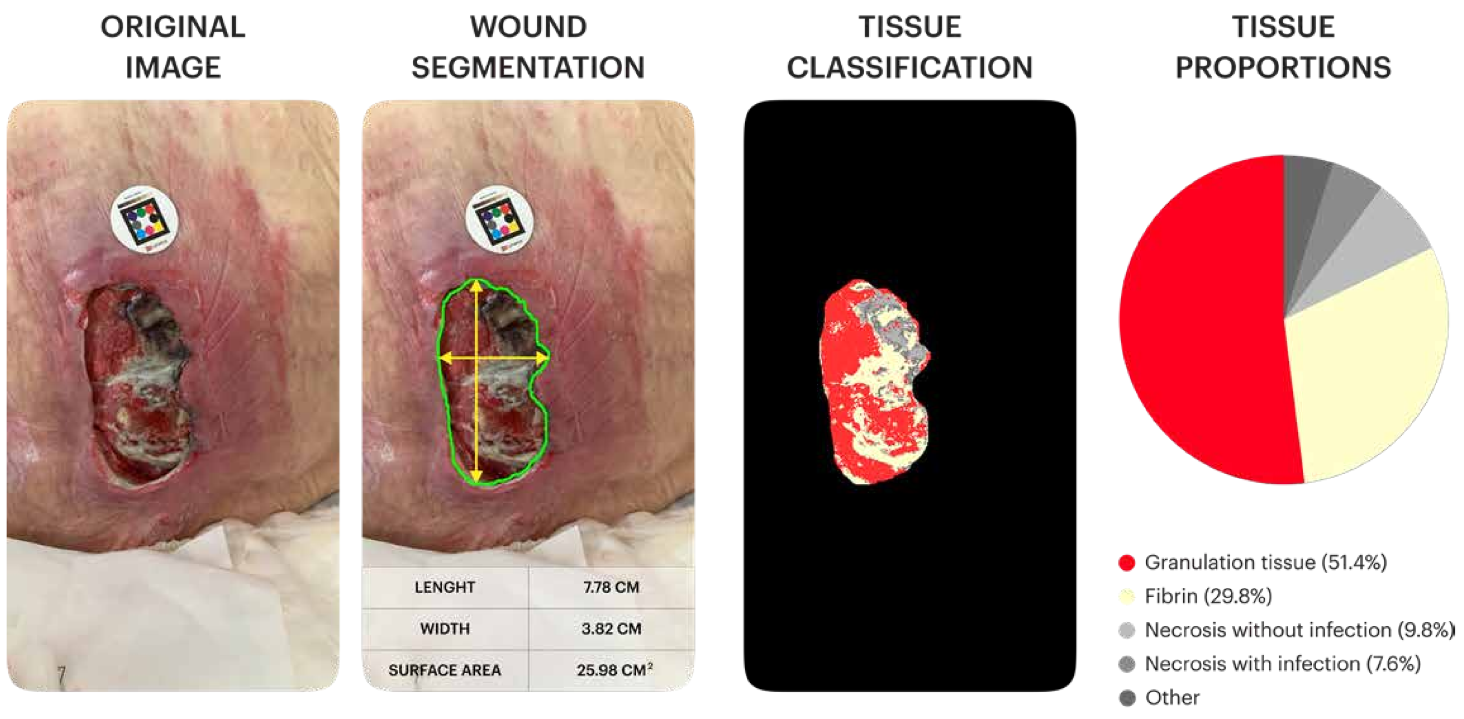


Figure 1: Automated wound segmentation and planimetric analysis followed by pixel-wise tissue classification of a representative wound image. The proportional diagram displays the relative coverage of tissue types occupying more than 1% of the wound area

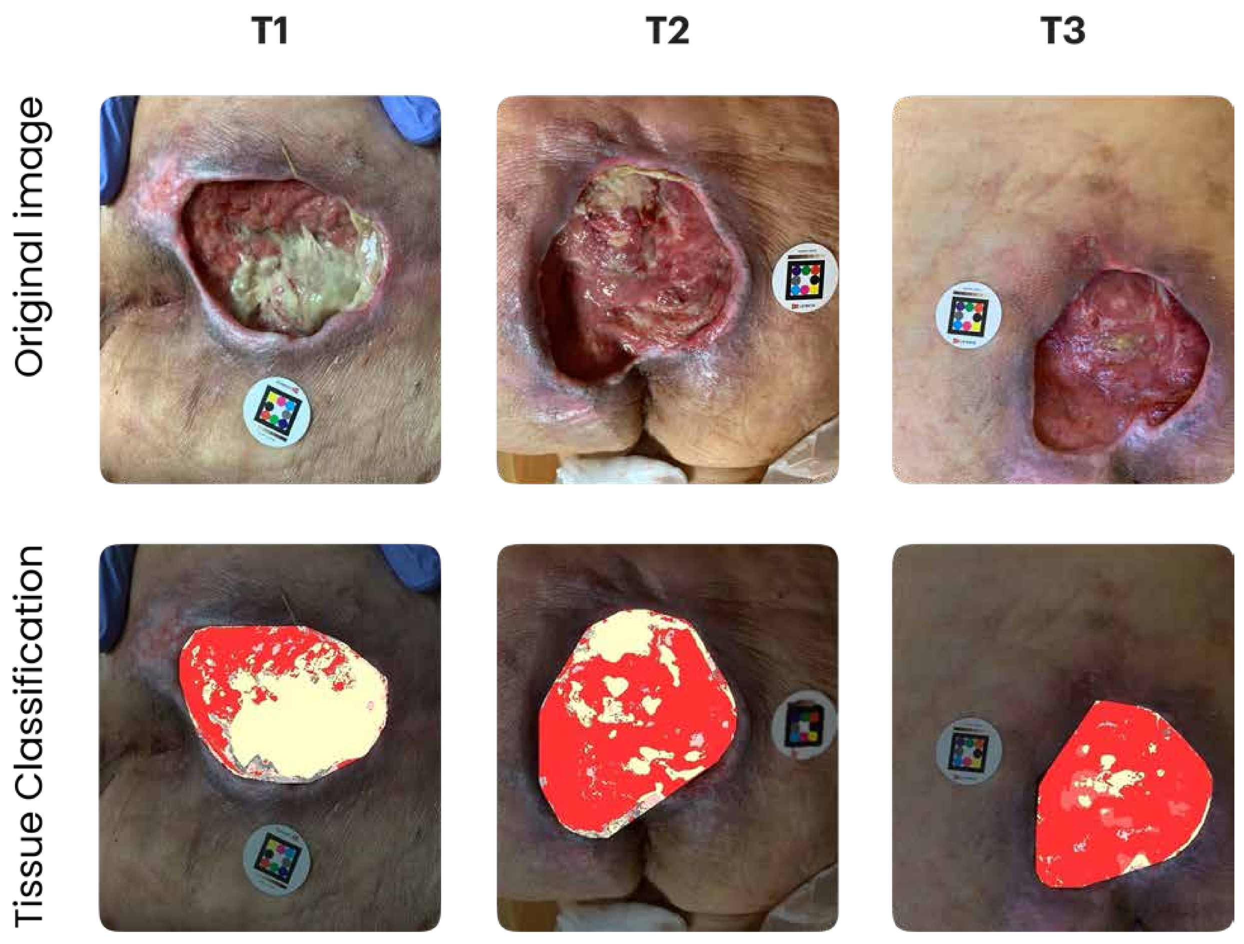


Figure 2: Sequential analysis of a representative wound across multiple treatment time points with automated wound segmentation and tissue composition analysis

Clinimetrically relevant wound assessment can be achieved from standardized smartphone-based image acquisition. By combining AI-assisted wound segmentation, tissue composition analysis, and calibrated 3D volumetric reconstruction, this approach unlocks the potential for scalable, objective, and longitudinal chronic wound monitoring in real-world clinical settings. This work lays the foundation for a comprehensive and accessible decision-support tool designed to standardize wound assessment, support clinical trial endpoints, and enhance evidence-based decision-making in routine wound care.

Intended use of the Scarletred® Vision system

Scarletred® Vision is a clinically validated and approved Software as a Medical Device (SaMD) platform for contactless monitoring and objective digital assessment of cutaneous drug effects, skin conditions, or changes in skin pigmentation. The Scarletred® Mobile App integrates the use of the Scarletred® Skin Patch, which serves as an internal reference and enables to standardize and automate the process of image documentation and measurement. The patented system is supplied online and used worldwide in pre-clinical and clinical phase I-IV studies in a broad range of indications and product biocompatibility testing.

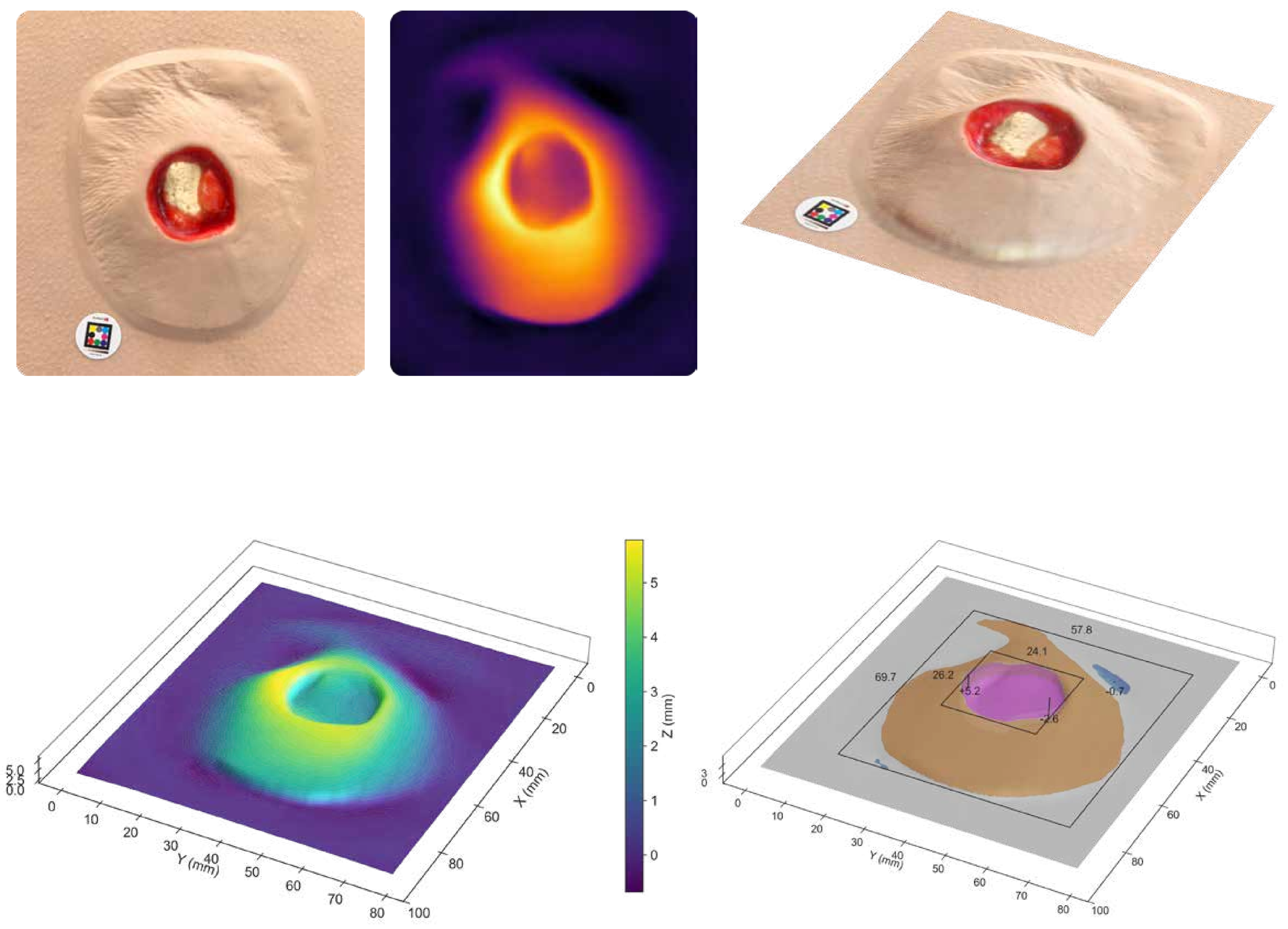
Materials and Methods

We used a dataset of 519 image and mask pairs, spanning several chronic wound etiologies: diabetic wounds, pressure ulcers, venous ulcerations, pyoderma gangrenosum, and epidermolysis bullosa. This range of wound types and acquisition settings reflects the variability of real-world clinical use. We preprocessed and augmented the images and explored both RGB and LAB color-space representations to identify the combination of channels that performed best for wound-area detection and for tissue classification.

We trained a convolutional neural network (CNN) architecture, a U-Net specifically, to delineate the wound boundary, separating the wound area from the surrounding healthy skin. For tissue classification, trained experts annotated a subset of 45 images across nine tissue types. We then extracted colorimetric descriptors, including the standardized erythema value (SEV) [2,3], together with textural descriptors, from superpixels to better capture local spatial variability. A random forest classifier trained on these descriptors assigned a tissue type to each superpixel within the detected wound area.

Wound Topography and Volume

Alongside the RGB images, the Scarletred® Vision app captures a depth map of the wound and the surrounding skin, which we reconstruct into a 3D mesh and correct for tilt. We then compute wound topography relative to the surrounding healthy skin, which serves as a reference plane that adapts to the body's curvature at the wound site. From this corrected surface, we derive maximum depth, elevation, and total volume in physical units, anchored by the Scarletred® reference patch.



Region	Volume (cm3)	Area (cm3)	Max depth / elevation (mm)
Periwound skin	6.6311	27.8779	27.8779
Wound	0.6330	4.5482	4.5482

Figure 3: Volumetric analysis of a wound and the surrounding periwound skin of a staging model. The RGB and depth map images (top left) are captured by the Scarletred® Vision app and processed into a 3D mesh (top right) used to obtain a topography maps displaying the elevation (bottom left) and volumetric features (bottom right)

System accuracy was characterised on calibrated gauge block phantoms: depth and height measurements matched the reference to within about a millimetre.

Key Takeaways

- Automated wound boundary detection allows for precise planimetric measurements from a single smartphone photo.
- Pixel-wise tissue classification reaches 97% accuracy across nine tissue types.
- Depth capture reconstructs 3D wound topography, adding elevation and volume to the assessment.
- The same pipeline tracks wound healing objectively across treatment timepoints.
- One capture contains three complementary measurements: 2D, 3D, and tissue composition, from a single smartphone image.

[1] Rodolfo Herman Lara e Silva and Alexei Manso Correa Machado. Automatic measurement of pressure ulcers using support vector machines and grabcut. Computer Methods and Programs in Biomedicine, 200:105867, 2021.
[2] Andreas Neubauer and Harald Schnidar. Methods for assessing erythema. European Patent EP2976013A1, 27 Jan 2016.
[3] Rahul Ranjan, Richard Partl, Ricarda Erhart, Nithin Kurup, and Harald Schnidar. The mathematics of erythema: development of machine learning models for artificial intelligence assisted measurement and severity scoring of radiation induced dermatitis. Computers in Biology and Medicine, 139:104952, 2021.

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