ORIGINAL RESEARCH

A Digital Assessment and Documentation Tool Evaluated for Daily Podiatric Wound Practice

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Abstract: *Introduction.* Foot ulcers are a common complication of diabetes. Regular screening of patients with ulcers enables better treatment and reduces the number of amputations. The lack of wound specialists, especially in nonurban areas, drove the development of an IT-based system for analyzing wounds, the Wound Healing Analyzing Tool (WHAT). Digital images are scored and documented using software that runs on a laptop computer. The aim of this study was to evaluate WHAT's use in daily podiatry practice. *Methods.* Eighteen ambulant patients presenting with diabetic foot ulcers at the participating podiatric clinic were recruited to the study. Digital ulcer images were obtained. To measure size and assess wound bed condition, the evaluated software recognizes the square mark, which is printed on a sticker and placed next to the ulcer. A trained, blinded physician assessed the same digital images and results were compared. *Results.* Fifteen of the 18 results obtained with the digital tool for ulcer area and wound bed condition were in line with the visual assessment conducted by the blinded physician. Eighty-seven percent of the images were correctly scored, with the main problem being a missing or partially visible square mark in the photograph (n = 3/18). *Conclusion.* The results indicate that WHAT showed sufficient accuracy to be considered for use in clinical settings for determination of wound area and wound bed characteristics. The tool also seems to be an attractive option for digital consulting.

With numbers exceeding 1 million in 2010, Australians with diabetes mellitus reflect a total of approximately 5% of the population and an even higher rate of 13% in Aboriginal and Torres Strait Islander communities.[1] These patients are 2 to 4 times more likely to develop cardiovascular disease with a less favorable prognosis. For the year 2000, coronary heart disease and stroke were listed as the underlying cause of death in 55.7% of Australians with diabetes.[2,3] In addition, nervous system damage affecting heart and blood vessels occurred in up to 60%-70% of individuals with diabetes.[4] In developed countries, diabetic foot problems have a high prevalence:[5] 19.4% of patients were found to be at risk of diabetic foot ulceration (DFU), and 2.1% reported amputations.[6,7] The burden on patients is significant because of suffering, long-lasting therapies, and dependence on nursing services.[5] Regular monitoring of the feet for early signs of diabetic neuropathy, peripheral vascular disease, and deformities is necessary to reduce the number of complications and amputations.[6,7] An important adjunct to reducing amputations is to have appropriate assessment methods for recognizing vascular disease[8,9] and comporting risk factors.

Digital Assessment and Documentation

Wound healing practice in Australia lacks specialists who are available for regular screening and follow up of DFU, and patients at risk for DFU. Due to logistic and economic constraints, only a small number of these patients are able to visit specialized podiatric care centers or wound healing clinics. In many areas of medicine, information and communications technology (ICT)-based diagnostics is established, yet accurate, digital wound assessment and documentation are rarely conducted.[10] Often, evaluation of the wound is limited to measurement with a ruler and a limited medical history and diagnostic documentation.[11-13] In some cases, a photo of the wound may be included in the medical history. Objective assessment of wound bed condition and evaluation of granulation, slough/fibrin, and necrosis are not performed.[18] A lack of correct information may lead to inadequate treatment, as shown in a study where both physicians and nurses failed to correctly identify wound bed condition and dimensions.[18] For accurate wound documentation and healing process assessment, the tissue composition of the wound bed has to be included. Based on histology, the following color modeling can be differentiated: granulation tissue appears in shades of red; slough/fibrin is yellow and dry; and necrotic tissue is dark or black. Infected necrosis shows shades of yellow and is soft. Other colors in the wound can include blue, which is due to topical medication, or green, due to bacterial overgrowth, (eg, Pseudomonas). The authors selected the Wound Healing Analyzing Tool (WHAT) Software (Vertriebs GmbH, Vienna, Austria), an ICT-based system, developed at the Medical University of Vienna.[15] WHAT has been successfully used as an assessment and digital documentation tool for clinical trial purposes[16,17] and for daily clinical practice.[15-17] The system has been tested in these settings where wound tracings and digital images were also assessed by a trained clinician to ensure accurate comparison. Furthermore, the tool is cost-effective with little or no extra costs for disposables or additional equipment needed. To address these issues, a study was designed to evaluate the digital analysis and documentation system for use in daily podiatric and DFU care practice.

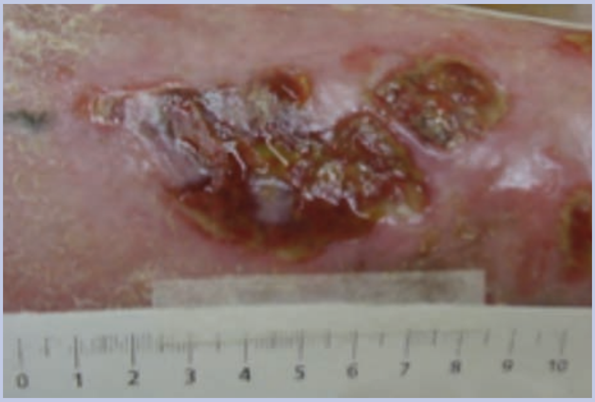
KEYPOINTS
- For accurate wound documentation and healing process assessment, the tissue composition of the wound bed has to be included.
- Based on histology, the following color modeling can be differentiated: granulation tissue appears in shades of red; slough/fibrin is yellow and dry; and necrotic tissue is dark or black.
- Infected necrosis shows shades of yellow and is soft. Other colors in the wound can include blue, which is due to topical medication, or green, due to bacterial overgrowth.

Materials and Methods

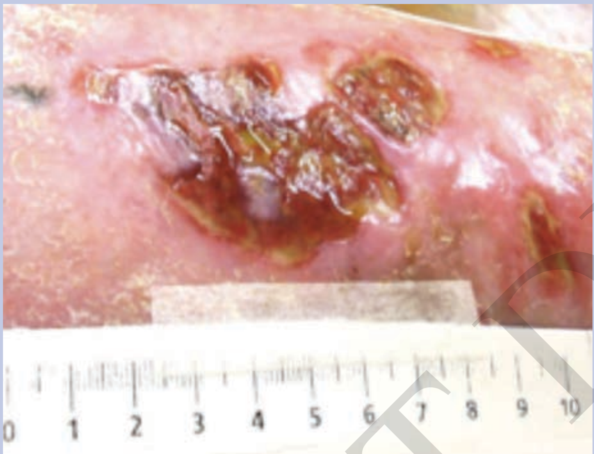
Eighteen patients with DFUs from the Allied Health Clinic (Podiatry Services), Albury, Australia, were included in the study. The analyzed images differed with respect to whether a low-grade infection, high-grade infection, or no infection was present. After patients had given written consent, digital images of their ulcers were obtained using a Pentax Optio camera at a resolution of 2 megapixels. The WHAT software ran on a Dell Latitude D630 laptop computer with an Intel Duo CPU T730 at 2GHz and 1.99 GB of RAM. Images and the pseudo-color output were also examined by a podiatrist blinded for the digital assessment, to ascertain the correctness of the digitalized analysis. A power analysis was performed to determine that the number of images analyzed represented an adequate sample size. The power analysis was based on the hypothesis that there is no difference between the images at a cut-off of $P = 0.05$. If there were a difference between the podiatric specialist's results and the WHAT results, it would easily be recognized. It was proposed that 8 images be required from the power analysis for this research.

Preprocessing. Before the wounds were analyzed by WHAT, the digital wound image had to be preprocessed. To evaluate the absolute size of a photographed wound in millimeters, the program semi automatically recognizes the square mark printed on the sticker that was placed next to the ulcer. The program performs a white balance correction and corrects the distortion of the image with help of a projection algorithm. The square mark borders detected by the program are used to calculate the position of the wound in space.

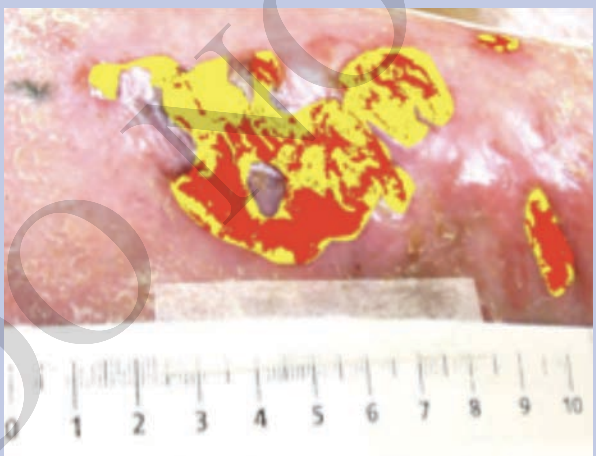
Segmentation. To proceed with the analysis, the



1a. Original Image



1b. Corrected Image



1c. Pseudo-color

Figure 1. Wound Healing Analyzing Tool (WHAT) image processing.

Table 1. Wound Healing Analyzing Tool (WHAT) analysis for a single image.

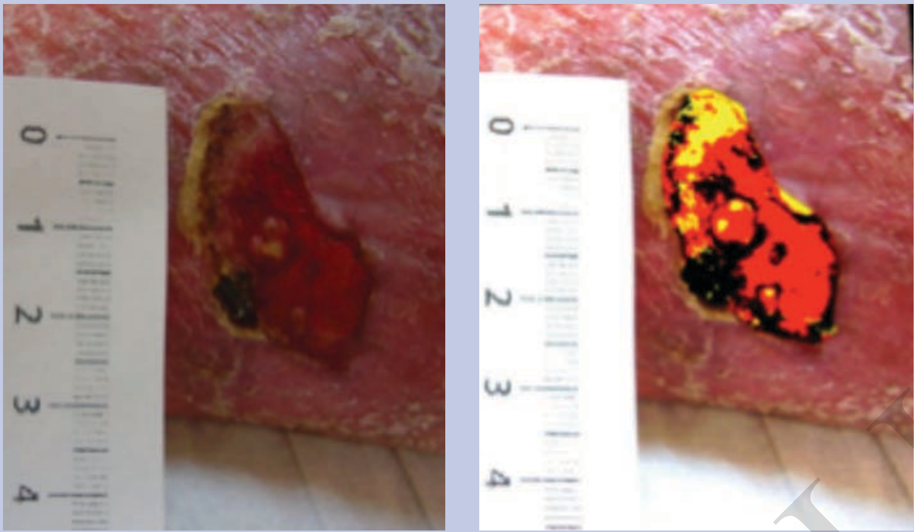
Analysis	Image (Figure 2)
Outline (mm)	83.5
Area (mm²)	363.83
Max. length (mm)	32.03
Max. width (mm)	20.12
Granulation (%)	48.33
Fibrin (%)	16.71
Necrosis (%)	34.96
Granulation (mm²)	175.83
Fibrin (mm²)	60.81
Necrosis (mm²)	127.19

wound border has to be marked using the computer mouse. Structures like bones and tendons can be manually excluded from processing if they are present within the ulcer. Existing epithelial areas can be unmarked and are not included in the analysis. The tool then automatically evaluates the horizontal and vertical diameter, area, and circumference of the wound. The size is displayed in mm^2 or square inches. Next, the automatic tissue evaluation is performed. Red is predefined as granulation tissue, yellow as slough or fibrin, and black as necrosis.

Data presentation. Results are presented as pseudo-color and as quantitative output including boundary length, area of total wound, and individual tissue types, as well as percentage of total wound bed covered by different tissue types.

Results

Fifteen of the 18 images were analyzed after 3 were identified as having suboptimal image quality. This was due to the placement of the calibration strip not being in line with the wound, leading to slanting of the images (Figure 1). Of these 3 images, the extent of the wound could not be correctly identified, and therefore, slough or granulation tissue was either underestimated or overestimated. The results obtained for wound area assessment



2a. Original Image **2b.** Pseudo-color

Figure 2. Example of a correctly classified digital image with respect to granulation, fibrin, and necrotic tissue.

Table 2. Averages of parameters measured for the 15 images.

Wound Characteristics	Average	Standard Deviation	Minimum	Maximum
Outline (mm)	82.76	60.51	13.91	259.95
Area (mm^2)	303.74	445.63	8.47	1832.2
Max. length (mm)	26.52	17.62	5.11	73.04
Max. width (mm)	17.64	15.52	3.88	68.81
Granular (%)	63.81	25.84	7.82	97.04
Fibrin (%)	27.86	20.68	1.07	68.36
Necrosis (%)	8.31	13.52	0	37.27
Granular (mm2)	214.92	380.05	6.77	1533.61
Fibrin (mm^2)	62.65	78.48	1.70	257.85
Necrosis (mm^2)	26.16	40.31	0	127.19

with the digital tool (n = 15/18) were in line with the visual assessment of the digital photographs, performed by a trained, blinded physician. The results further indicated 87% accuracy for identification of tissue types within the wound bed. An example of a correct analysis is given in Figure 2. The data of this case is shown in Table 1. The program only slightly misinterpreted 2 images (13%) in terms of percentage tissue type present, with 1 (6.5%) having an uneven wound depth and appearing "bubbly," leading to the fibrin percentage and granulation tissue being incorrectly quantified. The second image was slightly slanted with very dark granulation tissue and an undefined sloughy area, as heavily curved wounds are difficult to measure. The average of the total perimeter, total area, area of the 3 tissue types, and percentage of the wound bed covered by the tissue types is shown in Table 2.

Discussion

The results from the study indicated there is good agreement between the results obtained with the WHAT tool and the expert assessment. The wound images are representative of the type of wounds treated in podiatric practice, and therefore, when implemented correctly, the use of WHAT for assessment and documentation may enhance quality of assessment, treatment, and prevention. The results of the wound analysis using WHAT showed this tool can accurately indicate the wound area and amount of granulation, slough, and necrotic tissue present in the wound bed. WHAT also was able to accurately identify tissue with infection present. Podiatrists can base decisions on whether to refer patients to specialists on quantitative data, which can reduce the burden on specialists by identifying patients in need of a consultation. Therefore, these tools are useful for digital consultation. Although there are a variety of digital wound assessment systems available, no gold standard has been defined.[18] Moreover, measurements such as diameter or circumference of wounds are rarely routinely taken in medical practice, based on the authors' collective experience in hospitals and podiatry clinics. Although digital photographs are now included in patient reports, the diagnosis and future assessment remains an area requiring improvement.[10,11,18]

Several methods for determining wound size are currently in use, with vertical and horizontal diameter easily determined.12,14 The main method used in Australia is to overlay the wound with a plastic film and trace the wound border. The tracing is subsequently retraced on a digital tracing tablet that provides the area and circumference of the wound.[12-14] This method is time-consuming and rather expensive if bought from a medical supplier, as each film can only be used once.[13] In addition, the wound has to be covered by the film which may cause damage to new areas of granulation tissue when it is removed. There is also a possibility of transferring microorganisms to the calculating tablet.[13] Another innovative device, the digitizing tablet, combines a digital camera and structured lighting in the form of 2 laser beams to automatically correct for image scale and skin curvature.[19,21] The scanner was found to be accurate in clinical practice and trials in patients with various wound types. [19,21] However, it is more costly than the WHAT system. Although the scanner can be used on curved ulcer areas, the authors' have found it more suitable for use in clinical studies.[20] The WHAT tool does not require the clinician to touch the wound, and expedites the assessment process while improving accuracy.[18] Moreover, clinicians are often already used to taking digital photographs of ulcers; therefore, the only extras required are the stickers and software.

Keypoints

- The results of the wound analysis using WHAT showed this tool can accurately indicate the wound area and amount of granulation, slough, and necrotic tissue present in the wound bed. WHAT also was able to accurately identify tissue with infection present.
- The WHAT tool does not require the clinician to touch the wound, and expedites the assessment process while improving accuracy.[18]

Limitations

For effective use of the WHAT tool, clinicians should be instructed to use the specific sticker correctly. Heavily curved wounds are difficult to measure with the tool and should be assessed visually to enable accurate information. WHAT analysis is based on identifying and classifying specific colors in the image; therefore, care needs to be taken to differentiate, for instance, normal healing tissue from inflammatory tissue. This requires resetting the range of values defining normal healing tissue, and also incorporating clinical signs and symptoms such as presence of exudates, pain, and swelling. Possible pitfalls of color segmentation include fresh bleeding being mistaken for granulation tissue; fat necrosis, fascia, tendons, and bony structures identified as fibrin; and shadows in the wound or dried clots being classified as necrosis.

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- WHAT analysis is based on identifying and classifying specific colors in the image; therefore, care needs to be taken to differentiate, for instance, normal healing tissue from inflammatory tissue.
- Possible pitfalls of color segmentation include fresh bleeding being mistaken for granulation tissue; fat necrosis, fascia, tendons, and bony structures identified as fibrin; and shadows in the wound or dried clots being classified as necrosis.

Conclusion

Accurate and reliable wound measurement, as well as digital documentation, is an essential component of wound assessment and defining outcomes of clinical practice. The digital tool that was tested in this study showed positive accuracy. Apart from the software, no extra equipment is required. These factors make the WHAT tool an attractive option for daily podiatric practice.

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