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Attempt to Evaluate a Structure Sensor's Accuracy in Recording the Status of Venous Ulcers of the Lower Extremities

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This article attempts to assess the accuracy of a Structure Sensor — a low-precision 3D scanning device — to monitor the progression of venous leg ulcers. The study was conducted on 11 volunteers. Preliminary results indicate that this technology can be used as an effective tool in the ulcer diagnosis. Because the device is easy to use and its cost is low, it has the potential to enter everyday medical practice. Faster and simpler ways to perform diagnostics can help improve patients' quality of life and optimize treatment processes. This study opens up new perspectives on the use of low-precision 3D scanners in some areas of medicine.

topics: venous ulcers of lower extremities, chronic venous insufficiency, planimetry, ulcer measurement

1. Introduction

Venous leg ulcers (VLUs) are a chronic, recurrent condition and represent the most severe form of chronic venous insufficiency. Most VLUs are caused by impaired blood flow through the skin and subcutaneous tissue and usually arise in the medial ankle region [1]. Venous ulcers are one of the most difficult problems in modern medicine and there is a lack of uniform standards in their treatment. The choice of therapy depends on the particular center and the standards adopted for treating chronic wounds [2]. However, regardless of the therapy used, the undeniable fact remains that it is a long-term and very expensive treatment [3]. Regardless of the method of VLUs treatment, performing a thorough causal diagnosis and a local wound assessment is necessary at the outset. In evaluating the ulceration, the location of the wound, its extent and shape must be determined in detail. A key measurement is the area [cm^2] of the ulceration and the depth of tissue damage [cm] [4]. Once treatment is initiated, regular and detailed monitoring of the progress of healing every 2 weeks is mandated, and the measurements of wound area (cm^2) and ulcer depth [cm] and changes in the appearance of the wound are mentioned as some of the most important elements to be monitored [4]. In this situation, the diagnosis and treatment of ulcers, it is necessary to use methods and devices that allow for the collection of documentation and measurement. The ideal measurement method (device) should allow for reliable and reproducible results, be easy and quick to apply, and be affordable. Unfortunately, the location of ulcers on curved parts of the body and their irregular shape means that their measurement is not easy, and despite the availability of several methods and measuring devices, none of them meets the criteria of an "ideal" method set above. Therefore, it is important to continue searching for an effective measurement method for venous ulcers in this situation. Currently, new opportunities are brought by the development of new technologies and, with them, mobile devices. In recent years, a growing number of 3D scanners have appeared on the market at affordable prices, allowing the collection of information about the shape and color of the measured object. Most importantly, these devices are small and handy, which allows them to be easily used practically anywhere, simplifying work with patients, and the low price promotes their widespread use. In this category, the most popular devices are Microsoft Kinect version 1.0 and 2.0, Structure Sensor from Occipital, Xtion PRO from Asus, and F200, resulting from a collaboration between Intel and Creative. Although these are not professional scanners, devices of this type are successfully used in medicine, for example, for anthropometric measurements [5] or measurements of postural disorders [6]. However, no one has tried to use any of the devices mentioned earlier in the text for measurements in which the faithfully measured shape and collected texture reflecting reality are important.

This study aimed to evaluate the utility of an inexpensive 3D scanner in recording the condition of venous ulcers of the lower extremities. At the outset, it was assumed that the existing software available for the device would be used to scan the ulcers. In this way, we will be able to quickly assess the suitability of the scanner in the mentioned application in the first place, and if it turns out that it does not live up to expectations, the experience and data collected will provide answers as to why this is the case and what needs to be changed to make it possible.

The research is in accordance with the Declaration of Helsinki. All patients signed an informed consent to participate in this study and to have photographic documentation made.

2. Materials and methods

The study sample included 11 volunteers between the ages of 60 and 87, with a mean age of 73, who had venous ulcers of the shin. Thirteen ulcer sites were analyzed. All patients qualified for the study sample underwent a classic planimetric examination, where the ulcer was imaged on a planimetric film. The film was scanned at a resolution of 200 dpi, and then the resulting image, saved in the lossless TIFF format with Lempel–Ziv–Welch (LZW) compression, was analyzed using a dedicated script in MATLAB, the task of which was to determine the area of the area bounded by the ulcer outline. The obtained values constituted the subsequent analysis's baseline (ground truth).

During the same study, 3D data was collected with a Structure Sensor scanner (Occipital, Inc., USA) connected to an iPad Mini 3 using the Scanner-Structure Sensor Sample program from Occipital, Inc. The article by G. Guidi et al. [7], in which the authors analyze the systematic and random error of selected low-cost scanning devices, helped select the device. The accuracy of the device we chose is, to quote the manufacturer, "Precision: 0.5 mm at 0.4 m (0.15%), 30 mm at 3 m (1%)), it records, depending on whether it operates at VGA (640 × 480) or QVGA (320 × 240) resolution, 30 or 60 frames per second, respectively." The scanner's field of view is 58° horizontally and 45° vertically. The minimum recommended

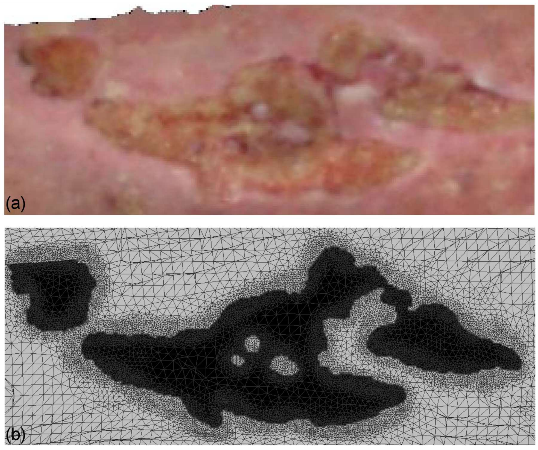

Fig. 1. Exemplary scanned image (a) texture before processing) and after processing overlaid on a locally dense triangle mesh (b).

working distance is 0.4 m, and the maximum value given by the manufacturer is not specified precisely and is slightly more than 3.5 m, as this depends on what is being scanned and under what lighting conditions.

The data that the device provides after scanning includes two independent files. The first contains the texture, represented by an image encoded in jpg format, while the second contains the triangle mesh information in obj format. When the data in this form is loaded in a graphics program, the texture is mapped to triangles to form a color 3D image. This form of data representation simplified further work, because it was possible to proceed to data analysis without converting the data or creating dedicated software. Since no software could automatically determine the area of ulceration based on the aforementioned data, it was processed using two free, open-source programs, namely GIMP [8] and Blender [9]. The algorithm of the procedure is as follows. First, an area of ulceration was pre-selected in GIMP using the Magic Wand tool. The resulting mask was modified manually to cover only the mentioned region. The selected area was painted black, and everything outside it was white. As a result of these actions, a time-and-white image was obtained, which became a new texture for the recorded data. The 3D data with the new texture was loaded into Blender, where the mesh was edited by thickening it within the ulceration. This made it possible to simplify the process of analyzing the data, as only whole triangles of the mesh, whose vertices (vertex) were assigned the color black, was taken for surface calculations, rather than parts of the triangles calculated based on the distribution of the texture on their surface. An example image of the texture and locally thickened mesh for one of the analyzed ulcers is shown in Fig. 1a and b. In addition, classic photographic documentation was performed using the Fotomedicus system (ELFO®, Poland).

3. Results and discussion

The results obtained during the work are summarized in Table I. The subsequent columns contain the measurement result obtained from planimetry (column named "PNM"), followed by the result from the scanner measurement (column named "S3D"), and the relative percentage difference (DF) between the results was calculated taking planimetry as a reference, thus

$$\mathrm{DF} = \frac{(\mathrm{S3D} - \mathrm{PNM})}{\mathrm{PNM}} \times 100\%. \qquad (1)$$

The absolute difference was omitted as the measured areas are of different sizes and the data obtained would be difficult to compare with each other.

The relative percentage difference was compared with the decimal logarithm counted for the area determined using planimetry expressed in mm^2 to see if the size of the area affects the difference (Fig. 2).

Analyzing the image in Fig. 2, it was noted that the application performs better with small ulcers, where there is no need to move the sensor around. This is probably due to the fact that the errors caused by the algorithm for merging compound texture images into a single entity are small here for this reason. Image merging algorithms don't do very well with images without many feature points to rely on in the calculations. Unfortunately, a small area also means a small area in the image that is a texture for the data and a high chance of marking points that do not belong to the ulceration, which can be a source of error.

TABLE I

The area of ulceration determined by planimetry (PNM) and using a 3D scanner (S3D) along with the relative percentage difference (DF) calculated from them and the decimal logarithm calculated for the PNM parameter ($\log_{10}$(PNM)).

PNM [mm^2]	$\log_{10}$(PNM)	S3D [mm^2]	DF [%]
875	2.94	1004	14.7%
19464	4.29	12476	35.9%
212	2.33	342	61.8%
346	2.54	510	47.5%
99	2.00	131	31.5%
230	2.36	144	37.4%
77	1.89	86	11.8%
392	2.59	437	11.6%
1092	3.04	1812	66.0%
48	1.68	86	79.7%
366	2.56	428	17.0%
2803	3.45	3544	26.5%
72	1.86	71	2.1%

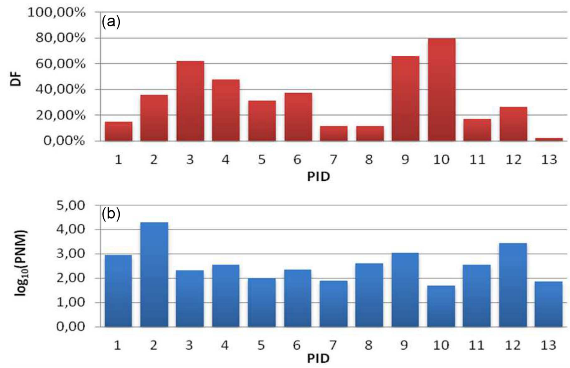

Fig. 2. Relative percentage difference between 3D scanner and planimetry measurements — DF (a), decimal logarithm of ulcer area calculated based on planimetry — $\log_{10}$(PNM) (b), PID is a patient sequence number.

TABLE II

Selected statistical parameters counted for the relative percentage difference between the results from 3D scanner measurement and planimetry with respect to the latter.

Parameter	Value
mean	34%
maximum	80%
median	31%
standard deviation	24%
variance	568%

A clear relationship between the relative percentage difference and the area calculated based on planimetry visually was not found, so it was checked analytically whether there was a correlation between them using the r-Pearson correlation. The obtained result indicates that no correlation confirms the previous observation. Therefore, it can be concluded that the relative percentage difference does not depend on the area of the ulceration.

Finally, for the relative percentage difference, selected statistical parameters were counted (see Table II). Here one can see a large maximum value of almost 80% and a very large variance amounting to a high variability of this parameter.

4. Conclusions

The results of the study indicate that using the 3D sensor to assess ulceration is a valuable alternative to previously used methods, i.e., planimetry. The distinguishing feature of the 3D sensor compared to other methods is primarily its ease of use and low price. However, given the relatively small number of patients and ulcers in the research sample, it would be important to continue the study on a larger sample. Besides, it is necessary to refine the software used by the 3D sensor, which will translate into the development of a standard for this procedure. We believe mobile devices equipped with appropriate software will increasingly be used in daily medical practice.

The patient group is sufficient to show that using the software available for the device, there is no way to collect data that would be reliable. The maximum difference in results was as high as 80%, the mean was 34%, and the variance, i.e., a measure of the variability of the observed data, was as high as 568%.

Since there are few scientific reports in this area, it is necessary to conduct research and develop software in a direction that would eliminate the disadvantages of the current solution.

References

[1] J.D. Raffetto, D. Ligi, R. Maniscalco, R.A. Khalil, F. Mannello, *J. Clin. Med.* **10**, 29 (2021).

[2] A.N. Geisler, N. Taylor, *Curr. Geriatr. Rep.* **9**, 219 (2020).

[3] L. Swanson, *Can. Med. Assoc. J.* **160**, 556 (1999).

[4] A. Jawień, M.T. Szewczyk, A. Kaszuba, Z. Gaciong, Z. Krasiński, J. Wroński, T. Grzela, T. Koblik, *Leczenie Ran* **8**, 59 (2011).

[5] C.A.A. Beaumont, P.G.M. Knoops, A. Borghi, N.U.O. Jeelani, M.J. Koudstaal, S. Schievano, D.J. Dunaway, N. Rodriguez-Florez, *J. Cranio-Maxillofac. Surg.* **45**, 921 (2017).

[6] O. Ciobanu, G. Ciobanu, A. Aiello, in: *CMBEBIH 2017*, Vol. 62, Ed. A. Badnjevic, Springer, Singapore 2017.

[7] G. Guidi, S. Gonizzi, L. Micoli, *Int. Arch. Photogramm. Remote Sensing Spatial Inform. Sci.* **XLI-B5**, 33 (2016).

[8] The GIMP team, GIMP — GNU Image Manipulation Program, 2024.

[9] Blender Foundation, The Blender project — Free and Open 3D Creation Software, 2024.