Original research | Оригинальное исследование
DOI: https://doi.org/10.35693/SIM643331

Comparative analysis of accuracy and time of calculation of wound surface area using mobile applications

Nikolai O. Mikhailov[1], Aleksandr A. Glukhov[1], Aleksandr A. Andreev[1], Anastasiya Yu. Laptieva[1], Oleg V. Sudakov[1], Vladimir Yu. Ivashkov[2], Aleksandr S. Denisenko[2]

[1]Voronezh State Medical University named after N.N. Burdenko (Voronezh, Russian Federation)
[2]Samara State Medical University (Samara, Russian Federation)

Abstract

Aim – to carry out a comparative assessment of the accuracy and time of calculating the area of the wound surface using mobile applications.

Material and methods. Wound areas were measured using mobile applications +WoundDesk, ImitoWound and V2F in four blocks of the study: schematic 2D image of soft tissue wounds (block I), volumetric (3D) models of wounds in fractures of the shoulder and leg (block II), experimental wounds in laboratory animals (block III) and assessment of combined wound defects upper and lower jaws in patients (IV block). In the first block, four groups were identified: the 1st group was measured by the area of schematic wounds on a flat surface; in the 2nd, 3rd and 4th groups, by the area of schematic wounds painted on cylindrical surfaces with a diameter of 7, 10 and 20 cm, imitating the surfaces of the forearm, shoulder and head, respectively.

Results. In block I, there is a direct relationship between the curvature of the examined wound surface and the accuracy of determining its area. In the second block, the measurements obtained using the ImitoWound mobile application turned out to be the most accurate, 96.22±3.41% and 97.80±2.37%. In the III block of the study conducted on laboratory rats of the Wistar line, the average deviation when using +WoundDesk was 90.84±7.51%, V2F – 88.96±9.52%, ImitoWound – 92.51±2.54%. In the IV block of the study, when analyzing the accuracy of determining the area of defects of superficial soft tissues in patients with facial defects, the ImitoWound mobile application and the Autoplan complex showed similar results.

Conclusion. Most wounds encountered in medical practice have a complex configuration that changes during treatment, changing from one form to another, which calls into question the expediency of using the presented mobile applications as the main method of conducting planimetric studies in medicine.

Keywords: wounds, wound area, planimetry, mobile applications, Autoplan, reconstruction of facial defects.

Conflict of interest: nothing to disclose.

Citation
Mikhailov NO, Glukhov AA, Andreev AA, Laptieva AYu, Sudakov OV, Ivashkov VYu, Denisenko AS. **Comparative analysis of accuracy and time of calculation of wound surface area using mobile applications.** *Science and Innovations in Medicine*. 2025;10(2):161-168. DOI: https://doi.org/10.35693/SIM643331

Information about authors
***Nikolai O. Mikhailov** – MD, assistant of the Department of General and Outpatient Surgery, Junior Researcher.
ORCID: 0000-0002-1710-205X
E-mail: n.o.mikhailov@yandex.ru
Aleksandr A. Glukhov – MD, Dr. Sci. (Medicine), Professor, Head of the Department of General and Outpatient Surgery.
ORCID: 0000-0001-9675-7611
E-mail: gs@vrngmu.ru
Aleksandr A. Andreev – MD, Dr. Sci. (Medicine), Professor of the Department of General and Outpatient Surgery, Senior Researcher.
ORCID: 0000-0001-8215-7519
E-mail: sugery@mail.ru
Anastasiya Yu. Laptieva – MD, Cand. Sci. (Medicine), Assistant of the Department of General and Outpatient Surgery.
ORCID: 0000-0002-3307-1425
E-mail: laptievaa@mail.ru
Oleg V. Sudakov – MD, Dr. Sci. (Medicine), Professor of the Department of Health Organization.
ORCID: 0000-0003-2677-2300
E-mail: sudakov_ol@mail.ru
Vladimir Yu. Ivashkov – MD, Cand. Sci. (Medicine), Chief Scientific Advisor of the NTI Center for Bionic Engineering in Medicine.
ORCID: 0000-0003-3872-7478
E-mail: v.yu.ivashkov@samsmu.ru
Aleksandr S. Denisenko – MD, Resident of the Department of Plastic Surgery.
ORCID: 0000-0002-6791-2237
E-mail: allexander.pafem@gmail.com
***Corresponding Author**

Received: 23.12.2024
Accepted: 24.02.2025
Published: 17.03.2025

Сравнительный анализ точности и времени расчета площади раневой поверхности с использованием мобильных приложений

Н.О. Михайлов[1], А.А. Глухов[1], А.А. Андреев[1], А.Ю. Лаптиёва[1], О.В. Судаков[1], В.Ю. Ивашков[2], А.С. Денисенко[2]

[1] ФГБОУ ВО «Воронежский государственный медицинский университет имени Н.Н. Бурденко» Минздрава России (Воронеж, Российская Федерация)
[2] ФГБОУ ВО «Самарский государственный медицинский университет» Минздрава России (Самара, Российская Федерация)

Аннотация

Цель – провести сравнительную оценку точности и времени расчета площади раневой поверхности с использованием мобильных приложений.

Материал и методы. Выполнено измерение площадей ран с использованием мобильных приложений +WoundDesk, ImitoWound и V2F в четырех сериях исследования. Серия I – схематическое 2D изображение ран мягких тканей. Серия II – объемные (3D) муляжи ран при переломе плеча и ноги. Серия III – экспериментальные раны у лабораторных животных. Серия IV – оценка комбинированных раневых дефектов верхней

и нижней челюстей у пациентов с помощью программного комплекса «Автоплан». В серии I выделили четыре группы: в первой группе проводили измерение площади схематических ран на плоской поверхности; во второй, третьей, четвертой группах измерялись схематические раны, нарисованные на цилиндрических поверхностях диаметром 7, 10 и 20 см, имитирующих поверхности предплечья, плеча и головы соответственно.
Результаты. В серии I прослеживается прямая связь между кривизной исследуемой раневой поверхности и точностью определения ее площади. В серии II наиболее точными оказались измерения, полученные с помощью мобильного приложения ImitoWound – 96,22±3,41% и 97,80±2,37%. В серии III исследования, проведенного на лабораторных крысах линии Wistar, среднее отклонение при использовании +WoundDesk составило 90,84±7,51%, V2F – 88,96±9,52%, ImitoWound – 92,51±2,54%. В серии IV исследования при анализе точности определения площади дефектов поверхностных мягких тканей у пациентов с дефектами лица мобильное приложение ImitoWound и комплекс «Автоплан» показали схожие результаты.
Выводы. Большинство ран, встречающихся во врачебной практике, имеют сложную, изменяемую в процессе лечения конфигурацию, переходящую из одной формы в другую, что ставит под сомнение целесообразность использования представленных мобильных приложений как основного метода проведения планиметрических исследований в медицине.
Ключевые слова: раны, площадь ран, планиметрия, мобильные приложения, «Автоплан», реконструкция дефектов лица.
Конфликт интересов: не заявлен.

Для цитирования:
Михайлов Н.О., Глухов А.А., Андреев А.А., Лаптиёва А.Ю., Судаков О.В., Ивашков В.Ю., Денисенко А.С. **Сравнительный анализ точности и времени расчета площади раневой поверхности с использованием мобильных приложений.** *Наука и инновации в медицине.* 2025;10(2):161-168.
DOI: https://doi.org/10.35693/SIM643331

Сведения об авторах
***Михайлов Николай Олегович** – ассистент кафедры общей и амбулаторной хирургии, младший научный сотрудник.
ORCID: 0000-0002-1710-205X
E-mail: n.o.mikhailov@yandex.ru
Глухов А.А. – д-р мед. наук, профессор, заведующий кафедрой общей и амбулаторной хирургии.
ORCID: 0000-0001-9675-7611
E-mail: gs@vrngmu.ru
Андреев А.А. – д-р мед. наук, профессор кафедры общей и амбулаторной хирургии, старший научный сотрудник.
ORCID: 0000-0001-8215-7519
E-mail: sugery@mail.ru
Лаптиёва А.Ю. – канд. мед. наук, ассистент кафедры общей и амбулаторной хирургии.
ORCID: 0000-0002-3307-1425
E-mail: laptievaa@mail.ru
Судаков О.В. – д-р мед. наук., профессор кафедры организации здравоохранения.
ORCID: 0000-0003-2677-2300
E-mail: sudakov_ol@mail.ru
Ивашков В.Ю. – канд. мед. наук, главный научный консультант Центра НТИ «Бионическая инженерия в медицине».
ORCID: 0000-0003-3872-7478
E-mail: v.yu.ivashkov@samsmu.ru
Денисенко А.С. – клинический ординатор кафедры пластической хирургии.
ORCID: 0000-0002-6791-2237
E-mail: allexander.pafem@gmail.com
Автор для переписки

Получено: 23.12.2024
Одобрено: 24.02.2025
Опубликовано: 17.03.2025

Список сокращений
СР – схематическая рана.

INTRODUCTION

Treatment of soft tissue wounds is one of the costliest items of surgical care worldwide that increases greatly in case of complications [1–3]. The cost of care of patients with this kind of pathology comprises expenses on medications, patient's stay in the hospital, treatment itself, medical manipulations, rehabilitation, etc. [4]. These facts, as well as high rate of incidence of onset of surgical site infections indicate a necessity of development of new methods of treatment of this condition.

Studies of effectiveness of various methods of treating soft tissue wounds increases the need for an objective assessment of the wound surface area and monitoring the dynamics of defect closure [5–6]. This data is necessary for clinical work, experimental and scientific practice. The calculation of the area of soft tissue defect makes it possible to calculate the amount of dressing material or medications needed to treat the wound surface, which may assist standardization of various surgical procedures or monitor economic efficiency of different methods of treatment [7–9]. Considering the difficulty of planning the reconstructive stage for patients with combined facial defects, this data can be used to calculate the required area of the flap skin paddle to repair defects of skin cover [10, 11]. Given the rapid development of modern technology, there are many IT approaches to the task that are gaining momentum: applications for mobile devices and computer programs including laser grids and three-dimensional scanning [12–16]. The mobile applications generate much interest: patients and doctors have mobile phones, which facilitates remote monitoring of regenerative processes of the wounds [17]. According to the website of the developer of the mobile application ImitoWound, their product is used in more than 30 clinics worldwide[1].

AIM

To carry out a comparative assessment of accuracy and time of calculating the area of the wound surface using mobile applications.

MATERIAL AND METHODS

We measured wound surface areas using mobile applications +WoundDesk, ImitoWound and V2F most frequently mentioned in scientific literature [18–22]. To calculate the area, a special target is required that is placed next to the wound, after which a photo is taken with the aid of the application (**Fig. 1**). In the +WoundDesk application, the target is a 2×2 cm black square on a white background with a centimeter scale on the sides; ImitoWound uses a target sized 1.5×1.5 cm; V2F uses a 1×1 cm white square within a 3×3 cm black square. After capturing the image, the user confirms the contours of the wound defect recognized automatically or makes manual adjustments. After this, the area is calculated, and the data is saved in the patient's profile or in the history of measurements depending on the functionality of the app.

[1] Available online: https://imito.io/en/references-and-partners#clinicalresearch

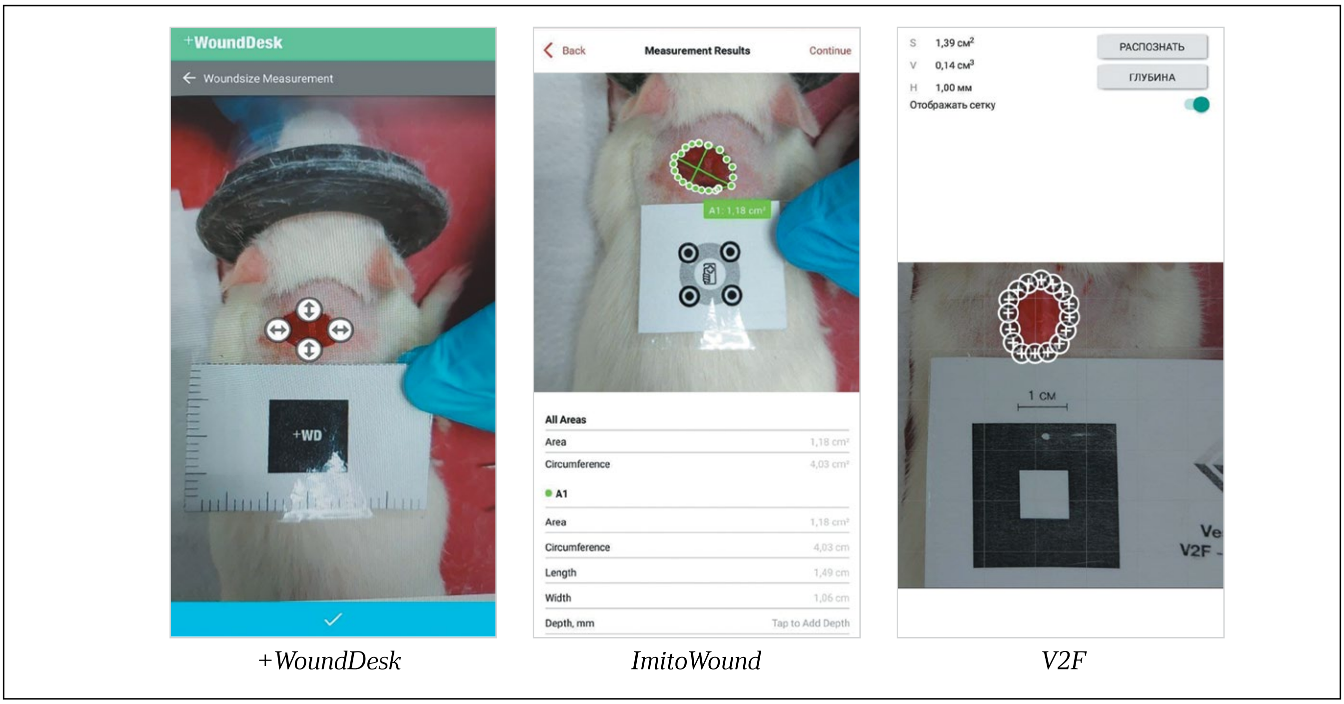

Figure 1. *Measurement of wound surface area using the mobile applications under inquiry.*
Рисунок 1. *Измерение площади раневой поверхности с использованием исследуемых мобильных приложений.*

The study did not include measurements of the depth and the volume of wounds due to the lack of such functions in the apps under inquiry.

When taking photos for subsequent processing with mobile apps, the same distance of 25 cm from the lens to the wound surface was observed, the same positioning of targets to determine scale relative to the wound surface, the defect contours were manually adjusted in all cases, and any foreign objects were removed from the frame. The photos were taken using the Google Pixel 7 mobile phone with Android 14 operating system. The main camera was 50+12 megapixels.

The study was performed in four blocks: schematic 2D image of soft tissue wounds (Block I), three-dimensional (3D) wound models of arm and leg fracture (Block II), experimental wounds in laboratory animals (Block III), and evaluation of combined wound defects of the maxilla and mandible of patients (Block IV).

Block I of the study was performed in four groups. In the first group, areas of wound schemes (WS) on flat surface were measured; in groups two, three and four, the WS were measured drawn on cylindrical surfaces with diameters of 7, 10 and 20 cm simulating the surfaces of the forearm, shoulder and head, respectively.

In each group, subgroups were made which studied the round, oval, square, rectangular, triangular and trapezoidal WS of soft tissues with known area drawn on paper.

The WS area was calculated using L.N. Popova's method, using the mobile apps +WoundDesk, ImitoWound, V2F. The obtained data were compared with the base area calculated using standard geometric equations: round, 12.5±0.003 cm^2, oval, 39.2±0.007 cm^2, square, 4.8±0.002 cm^2, rectangular, 12.3±0.004 cm^2, triangular, 13.7±0.006 cm^2, and trapezoidal, 14.9±0.004 cm^2.

Among the obtained areas of WS, the average area values were taken as 100% to be used as reference values;

Figure 2. *Models of arm fracture wounds and leg wounds used in the second series of the study.*
Рисунок 2. *Муляжи ран перелома плеча и раны на ноге, используемых во II серии исследования.*

after which measurements were performed using mobile apps.

Block II of the study was performed at the multidisciplinary accreditation and simulation center of the N.N. Burdenko Voronezh State Medical University. This block included models of wounds of shoulder fracture (Simulaids compound fracture humerus) and leg amputation wound for accident simulation kit, fragment (**Fig. 2**).

Block III of the study (experimental wounds in laboratory animals) was performed in the Experimental Biology and Medicine Research Institute of the N.N. Burdenko Voronezh State Medical University. For the purposes of the experiment, Wistar line rats were used. The experiment is an addition to the scientific research in various fields whose objectives did not include measurement of wound area; e.g. studies of wounds after laparotomy or thoracotomy access to allow main stages of surgeries. The length of laparotomy wounds was 9.7±1.4 cm, and the length of thoracotomy wound was 4.7±0.5 cm. After the linear incision was made, the edges of the wound were spread out, forming the wound contour of a complex arbitrary shape, and the obtained defect was measured using L.N. Popova's method, and then using the mobile apps.

Block IV of the study was performed in the Clinics of the Samara State medical University. It involved an analysis of precision of the apps under consideration in the measurement of defects of cover tissues of the head. The range of defects analyzed with the above mentioned apps and the "Autoplan" software suite included defects of the cover tissues of the head of post-traumatic and post-cancer treatment type, and defects of the skin due to post-surgery cicatrical deformations. Some defects had an end-to-end component that was not regarded due to the lack of the respective functionality of the programs. Intra-oral defects of the mucosa were not accounted. Clinical data of 100 patients with combined wound defects of the head were used, including post-cancer treatment (70) and post-traumatic (30) defects of the maxilla and the mandible.

The study is implemented in accordance with the plan of research work of the N.N. Burdenko Voronezh State Medical University within the complex topic "Vital Problems of Prevention and Treatment of Surgical Diseases" (State registration No. 121060700037-3) in compliance with the effective regulations of work with laboratory animals.

The method of L.N. Popova was chosen as the gold standard to evaluate the efficiency of using mobile apps in Blocks II, III and IV of the study due to the high precision of the former not depending on the curvature of the surface [23]. At first, measurements were taken using L.N. Popova's method, the results of which were taken as 100%, afterwards, the results obtained with mobile apps were compared. The measurement of the wound surface area by L.N. Popova's method included covering the wound with a transparent sterile millimeter-squared plastic sheet, making an outline of the defect, and manual calculation of its area [24–26].

Block IV of the study used the "Autoplan" software suite, since it is the base of a three-stage algorithm of performance if reconstructive plastic surgeries for patients with combined facial defects.

Statistic processing of obtained data. Methods of descriptive statistics with preliminary assessment of normality of distribution were used both for the accuracy of measurement of wound surfaces using the proposed methods, and for the time required to perform the study: graphical, numerical and quantitative tests (Kolmogorov-Smirnov, Shapiro-Wilk). Calculations were performed of the average value of the obtained results, mean root square deviation, standard error of mean within the studied groups. The first stage included one-way ANOVA. After the differences were identified, the Student's t-test was applied to identify significance of differences in the samples. The level of validity of obtained result difference was taken to be 5% ($p<0.05$).

The data processing was performed in the Statictica 10.0 and Microsoft Office Excel 2010 software suites.

The total number of measurements using all suggested methods was 4480 in the four blocks of the study: Block I, 960; Block II, 80; Block III, 1440; Block IV, 2000, respectively. Each wound defect was measured with the mobile apps under inquiry and with the L.N. Popova's method (Blocks II, III and IV). The obtained results are presented as percent ratios for the following reasons: in the course of the study, we were interested in the accuracy of measurement of the wound surface area with the suggested methods with respect to the original area and to the L.N. Popova's method, which is the most important factor from the standpoint of looking into the posiibility of using these apps in clinical practice. In Blocks III and IV, 3440 measurements were performed (190 unique wounds). The use of other methods would result is a significant increase of amount of results; the numerical expression of area measurements prevents their graphic interpretation.

RESULTS AND DISCUSSION

Group 1 of Block I of the study included measurements of WS of soft tissues on a flat surface using the methods under consideration (**Table 1**).

In the measurement of area of round and oval WS, the +WoundDesk app showed the highest accuracy as compared to other apps, 98.92±6.55% and 98.57±8.32% from the base area, respectively. In the calculation of area of square and rectangular WS, V2F and ImitoWound demonstrated accuracy above 95%. The use of +WoundDesk in the calculation of the area of triangular WS results in a significant overestimation of area, 158.78±4.71% from the base value. The V2F app shows the lowest accuracy, 70%, in the measurement of area of triangular and trapezoidal WS.

In the second group of the study, WS were placed on a cylinder with a diameter of 10 cm to simulate wounds of the shoulder (**Table 2**).

We see a decrease in accuracy in all of the apps used. At the same time, ImitoWound yielded the average accuracy value above 85% in all subgroups, the use of

WS Type	Mobile apps used to measure WS area		
	+WoundDesk	V2F	ImitoWound
Round	98.92±6.55 (p1=0.068) (p3=0.038) (p4=0.048)	72.05±15.34 (p1=0.024) (p2=0.038) (p4=0.045)	92.43±8.82 (p1=0.041) (p2=0.048) (p3=0.045)
Oval	98.57±8.32 (p1=0.071) (p3=0.032) (p4=0.041)	71.97±13.92 (p1=0.019) (p2=0.032) (p4=0.024)	92.5±9.41 (p1=0.034) (p2=0.041) (p3=0.024)
Square	79.25±5.17 (p1=0.045) (p3=0.028) (p4=0.031)	97.81±9.12 (p1=0.053) (p2=0.028) (p4=0.074)	96.25±6.47 (p1=0.026) (p2=0.031) (p3=0.074)
Rectangular	74.63±9.24 (p1=0.027) (p3=0.039) (p4=0.042)	96.49±5.94 (p1=0.038) (p2=0.039) (p4=0.055)	99.47±3.52 (p1=0.078) (p2=0.042) (p3=0.055)
Triangular	158.78±4.71 (p1=0.031) (p3=0.015) (p4=0.024)	66.9±15.64 (p1=0.022) (p2=0.015) (p4=0.026)	93.52±8.10 (p1=0.042) (p2=0.024) (p3=0.026)
Trapezoidal	101±4.61 (p1=0.043) (p3=0.019) (p4=0.045)	69.53±7.73 (p1=0.029) (p2=0.019) (p4=0.023)	92.48±13.75 (p1=0.019) (p2=0.045) (p2=0.023)

Notes: p^1 – significance of differences vs. L.N. Popova's method; p^2 – significance of differences vs. WoundDesk app; p^3 – significance of differences vs. V2F app; p^4 – significance of differences vs. ImitoWound app.

Table 1. *Accuracy of WS measurement on a flat surface in the 1st group of the 1st block of the study in relation to the initial area, %*

Таблица 1. *Точность измерения СР на плоской поверхности в 1-й группе I серии исследования по отношению к исходной площади, %*

+WoundDesk in the measurement of square and rectangular WS produces accuracy of 67.51% to 85.13%, and still gives overestimation of the area of triangular defects. V2F demonstrated the greatest mean square root deviation in all groups of the study, and accuracy above 85% was only obtained to square and rectangular WS.

In the third group, WS were placed on a cylinder with the diameter of 7 cm to simulate wounds of the forearm (**Table 3**).

With a further decrease in the diameter of the cylindrical surface and an increase in the curvature of the object, the measurement accuracy of the proposed methods continues to decrease. The greatest accuracy in the measurement of WS area is still shown by +WoundDesk for round, oval and trapezoidal WS, V2F for square and rectangular WS, ImitoWound for all types, the average accuracy was 91.73±8.58%.

In the fourth group, WS were placed on a cylinder with the diameter of 20 cm, simulating the surface of the head (**Table 4**).

We observe an increase in the accuracy of measurement results in this group in comparison with the first and third groups of Block I of the study; this relates to a lower curvature of the object. In comparison with the third group, we see a minor increase in accuracy of the value in question. Therefore, there is a direct correlation between the curvature of the examined wound and the accuracy of measurement of its area. It follows from the obtained results that the ImitoWound app is the all-purpose tool to perform planimetry measurements of wound schemes thanks to its high accuracy, which is 92.81±6.52%, on average.

WS Type	Mobile apps used to measure WS area		
	+WoundDesk	V2F	ImitoWound
Round	97.21±8.44 (p1=0.059) (p3=0.039) (p4=0.047)	70.15±16.26 (p1=0.020) (p2=0.039) (p4=0.031)	90.17±13.55 (p1=0.018) (p2=0.047) (p3=0.031)
Oval	96.83±5.31 (p1=0.055) (p3=0.026) (p4=0.045)	69.34±26.81 (p1=0.024) (p2=0.026) (p4=0.036)	89.58±14.73 (p1=0.015) (p2=0.045) (p3=0.036)
Square	76.32±8.81 (p1=0.034) (p3=0.041) (p4=0.028)	93.34±9.48 (p1= 0.017) (p2=0.041) (p4=0.056)	97.32±5.63 (p1=0.027) (p2=0.028) (p3=0.056)
Rectangular	74.27±4.63 (p1=0.029) (p3=0.048) (p4=0.023)	89.77±7.29 (p1=0.023) (p2=0.048) (p4=0.054)	96.31±7.85 (p1=0.033) (p2=0.023) (p3=0.054)
Triangular	161.78±11.52 (p1=0.021) (p3=0.008) (p4=0.015)	64.53±28.25 (p1=0.028) (p2=0.008) (p4=0.039)	89.44±14.48 (p1=0.035) (p2=0.015) (p3=0.039)
Trapezoidal	103.00±4.17 (p1=0.045) (p3=0.012) (p4=0.019)	68.71±31.73 (p1=0.025) (p2=0.012) (p4=0.017)	87.58±5.83 (p1=0.038) (p2=0.019) (p3=0.017)

Notes: p^1 – significance of differences vs. L.N. Popova's method; p^2 – significance of differences vs. WoundDesk app; p^3 – significance of differences vs. V2F app; p^4 – significance of differences vs. ImitoWound app.

Table 2. *Accuracy of WS measurement on cylindrical surfaces with a diameter of 10 cm, simulating the surface of the shoulder, %*

Таблица 2. *Точность измерения СР на цилиндрических поверхностях диаметром 10 см, имитирующих поверхность плеча, %*

Block II of the study is performed on wound models of shoulder and leg fractures. Using L.N. Popova's method to measure the area of the soft tissue defects, we obtained the following measurement results 34.7±1.2 cm^2 and

WS Type	Mobile apps used to measure WS area		
	+WoundDesk	V2F	ImitoWound
Round	96.21±4.14 (p1=0.036) (p3=0.015) (p4=0.047)	70.15±19.48 (p1=0.024) (p2=0.015) (p4=0.033)	90.17±11.38 (p1=0.031) (p2=0.047) (p3=0.033)
Oval	97.14±5.48 (p1=0.047) (p3=0.011) (p4=0.042)	69.34±21.22 (p1=0.037) (p2=0.011) (p4=0.026)	89.58±8.29 (p1=0.022) (p2=0.042) (p3=0.026)
Square	76.32±4.51 (p1=0.029) (p3=0.022) (p4=0.044)	93.34±9.27 (p1=0.023) (p2=0.022) (p4=0.064)	97.32±7.15 (p1=0.026) (p2=0.044) (p3=0.064)
Rectangular	76.83±7.11 (p1=0.031) (p3=0.040) (p4=0.037)	89.77±8.35 (p1=0.042) (p2=0.040) (p4=0.039)	96.31±4.63 (p1=0.045) (p2=0.037) (p3=0.039)
Triangular	158.78±9.52 (p1=0.018) (p3=0.016) (p4=0.034)	64.53±24.51 (p1=0.041) (p2=0.016) (p4=0.025)	89.44±11.73 (p1=0.037) (p2=0.034) (p3=0.025)
Trapezoidal	103±6.18 (p1=0.045) (p3=0.019) (p4=0.045)	68.71±31.16 (p1=0.033) (p2=0.019) (p4=0.018)	87.58±8.30 (p1=0.043) (p2=0.045) (p3=0.018)

Notes: p^1 – significance of differences vs. L.N. Popova's method; p^2 – significance of differences vs. WoundDesk app; p^3 – significance of differences vs. V2F app; p^4 – significance of differences vs. ImitoWound app.

Table 3. *Accuracy of WS measurement on cylindrical surfaces with a diameter of 7 cm, simulating the surface of the forearm, %*

Таблица 3. *Точность измерения СР на цилиндрических поверхностях диаметром 7 см, имитирующих поверхность*

WS Type	Mobile apps used to measure WS area		
	+WoundDesk	V2F	ImitoWound
Round	96.47±4.59 (p1=0.065) (p3=0.023) (p4=0.047)	71.05±17.34 (p1=0.029) (p2=0.023) (p4=0.034)	91.55±9.19 (p1=0.038) (p2=0.047) (p3=0.034)
Oval	95.14±8.74 (p1=0.063) (p3=0.025) (p4=0.051)	70.72±21.44 (p1=0.027) (p2=0.025) (p4=0.031)	90.34±6.11 (p1=0.031) (p2=0.051) (p3=0.031)
Square	76.32±6.04 (p1=0.028) (p3=0.021) (p4=0.039)	95.78±7.15 (p1=0.081) (p2=0.021) (p4=0.054)	98.03±4.32 (p1=0.062) (p2=0.039) (p3=0.054)
Rectangular	74.83±7.41 (p1=0.021) (p3=0.028) (p4=0.033)	90.74±5.29 (p1=0.026) (p2=0.028) (p4=0.041)	98.61±3.24 (p1=0.059) (p2=0.033) (p3=0.041)
Triangular	158.78±5.12 (p1=0.016) (p3=0.014) (p4=0.042)	65.56±28.42 (p1=0.035) (p2=0.014) (p4=0.025)	90.76±9.01 (p1=0.027) (p2=0.042) (p3=0.025)
Trapezoidal	102.00±4.15 (p1=0.072) (p3=0.020) (p4=0.047)	69.97±31.13 (p1=0.038) (p2=0.020) (p4=0.039)	90.82±7.92 (p1=0.025) (p2=0.047) (p3=0.039)

Notes: p[1] – significance of differences vs. L.N. Popova's method; p[2] – significance of differences vs. WoundDesk app; p[3] – significance of differences vs. V2F app; p[4] – significance of differences vs. ImitoWound app.

Table 4. *Accuracy of WS measurement on a spherical surface with a diameter of 20 cm, simulating the surface of the head, %*

Таблица 4. *Точность измерения СР на сферической поверхности диаметром 20 см, имитирующих поверхность головы, %*

9.5±0.8 cm², respectively. After this, measurements were taken using other methods (**Table 5**).

In both models, the measurements taken with the ImitoWound app had the highest accuracy: 96.22±8.05% and 97.80±7.46%. +WoundDesk and V2F yielded the accuracy of 86.83±12.74% and 70.86±18.11% for the model of the shoulder fracture wound and 85.26±9.13% and 82.21±15.62% for the model of the leg wound, respectively.

In Block III of the study performed on Wistar line laboratory rats, the average deviation when using +WoundDesk was 90.84±9.48%, V2F, 88.96±13.41%, and ImitoWound, 92.51±6.94% (**Table 6**). Another important parameter was the time required to perform the measurements: the +WoundDesk app required the least time, because manual adjustment of outlines requires matching of a lower number of defect boundary to identify it.

In Block IV of the study, the following average deviations were registered in the analysis of accuracy of the measurement of the area of superficial defects of

Model type	L.N. Popova's method	Mobile apps used to measure WS area		
		+WoundDesk	V2F	Imito Wound
Wound in shoulder fracture	100%	86.83±12.74 (p1=0.039) (p3=0.045) (p4=0.041)	70.86±18.11 (p1=0.022) (p2=0.045) (p4=0.027)	96.22±8.05 (p1=0.061) (p2=0.041) (p1=0.027)
Leg wound	100%	85.26±9.13 (p1=0.042) (p3=0.057) (p4=0.044)	82.21±15.62 (p1=0.031) (p2=0.057) (p4=0.043)	97.80±7.46 (p1=0.065) (p2=0.044) (p3=0.043)

Notes: p[1] – significance of differences vs. L.N. Popova's method; p[2] – significance of differences vs. WoundDesk app; p[3] – significance of differences vs. V2F app; p[4] – significance of differences vs. ImitoWound app.

Table 5. *Accuracy of determining the area of wound models for shoulder and leg fractures, %*

Таблица 5. *Точность определения площадей муляжей ран при переломе плеча и на ноге, %*

facial soft tissue using the mobile apps and the "Autoplan" software suite: +WoundDesk, 89.86±10.31%, V2F, 86.56±18.94%, ImitoWound 91.34±9/52%, Autoplan, 91.48±10.14% (**Table 7**).

CONCLUSIONS

The results of measuring the area of wounds using the studied mobile applications in conditions close to ideal in terms of illumination, distance from the object and camera fixation, which is not always feasible in clinical conditions, often differ significantly from the actual sizes of defects and depend on their shape and degree of curvature of the surfaces.

In Block I of the study, the +WoundDesk app showed the lowest accuracy in the measurement of area of square, rectangular and triangular wound schemes; the V2F app showed low accuracy in round, oval, triangular and trapezoidal wound schemes. The most accurate average results in measurements of different wounds were produced in the ImitoWound app.

The analysis of accuracy of measurement of wound areas on models showed that the +WoundDesk app yielded better results than V2F, however, they reliably differ from the values obtained by the L.N. Popova's method, by 14.27±7.51% and 21.85±13.85% on average, respectively.

The most accurate app to measure wound area in laboratory animals was ImitoWound showing 92.51±5.93% from the values obtained by the L.N. Popova's method. The +WoundDesk and V2F apps measure the wound area with the accuracy of 90.84±12.77% and 88.96±15.36%, respectively.

	L.N. Popova's method	+WoundDesk	V2F	ImitoWound
Accuracy of mound area measurement, %	100%	90.84±9.48 (p1=0.041) (p3=0.066) (p4=0.053)	88.96±13.41 (p1=0.023) (p2=0.066) (p4=0.081)	92.51±6.94 (p1=0.021) (p2=0.053) (p3=0.081)
Time required for measurement, min	3.05 ±0.22	0.67 ±0.07	0.98 ±0.15	1.11 ±0.12

Notes: p[1] – significance of differences vs. L.N. Popova's method; p[2] – significance of differences vs. WoundDesk app; p[3] – significance of differences vs. V2F app; p[4] – significance of differences vs. ImitoWound app.

Table 6. *Accuracy and time of measuring wound areas using L.N. Popova's method and mobile applications in Wistar laboratory rats in the III block of the study, %*

Таблица 6. *Точность и время измерения площадей ран методом Л.Н. Поповой и с использованием мобильных приложений у лабораторных крыс линии Wistar в III серии исследования, %*

	L.N. Popova's method	+WoundDesk	V2F	ImitoWound	Autoplan
Defects of the maxilla and mandible	100%	89.86±10.31 (p1 = 0.025) (p3 = 0.062) (p4=0.054) (p5=0.081)	86.56±18.94 (p1 = 0.031) (p2 = 0.062) (p4 = 0.055) (p5 = 0.073)	91.34±9.52 (p1 = 0.029) (p2 = 0.054) (p3 = 0.055) (p5 = 0.063)	91.48±10.14 (p1 = 0.025) (p2 = 0.081) (p3 = 0.073) (p4 = 0.063)

Notes: p^1 – significance of differences vs. L.N. Popova's method;
p^2 – significance of differences vs. WoundDesk app;
p^3 – significance of differences vs. V2F app;
p^4 – significance of differences vs. ImitoWound app;
p^5 – significance of differences vs. Autoplan software suite..

Table 7. *Accuracy of determining the area of defects in superficial soft tissues in patients with facial defects using mobile applications and the Autoplan software, %*

Таблица 7. *Точность определения площади дефектов поверхностных мягких тканей у пациентов с дефектами лица с использованием мобильных приложений и программного комплекса «Автоплан», %*

It has been proven that most of the results we obtained differ significantly from the known initial area (Block I) and the area measured by the L.N. Popova's method (Blocks II, III and IV), which calls into question the appropriateness of using the presented mobile apps as the main method of conducting planimetric studies in medicine, since most wounds encountered in medical practice have a complex configuration that changes during treatment, changing from one shape to another.

In calculating the area of wound surfaces in patients with defects of the upper and lower jaws, the ImitoWound mobile app shows a similar result to the Autoplan software suite, however, the latter has significantly greater potential in planning and performing reconstructive plastic surgeries in patients with head defects, and therefore it can be recommended for use in assessing these defects.

Based on the conducted research, it is obvious that both the development of new methods or applications for calculating the area of the wound defect and the refinement of existing algorithms are required. A possible alternative to the studied mobile apps could be the laser grid and 3D scanning; however, these methods are complicated for use in practical healthcare, which leaves the L.N. Popova's method the main tool for planimetric studies.

ADDITIONAL INFORMATION	ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ
Study funding. The study was the authors' initiative without external funding.	***Источник финансирования.*** Работа выполнена по инициативе авторов без привлечения финансирования.
Conflict of interest. The authors declare that there are no obvious or potential conflicts of interest associated with the content of this article.	***Конфликт интересов.*** Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с содержанием настоящей статьи.
Compliance with Ethical Standards. The authors confirm that the rights of the people who participated in the study were respected, including obtaining informed consent.	***Соответствие нормам этики.*** Авторы подтверждают, что соблюдены права людей, принимавших участие в исследовании, включая получение информированного согласия.
Contribution of individual authors. Mikhailov N.O., Laptieva A.Yu., Denisenko A.S.: conducting of the research, writing of the text, preparation and analysis of literature. Glukhov A.A., Andreev A.A., Ivashkov V.Yu.: creation of research design, scientific editing. Sudakov O.V.: statistical data processing. All authors gave their final approval of the manuscript for submission, and agreed to be accountable for all aspects of the work, implying proper study and resolution of issues related to the accuracy or integrity of any part of the work.	***Участие авторов.*** Михайлов Н.О., Лаптиёва А.Ю., Денисенко А.С. – проведение исследования, написание текста, подготовка и анализ литературы. Глухов А.А., Андреев А.А., Ивашков В.Ю. – создание дизайна исследования, научное редактирование. Судаков О.В. – статистическая обработка данных. Все авторы одобрили финальную версию статьи перед публикацией, выразили согласие нести ответственность за все аспекты работы, подразумевающую надлежащее изучение и решение вопросов, связанных с точностью или добросовестностью любой части работы.

REFERENCES / ЛИТЕРАТУРА/

1. Lindholm C, Searle R. Wound management for the 21st century: combining effectiveness and efficiency. *Int Wound J*. 2016;13(2):5-15. DOI: 10.1111/iwj.12623

2. Nussbaum SR, Carter MJ, Fife CE, et al. An Economic Evaluation of the Impact, Cost, and Medicare Policy Implications of Chronic Nonhealing Wounds. *Value Health*. 2018;21(1):27-32. DOI: 10.1016/j.jval.2017.07.007

3. Tricco AC, Cogo E, Isaranuwatchai W, et al. A systematic review of cost-effectiveness analyses of complex wound interventions reveals optimal treatments for specific wound types. *BMC Med*. 2015;13:90. DOI: 10.1186/s12916-015-0326-3

4. Al-Gharibi KA, Sharstha S, Al-Faras MA. Cost-Effectiveness of Wound Care: A concept analysis. *Sultan Qaboos Univ Med J*. 2018;18(4):e433-e439. DOI: 10.18295/squmj.2018.18.04.002

5. Tan P, Basonbul RA, Lim J, et al. Performance of portable objective wound assessment tools: a systematic review. *J Wound Care*. 2023;32(2):74-82. DOI: 10.12968/jowc.2023.32.2.74

6. Foltynski P, Ladyzynski P, Ciechanowska A, et al. Wound Area Measurement with Digital Planimetry: Improved Accuracy and Precision with Calibration Based on 2 Rulers. *PLoS One*. 2015;10(8):e0134622. DOI: 10.1371/journal.pone.0134622

7. Flanagan M. Wound measurement: can it help us to monitor progression to healing? *J Wound Care*. 2003;12(5):189-94. DOI: 10.12968/jowc.2003.12.5.26493

8. Jørgensen LB, Sørensen JA, Jemec GB, et al. Methods to assess area and volume of wounds – a systematic review. *Int Wound J*. 2016;13(4):540-53. DOI: 10.1111/iwj.12472

9. Pavlovčič U, Diaci J, Možina J, et al. Wound perimeter, area, and volume measurement based on laser 3D and color acquisition. *Biomed Eng Online*. 2015;14:39. DOI: 10.1186/s12938-015-0031-7

10. Ivashkov VYu, Denisenko AS, Kolsanov AV, et al. Mandible reconstruction using the Autoplan software. *Plastic Surgery and Aesthetic Medicine*. 2024;(4-2):58-65. [Ивашков В.Ю., Денисенко А.С., Колсанов А.В., и др. Устранение дефектов нижней челюсти с применением программного комплекса «Автоплан». *Пластическая хирургия и эстетическая медицина*. 2024;(4-2):58-65]. DOI: 10.17116/plast.hirurgia202404258

11. Ivashkov VYu, Denisenko AS, Kolsanov AV, Verbo EV. An original method of nose reconstruction using an individualized titanium implant and a radial flap: a clinical case. *Issues of Reconstructive and Plastic Surgery*. 2024;27(3):93-99. [Ивашков В.Ю., Денисенко А.С., Колсанов А.В., Вербо Е.В. Оригинальный способ реконструкции наружного носа с применением индивидуального титанового импланта и лучевого лоскута: клинический случай. *Вопросы реконструктивной и пластической хирургии*. 2024;27(3):93-99]. DOI: 10.52581/1814-1471/90/08

12. Wu Y, Wu L, Yu M. The clinical value of intelligent wound measurement devices in patients with chronic wounds: A scoping review. *Int Wound J*. 2024;21(3):e14843. DOI: 10.1111/iwj.14843

13. Pena G, Kuang B, Szpak Z, et al. Evaluation of a Novel Three-Dimensional Wound Measurement Device for Assessment of Diabetic Foot Ulcers. *Adv Wound Care (New Rochelle)*. 2020;9(11):623-631. DOI: 10.1089/wound.2019.0965

14. Chan KS, Lo ZJ. Wound assessment, imaging and monitoring systems in diabetic foot ulcers: A systematic review. *Int Wound J*. 2020;17(6):1909-1923. DOI: 10.1111/iwj.13481

15. Darwin ES, Jaller JA, Hirt PA, et al. Comparison of 3-dimensional Wound Measurement With Laser-assisted and Hand Measurements: A Retrospective Chart Review. *Wound Manag Prev*. 2019;65(1):36-41. PMID: 30724748

16. Mamone V, Fonzo MD, Esposito N, et al. Monitoring Wound Healing With Contactless Measurements and Augmented Reality. *IEEE J Transl Eng Health Med*. 2020;8:2700412. DOI: 10.1109/JTEHM.2020.2983156

17. Dramburg S, Braune K, Schröder L, et al. Mobile Applikationen (Apps) zu Diagnosefindung und Therapiesteuerung in der Kinder- und Jugendmedizin: Chancen und Grenzen. *Monatsschr Kinderheilkd*. 2021;169(8):726-737. DOI: 10.1007/s00112-021-01233-6

18. Budnevsky AV, Tsvetikova LN, Andreev AA, et al. Experience of using the mobile application "+WOUNDDESK" to assess the dynamics of repair of experimental wounds. *Modeling, Optimization and Information Technology*. 2017; 1(16):1. (In Russ.). [Будневский А.В., Цветикова Л.Н., Андреев А.А., и др. Опыт применения мобильного приложения «+WOUNDDESK» для оценки динамики репарации экспериментальных ран. *Моделирование, оптимизация и информационные технологии*. 2017;1(16):1].

19. Vorontsov AV, Zaitseva EL, Tokmakova AYu, et al. Evaluation methods of wound size defect in diabetic foot syndrome. *Wounds and wound infections. The prof. B.M. Kostyuchenok journal*. 2018;5(1):28-35. [Воронцов А.В., Зайцева Е.Л., Токмакова А.Ю. Методы оценки размеров раневого дефекта при синдроме диабетической стопы. *Раны и раневые инфекции. Журнал имени проф. Б.М. Костючёнка*. 2018;5(1):28-35]. DOI: 10.25199/2408-9613-2018-5-1-28-33

20. Aarts P, van Huijstee JC, Ragamin A, et al. Validity and Reliability of Two Digital Wound Measurement Tools after Surgery in Patients with Hidradenitis Suppurativa. *Dermatology*. 2023;239(1):99-108. DOI: 10.1159/000525844

21. Vitsos A, Tsagarousianos C, Vergos O, et al. Efficacy of a Ceratothoa oestroides Olive Oil Extract in Patients With Chronic Ulcers: A Pilot Study. *Int J Low Extrem Wounds*. 2019;18(3):309-316. DOI: 10.1177/1534734619856143

22. Gluhov AA, Aralova MV. Clinical Efficiency of Various Debridement Methods of Venous Etiology Trophic Ulcers. *Novosti Khirurgii*. 2017;25(3):257-266. [Глухов А.А., Аралова М.В. Клиническая эффективность различных способов дебридмента трофических язв венозной этиологии. *Новости хирургии*. 2017;25(3):257-266]. DOI: 10.18484/2305-0047.2017.3.257

23. Bokov DA, Mikhailov NO. Comparative analysis of modern methods for measuring the area of the wound surface. *Youth Innovation Bulletin*. 2022;11(2):27-31. [Боков Д.А., Михайлов Н.О. Сравнительный анализ современных методик измерения площади раневой поверхности. *Молодежный инновационный вестник*. 2022;11(2):27-31].

24. Fedzianin SD. Autologous bone marrow aspirates in the treatment of extensive purulent wounds. *Bulletin of Pirogov National Medical & Surgical Center*. 2020;15(2):103-107. [Федянин С.Д. Аутологичные аспираты костного мозга в лечении обширных гнойных ран. *Вестник Национального медико-хирургического центра им. Н.И. Пирогова*. 2020;15(2):103-107]. DOI: 10.25881/BPNMSC.2020.92.91.018

25. Fedzianin SD, Buyanova SV.The method for stimulation of wound healing. *Vitebsk Medical Journal*. 2017;16(5):62-67. [Федянин С.Д., Буянова С.В. Способ стимуляции раневого заживления. *Вестник Витебского государственного медицинского университета*. 2017;16(5):62-67]. DOI: 10.22263/2312-4156.2017.5.62

26. Sharafutdinova IR, Mustafina ZZ, Gabitova AYa, Shaibakova AD. Innovative technologies in monitoring the rate of wound healing. *International Student Scientific Bulletin*. 2018;18(4):177-179. (In Russ.). [Шарафутдинова И.Р., Мустафина З.З., Габитова А.Я., Шайбакова А.Д. Инновационные технологии в мониторинге скорости заживления ран. *Международный студенческий научный вестник*. 2018;18(4):177-179]. URL: https://eduherald.ru/ru/article/view?id=18651