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Short Communication

Comparative assessment of smartphone-based digital planimetry for wound area measurement

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Abstract

Accurate wound area measurement is essential for effective wound care as it helps determine the progression of healing in patients. The aim of this study was to compare two wound area measurement techniques wound tracing (manual planimetry) and imitoMeasure (smartphone-based digital planimetry) with standard ImageJ-based digital image analysis in a rabbit wound healing study. The study involved 291 wounds categorized into small, intermediate, and large wounds. ImageJ was used as the reference method for comparisons. The intraclass correlation coefficient (ICC) was computed to assess the agreement and reliability between different wound measurement techniques. A mountain plot was used to assess the agreement between measurement methods, and a Bland-Altman plot was used to evaluate the agreement and concordance between measurement methods. The time required for analysis (processing time) was also compared. The study revealed that the imitoMeasure consistently demonstrated a greater level of agreement with ImageJ, especially in small and intermediate wounds. The ICC values indicated substantial agreement between ImageJ and imitoMeasure, with an exceptionally high ICC value for small wounds. Mountain plots revealed that the imitoMeasure had better agreement with ImageJ across all wound sizes. Bland-Altman plots further supported these findings, with wound tracing exhibiting wider limits of agreement and greater variability than imitoMeasure. ImitoMeasure consistently proved to be the quickest method across all wound sizes, whereas wound tracing required the longest processing time. These findings indicate that the imitoMeasure is a more reliable and consistent method for measuring the wound area, in particular for small and intermediate wounds.

Keywords: Wound area, wound healing, planimetry, digital planimetry, smartphone planimetry

Introduction

Wound management is a crucial aspect of healthcare, requiring accurate assessment and monitoring to guide treatment decisions [1]. Among the key parameters, wound area measurement is essential for evaluating healing progress and selecting appropriate interventions [1,2]. Traditionally, manual planimetry using transparent grid paper has been employed because of its simplicity and low cost. However, this method is prone to inter-observer variability, particularly for wounds with irregular shapes or depths, leading to potential inaccuracies [3].

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Similarly, ruler-based measurements can be time-consuming and imprecise, further limiting their clinical utility [2].

Digital planimetry, which uses digital imaging for surface area measurement, has emerged as a more reliable alternative [1,4,5]. With advancements in technology, smartphone-based digital planimetry has gained traction as a practical and accurate tool for wound assessment [4]. This method involves capturing wound images using a smartphone camera, with specialized software analyzing the images to calculate the wound dimensions [5]. The accuracy of this approach depends on factors such as image quality, wound morphology, and user expertise [5,6]. High-resolution, well-lit images taken from a standardized distance and angle are essential for precision [4]. Additionally, wounds with irregular contours may pose measurement challenges, necessitating careful image acquisition and software calibration [7]. Compared with conventional methods, smartphone-based digital planimetry offers several advantages. It is non-invasive, minimizes the risk of wound contamination, and provides rapid, reproducible measurements [1,4,8]. Its user-friendly interface allows for efficient implementation across various healthcare settings with minimal training, making it accessible to nurses, physicians, and wound care specialists [9]. Furthermore, it is cost-effective, reducing the need for specialized equipment and facilitating remote wound monitoring [8].

Several smartphone applications have been developed for wound measurement, but their accuracy, efficiency, and clinical utility vary significantly [5,10,11]. Smartphone-based wound measurement tools have the potential to rival traditional digital planimetry devices, with some even approaching the accuracy of 3D imaging systems [11,12]. While 3D imaging technologies offer a comprehensive view of wound topography and depth, they often require expensive equipment and technical expertise, limiting their widespread use in routine wound assessment [12]. In contrast, smartphone-based applications provide a balance of precision, affordability, and practicality, making them particularly valuable in resource-limited settings and large-scale studies.

The aim of this study was to compare smartphone-based digital planimetry using imitoMeasure (imito AG, Zurich, Switzerland) and manual planimetry technique with ImageJ-based digital image analysis (NIH, Bethesda, USA) for wound area measurement, assessing its accuracy and applicability in wound management. ImitoMeasure was selected for this study based on its validated accuracy, user-friendly interface, and ability to integrate seamlessly into digital health workflows [5,13-15].

Methods

Study design and setting

The present study was conducted as an additional objective of an experimental study conducted to evaluate the therapeutic potential of Pluronic F127 (PF127) hydrogel loaded with adipose-derived stromal vascular fraction (AdSVF), mesenchymal stem cells (AdMSCs), and conditioned media (AdMSC-CM) for wound healing in rabbits [16]. The experimental study was conducted on healthy adults (1–2 years) New Zealand white rabbits of both sexes (male: female ratio of 1:1). The study was conducted at the Division of Surgery, ICAR-IVRI, Izatnagar, Bareilly, Uttar Pradesh, India. The rabbits were procured from the Laboratory Animals Research (LAR) section, ICAR-IVRI, Izatnagar, Bareilly, Uttar Pradesh, India. The detailed study protocols and experimental conditions have been previously described in the published manuscript [16].

Sample size

R statistics (Package “ICC.Sample.Size,” version 1.0, function: calculateIccSampleSize) was used to calculate the sample size of the wounds, including the number of raters and measurements [17,18]. To assess concurrent validity, an intraclass correlation coefficient (ICC) was estimated at least 0.95 between the wound measurement tools, and the minimal sample size required was 49 wounds.

Animal acclimatization and housing

The rabbits were acclimatized for two weeks before the initiation of the study and maintained under uniform managerial conditions (12-hour light/dark cycle and constant temperature/humidity) throughout the study period. In addition, they were given access to a standard diet and *ad libitum* water for drinking [19]. All animal experiments were conducted according to the UK Animals (Scientific Procedures) Act, 1986, and associated guidelines, EU Directive 2010/63/EU for animal experiments [16].

Wound induction and treatments

The present study used a contraction-suppressed full-thickness wound model previously standardized in rabbits [16,19]. After inducing general anaesthesia, two full-thickness wounds (2×2 cm) were created on the posterior dorsal surface of each rabbit and treated according to the procedure described in Sharun *et al.* [16]. Immediately after creating full-thickness excision wounds, rabbits were randomly assigned to eight treatment groups, each comprising six animals. The initial four groups received intradermal injections of control medium, or adipose-derived stromal vascular fraction (AdSVF), or adipose-derived mesenchymal stem cells (AdMSC), or AdMSC-conditioned medium (CM). The remaining four groups were treated topically with pluronic F127 hydrogel, either alone or loaded with AdSVF, AdMSC, or AdMSC-CM. Intradermal treatments were administered using an 8-point injection technique, while hydrogel treatments were applied over the wound surface. All treatments were administered on days 0, 7, and 14. After treatment, the wounds were covered with a transparent adhesive dressing to prevent wound contraction. Additionally, owing to the loose skin of rabbits, the actual wound area exceeded the theoretical 4 cm^2 despite excising a 2×2 cm skin section.

Data collection

The wound area was measured on days 0, 7, 14, 21, and 28. The wound area was measured using three different methods: the wound tracing method (manual planimetry), smartphone-based digital planimetry (imitoMeasure; imito AG, Zurich, Switzerland), and digital planimetry using ImageJ (NIH, Bethesda, MD) software (**Figure 1**).

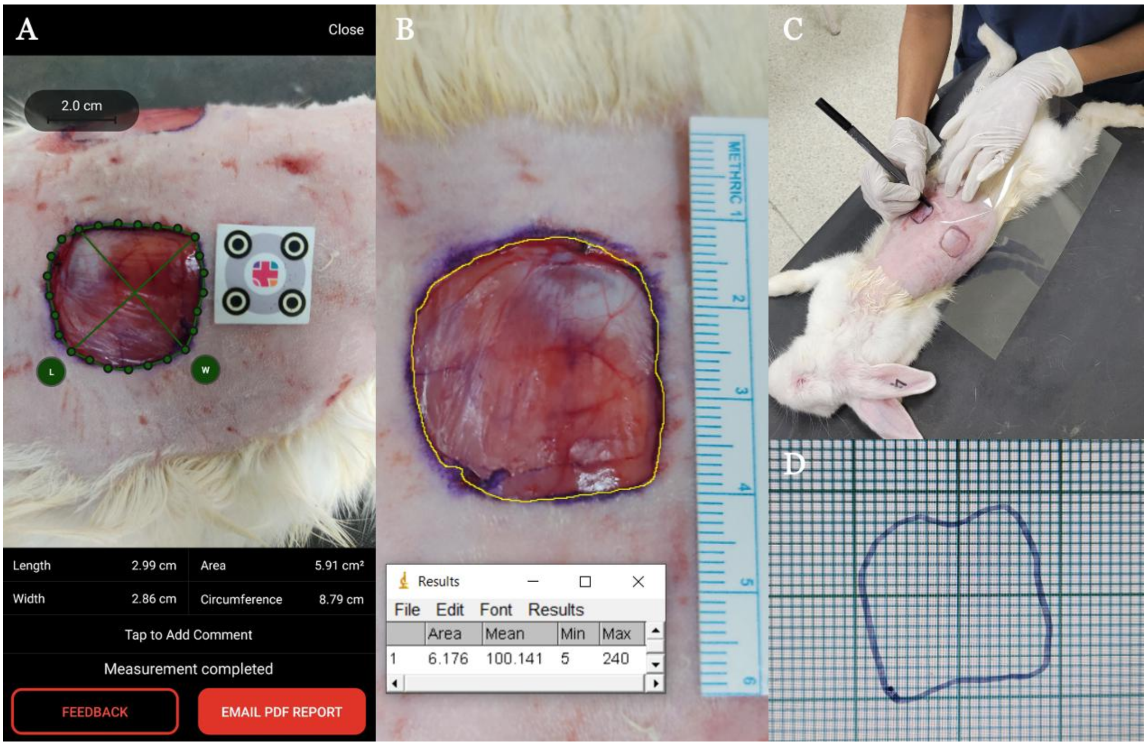

Figure 1. Wound area measurement using three different methods: (A) smartphone-based digital planimetry (imitoMeasure; imito AG, Zurich, Switzerland), (B) digital planimetry using ImageJ software (NIH, Bethesda, MD), and (C-D) the wound tracing method (manual planimetry).

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The first method, the wound tracing method, involved tracing the wound perimeter on a transparent sheet, which was then placed on graph paper to manually calculate the wound area by counting the enclosed squares. The second method, smartphone-based digital planimetry, utilized a mobile application to capture wound images with a reference marker placed adjacent to the wound [13,20,21]. The smartphone application imitoMeasure was downloaded from the Google Play Store and installed on an Android smartphone. The PDF-based calibration markers provided by the application developers were used for calibration. These markers were printed, carefully cut for single use, and disposed of after each measurement to maintain accuracy and hygiene. The calibration marker was placed adjacent to the wound to establish a reference scale during the measurement process. The imitoMeasure application automatically detected the marker, ensuring accurate spatial calibration. Once the marker was identified, the user captured an image of the wound through the application interface. The wound edges were then manually outlined on the touchscreen using the thumb, after which the app automatically calculated the wound area based on the reference marker. The third method, digital planimetry using ImageJ, involved capturing wound images with a smartphone camera while placing a scale bar adjacent to the wound for reference [5]. The wound edges were manually outlined using the freehand selection tool in ImageJ, and the wound area was measured using the scale bar as a reference for accurate calibration.

All the images were captured from a standardized distance under consistent lighting conditions to minimize zooming or focusing inconsistencies. This standardized workflow facilitated consistent and reproducible wound measurements across all samples. The wound area measured using ImageJ was considered the standard reference among the three methods. The accuracy of the other two methods was evaluated by comparing their measurements against this standard. To facilitate comparison, the wounds were categorized into three size groups based on the collected data: small wounds (<3 cm^2), intermediate wounds (3–6 cm^2), and large wounds (>6–9 cm^2). This classification was chosen only after completing the data collection, as it evenly divides the wound areas into three equal ranges, allowing for a systematic assessment of measurement variations across different wound sizes.

Processing time

In addition to measuring the wound area, the time taken to analyze the data and estimate the wound area using different methods was noted. The start and end points for different methods are as follows: (a) manual planimetry - from loading the transparent polyester sheet over the graph paper for area calculation to the manual calculation of wound area; (b) smartphone-based digital planimetry - from marking the wound borders to the generation of wound area in the smartphone; and (c) digital planimetry using ImageJ software - from setting the reference scale to the generation of wound area in the software. A single operator was responsible for data collection throughout the study to minimize operator bias and inconsistencies due to lack of experience.

Statistical analysis

The ICC was computed using R statistics Packages "ICC," "blandr," and "mountainplot" with a two-way random-effects model and a consistency score to assess agreement and reliability between wound measurement techniques [22]. ICC values with 95% confidence intervals (CIs) were calculated to compare ImageJ vs imitoMeasure and ImageJ vs wound tracing for each wound size category (small, intermediate, and large). To further evaluate the agreement between methods, the Bland-Altman plot, constructed with the "blandr" package, evaluated systematic bias, random differences, and limits of agreement between methods [23,24]. The mountain plot, generated using the "mountainplot" package, was employed to assess measurement agreement with ImageJ as the reference technique. The mountain plot provides a visual distributional comparison to further illustrate measurement concordance [25]. Additionally, Pearson's correlation coefficients were determined to examine linear relationships between wound area measurements obtained through different methods. The Kruskal-Wallis test, followed by Dunn's post hoc test with Bonferroni adjustment, was used to compare processing times among the three methods within each wound size category.

Results

Wound size classification

A total of 480 wounds were expected to be available for evaluation (two wounds each from 48 rabbits on days 0, 7, 14, 21, and 28) using the three measurement methods. However, due to the rapid and complete healing of some wounds following therapeutic interventions, fewer wounds were available (336 instead of 480 wounds) for evaluation, as some had fully healed before days 21 and 28 [16]. However, 45 wounds were excluded because of a change in the data collection operator, which could introduce bias. The treatment applied to each wound did not affect the wound area evaluation, as all three measurement methods were used on the same wound simultaneously, ensuring consistency in data collection. A total of 291 wounds were included in the study, with wound areas of less than 9 cm². Out of the 291 wounds evaluated, 108 were categorized as small, 114 as intermediate, and 69 as large.

Wound area measurement

For small wounds, wound tracing and imitoMeasure had similar mean wound areas (**Figure 2**), with tracing slightly higher (1.26±0.99 cm²) than imitoMeasure (1.25±0.94 cm²), while ImageJ provided slightly higher mean wound areas (1.28±0.94 cm²). For intermediate wounds, wound tracing had a slightly higher mean wound area (4.45±0.98 cm²), followed closely by imitoMeasure (4.41±0.95 cm²), with ImageJ having a slightly lower mean wound area (4.39±0.91 cm²). For large wounds, wound tracing had the lowest mean wound area (6.82±0.86 cm²), followed closely by ImageJ (7.01±0.76 cm²), while imitoMeasure had a slightly higher mean wound area (7.06±0.82 cm²).

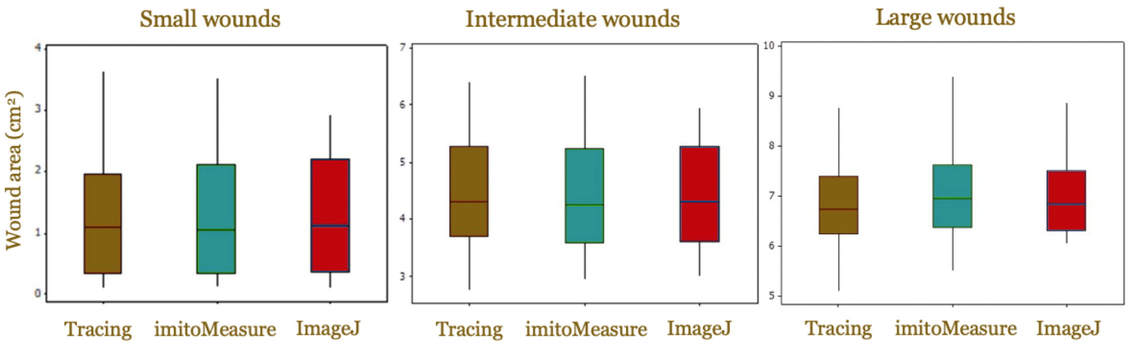

Figure 2. Average wound area (in cm²) for each wound area measurement technique under small, intermediate, and large wound classifications.

Processing time

Processing times for small wounds were longest with wound tracing (62.99±24.18 second (s)), followed by ImageJ (39.02±12.58 s), and shortest with imitoMeasure (16.93±0.87 s) (**Figure 3**). Wound tracing showed the highest variability, while imitoMeasure was the most consistent. Similar patterns were observed for intermediate wounds, with wound tracing (146.45±16.89 s) taking the longest, ImageJ requiring less time (65.59±7.68 s), and imitoMeasure remaining the quickest (20.05±1.67 s). For large wounds, the same trend persisted: wound tracing (213.70±33.05 s), ImageJ (96.49±15.09 s), and imitoMeasure (21.88±1.95 s). The Kruskal-Wallis test, followed by Dunn's post hoc test with Bonferroni adjustment, confirmed significant differences in processing times among and between the three methods for each wound size category (p<0.0001 for all comparisons). These results indicated that the method selected had a significant impact on processing time, regardless of wound size. Overall, imitoMeasure was consistently the fastest and most consistent method, while wound tracing was the slowest and most variable; ImageJ fell in between.

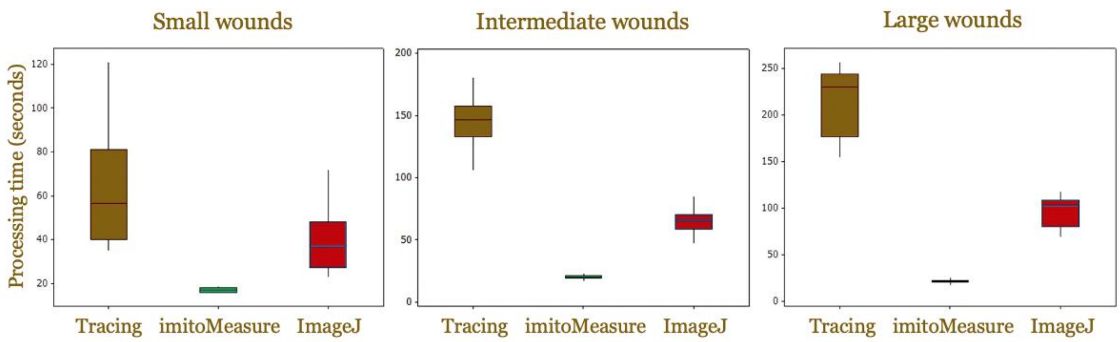

Figure 3. Comparative analysis of the processing time (in seconds) for each wound area measurement technique under small, intermediate, and large wound classifications.

Intraclass correlation coefficient (ICC)

A comparative assessment of wound area measurement methods across wound sizes was conducted using ICCs, with 95% CI presented in (**Table 1**). Overall, excellent agreement was observed between ImageJ and both imitoMeasure and wound tracing. For small wounds, high ICCs were obtained, with ImageJ vs imitoMeasure yielding 0.995. In intermediate wounds, strong agreement was maintained for ImageJ vs imitoMeasure (0.986), while a lower ICC was noted for wound tracing (0.938). For large wounds, reduced agreement was observed, although ICCs remained substantial (0.962 for ImageJ vs imitoMeasure and 0.837 for wound tracing).

Table 1. Intraclass correlation coefficients (ICC) and associated 95% confidence intervals for wound area measurements obtained through different methods for small, intermediate, large, and all wound categories

Comparison	Wounds (n)	ICC	95% confidence interval
Small wounds			
ImageJ vs imitoMeasure	108	0.995	0.994 to 0.997
ImageJ vs wound tracing	108	0.984	0.977 to 0.989
Intermediate wounds			
ImageJ vs imitoMeasure	114	0.986	0.980 to 0.990
ImageJ vs wound tracing	114	0.938	0.910 to 0.957
Large wounds			
ImageJ vs imitoMeasure	69	0.962	0.939 to 0.976
ImageJ vs wound tracing	69	0.837	0.737 to 0.899
Compiled wound data (all categories)			
ImageJ vs imitoMeasure	291	0.998	0.997 to 0.998
ImageJ vs wound tracing	291	0.991	0.989 to 0.993

Correlation coefficient

Correlation coefficients and associated statistical values for wound area measurements across methods and wound sizes are presented in (**Table 2**). For small wounds, an exceptionally high correlation was observed between ImageJ and imitoMeasure (r=0.991), and a strong correlation was also noted for ImageJ vs wound tracing (r=0.970), indicating near-perfect linear agreement. These findings confirmed that all three methods yielded highly consistent measurements for small wounds. For intermediate wounds, high correlation coefficients were also observed for both comparisons, although slightly lower than those for small wounds, suggesting substantial but slightly reduced agreement. In large wounds, the correlation between ImageJ and imitoMeasure remained strong, while a lower coefficient was observed for ImageJ vs wound tracing, indicating greater variability. Overall, strong correlations were maintained between ImageJ and imitoMeasure across all wound sizes, with the highest agreement in small wounds. Correlations with wound tracing were consistently positive but weaker, particularly in large wounds, reflecting reduced agreement. These findings reinforced the reliability of imitoMeasure in comparison to ImageJ.

Table 2. Correlation coefficients for wound area measurement comparisons across different wound size categories (small, intermediate, and large)

Comparison	Wounds (n)	Correlation coefficient	95% confidence interval	*p*-value
Small wounds				
ImageJ vs imitoMeasure	108	0.991	0.988 to 0.994	<0.001
ImageJ vs wound tracing	108	0.970	0.957 to 0.979	<0.0001
Intermediate wounds				
ImageJ vs imitoMeasure	114	0.974	0.962 to 0.982	<0.0001
ImageJ vs wound tracing	114	0.886	0.838 to 0.920	<0.0001
Large wounds				
ImageJ vs imitoMeasure	69	0.930	0.889 to 0.956	<0.0001
ImageJ vs wound tracing	69	0.726	0.591 to 0.821	<0.0001

Mountain plot/folded empirical cumulative distribution plot

A mountain plot, or folded empirical cumulative distribution plot, was used to assess agreement between measurement methods. This approach offered advantages such as clear identification of the central 95% of data and effective comparison of distributions. When centered at zero, the plot indicated no systematic bias between methods, while long tails reflected larger discrepancies. Mountain plot showing the agreement between two wound measurement methods (imitoMeasure and wound tracing) compared to ImageJ are presented in (**Figure 4**).

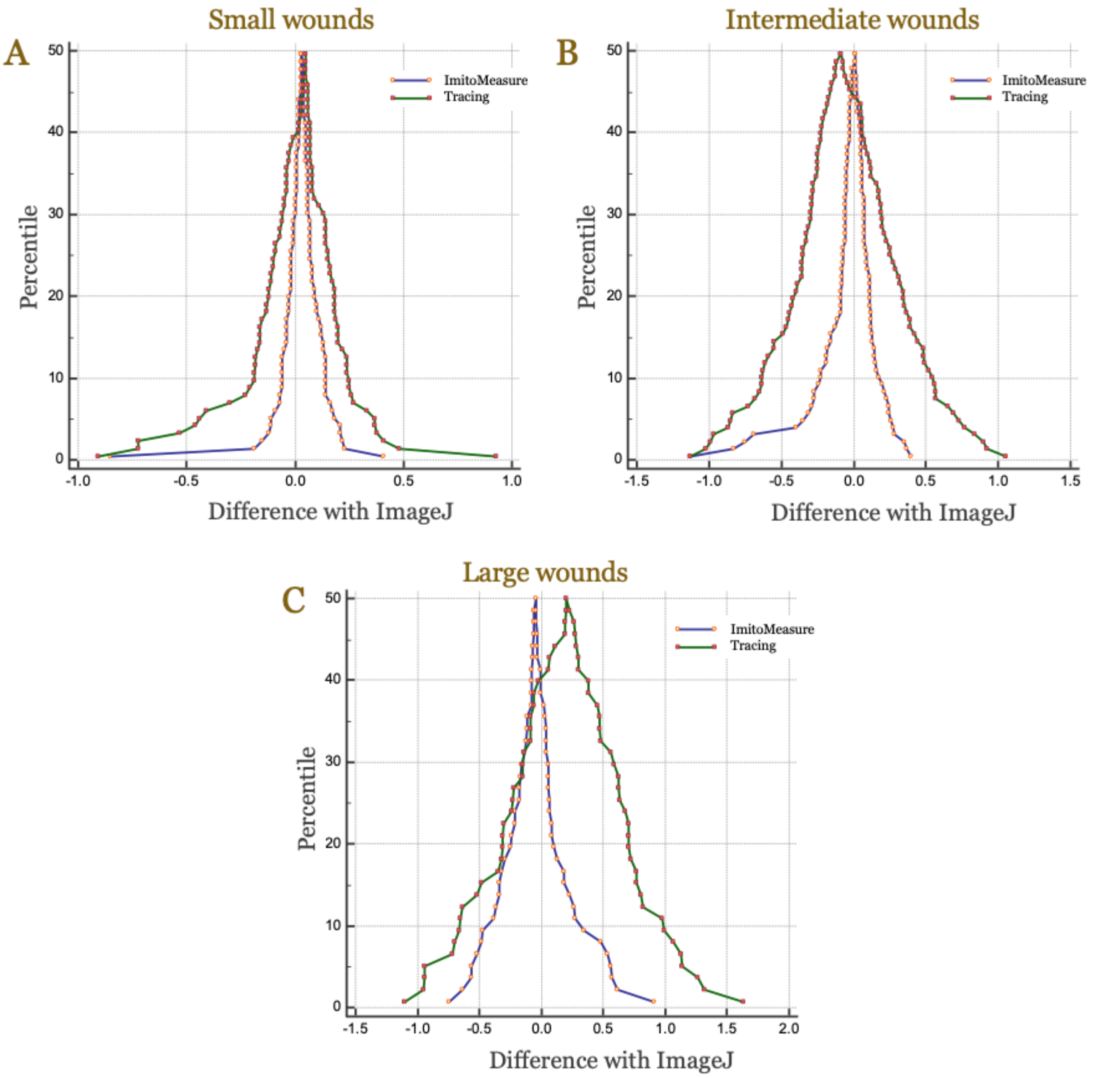

Figure 4. Mountain plot showing the agreement between two wound measurement methods (imitoMeasure and wound tracing) compared to ImageJ, serving as the reference standard for small (A), intermediate (B), and large wounds (C).

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Wound area measurements obtained by imitoMeasure and wound tracing were compared to ImageJ, which was used as the reference standard (**Figure 4**). For small wounds, the median differences were close to zero for both methods, though smaller differences were observed for imitoMeasure, indicating better agreement with ImageJ. For intermediate wounds, the median difference remained near zero for imitoMeasure but shifted for wound tracing, suggesting increased variability. In large wounds, imitoMeasure again showed median differences close to zero, while wound tracing demonstrated greater deviations (**Figure 4**). Overall, mountain plot analysis showed that imitoMeasure consistently provided closer agreement with ImageJ than wound tracing across all wound sizes. These results supported the greater reliability and consistency of imitoMeasure for wound area measurement.

Bland-Altman plot

Bland–Altman plot, also known as a Tukey mean-difference plot, was used to evaluate agreement between measurement methods. A mean difference near zero indicated minimal systematic bias, while even distribution of points around this line suggested random differences. The limits of agreement defined the range within which most differences lay; wider limits reflected greater variability. Bland–Altman plots comparing ImageJ vs imitoMeasure and ImageJ vs wound tracing for small, intermediate, and large wounds were presented in (**Figure 5**).

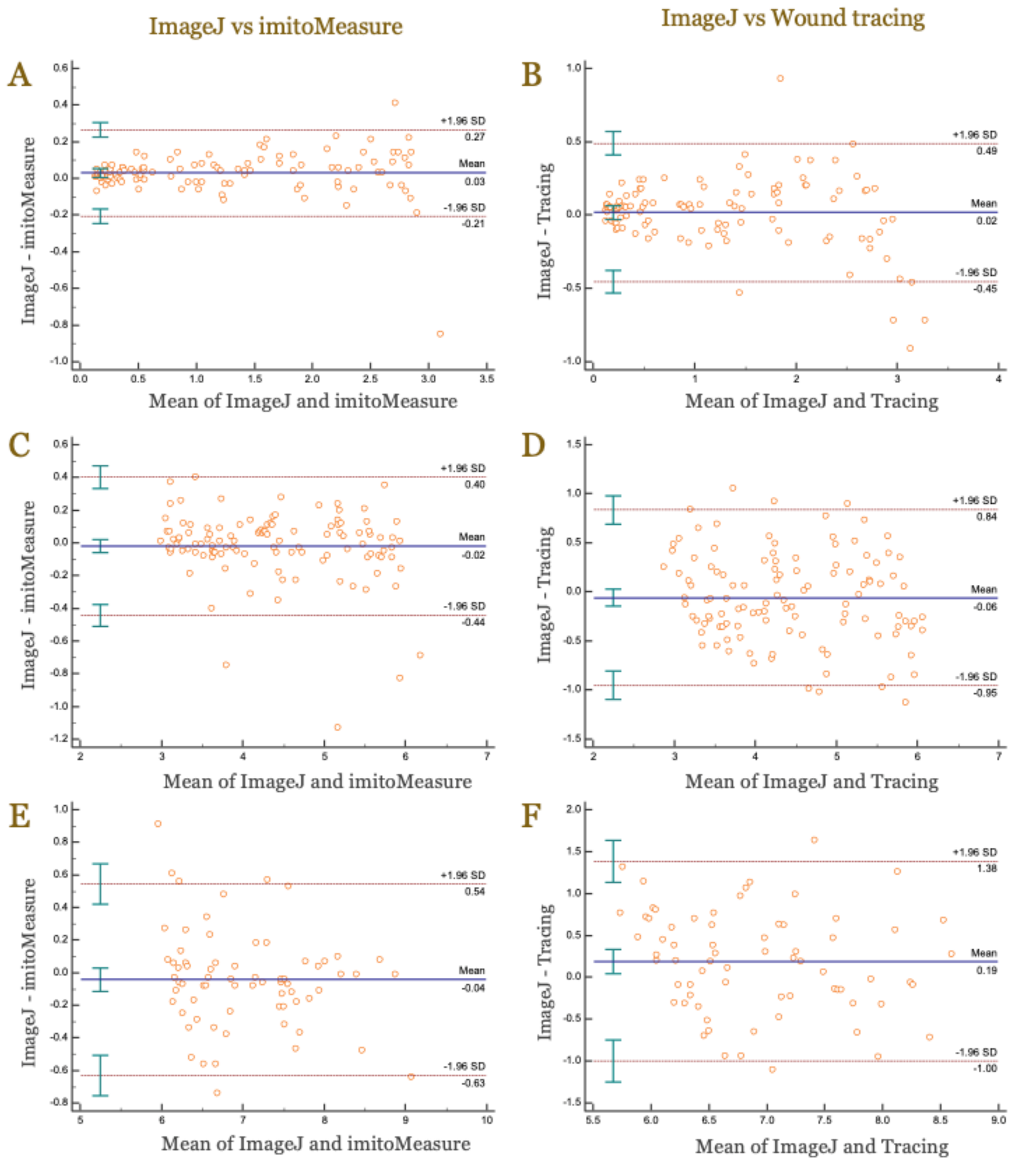

Figure 5. Bland-Altman plots for evaluating the agreement between two measurement methods to assess the concordance between ImageJ vs imitoMeasure and ImageJ vs wound tracing for small (A and B), intermediate (C and D), and large wounds (E and F).

Across all wound sizes, wider limits of agreement were observed for wound tracing, indicating greater variability and reduced agreement with ImageJ (**Figure 5**). In contrast, imitoMeasure consistently showed narrower limits and more uniform data distribution around the mean difference, suggesting better concordance with ImageJ. These findings confirmed that imitoMeasure exhibited stronger agreement with the reference method than wound tracing across all wound sizes. The reduced variability and tighter agreement range supported the use of imitoMeasure or ImageJ over wound tracing for wound area measurement.

Discussion

The rapid advancement of digital technology has introduced innovative tools for wound assessment, with smartphone-based digital planimetry emerging as a promising method for accurate and convenient wound area measurement [26]. This study comprehensively evaluated its efficacy and reliability compared to digital planimetry using ImageJ software. Smartphone-based digital planimetry offers several advantages over conventional wound measurement methods [27]. Notably, its streamlined workflow—from marking wound borders to generating measurements—significantly reduces data analysis time, making it particularly suitable for clinical settings [9,27]. Additionally, the portability of smartphones enhances accessibility, facilitating efficient wound assessments across diverse clinical contexts [27].

While smartphone-based digital planimetry has been extensively studied in human medicine [5,15,20,28,29], there is limited research on its application in wound healing in vivo studies [30]. This study provides the first detailed analysis of a smartphone app for wound area measurement in laboratory animal research. The ImitoMeasure app demonstrates significant potential in revolutionizing wound assessment by simplifying the evaluation of wound characteristics. The non-invasive nature minimizes animal discomfort, representing a notable improvement over conventional measurement techniques [30]. Furthermore, it offers the advantage of instant surface area data acquisition, eliminating the need for additional processing and calculations typically required in traditional methods [30].

Acetate tracing is a common wound area measurement method that has limitations, including prolonged processing time and hygiene concerns due to direct wound contact [26,28]. Previous studies have validated the reproducibility of the ImitoMeasure app for assessing pressure ulcers in human patients [28] and other wound types [5,15]. However, most of these studies were limited by small sample sizes, which affected their conclusions [15,20]. In contrast, our study assessed 291 wounds categorized into three subgroups for separate analyses: 108 small, 114 intermediate, and 69 large wounds. This classification allowed for a more comprehensive evaluation of the app's performance across different wound sizes.

Emerging 3D imaging technologies transform wound measurement by providing three-dimensional representations, offering advantages over traditional two-dimensional methods [20,31]. The inSight® 3D device captures detailed wound surface contours and dimensions, making it highly suitable for clinical research [20]. Studies suggest that while the inSight® 3D device is preferable for clinical research, imitoMeasure is more suitable for routine clinical practice [20]. Our findings indicate that the high accuracy and consistency of ImitoMeasure make it a viable alternative to ImageJ for in vivo wound healing studies.

ICC analysis was employed to compare wound area measurements obtained using different methods (ImageJ vs imitoMeasure and ImageJ vs wound tracing). Our findings revealed an exceptional ICC value of 0.998 for ImageJ vs ImitoMeasure in the compiled wound data, confirming that smartphone-based digital planimetry is highly accurate and comparable to ImageJ. While ImageJ and wound tracing also showed substantial agreement, manual tracing introduced greater variability, particularly for intermediate and large wounds, as reflected in lower ICC values. These results highlight the advantages of automated digital methods like ImageJ and ImitoMeasure in reducing measurement error and subjectivity.

The Bland-Altman plot provided valuable insights into the agreement between different wound measurement methods (ImageJ vs imitoMeasure and ImageJ vs wound tracing) used in the present study. The wider limits of agreement observed in the ImageJ vs wound tracing comparison indicate higher variability and lesser agreement between these methods across all wound size categories. In contrast, the narrower limits of agreement and even distribution of data points in the ImageJ vs imitoMeasure comparison suggest stronger agreement and more consistent measurements. These findings highlight the superior reliability of imitoMeasure over traditional wound tracing, reinforcing its suitability as a preferred method for wound area assessment. Given the observed variability in wound tracing, researchers and clinicians may benefit from adopting digital planimetry tools such as imitoMeasure to improve accuracy and reproducibility in wound measurement, particularly in research and clinical settings where precision is critical.

In addition, the significant differences in processing time among the three methods emphasize that the choice of analysis method can substantially impact wound analysis efficiency. Researchers and clinicians should consider accuracy and processing time when selecting an appropriate method, particularly in time-sensitive scenarios. This study demonstrated that smartphone-based digital planimetry provided measurements comparable to ImageJ-based digital planimetry. The consistency of results across different wound sizes underscores the reliability of this approach. Given the user-friendly interface of smartphone-based digital planimetry, its adoption in diverse clinical and research settings is feasible [13,32]. Its accessibility allows healthcare providers with varying levels of technical expertise to standardize wound assessments, ultimately improving patient care and clinical outcomes [32].

Our findings have significant implications for both research and clinical practice. The consistency and accuracy of ImitoMeasure suggest its suitability as a preferred method for wound assessment, particularly when evaluating wounds of different sizes. It can potentially enhance the reliability of wound analysis, leading to more informed treatment decisions. As demonstrated in this study, the time-saving benefits of smartphone-based planimetry hold significant potential for both large-scale animal studies and high-volume clinical settings. In veterinary research, rapid and consistent wound assessment could improve monitoring in experimental wound healing models. Similarly, smartphone-based tools could streamline workflow and enhance patient care in busy clinical wards, where healthcare providers must evaluate multiple wounds efficiently [27]. Further research is needed to evaluate the feasibility of integrating imitoMeasure into daily clinical practice and to assess its utility across diverse patient populations and wound types.

While imitoMeasure demonstrated efficiency and accuracy in wound area measurement, certain limitations should be acknowledged. Operator skills can influence measurement reliability, particularly in maintaining consistent camera angles and distances. Additionally, variations in smartphone camera quality, lighting conditions, and image resolution may introduce discrepancies, potentially affecting measurement precision [29,33]. Future studies should explore standardization protocols and user training programs to mitigate these variables and enhance reproducibility across different devices and clinical settings. Our findings align with previous studies validating smartphone-based wound measurement applications, reinforcing their accuracy and practicality [5,13,20,21]. However, more advanced 3D imaging systems offer additional advantages, such as capturing wound depth and topographical details, which remain the limitations of 2D planimetry [34,35]. Future comparative studies should evaluate the trade-offs between smartphone-based tools and 3D imaging technologies in different clinical and research scenarios to determine the most suitable applications for each method [35].

A limitation of this study is that only wounds on the dorsal aspect of rabbits were evaluated, meaning all wounds had uniform contours. Future research should explore the application of smartphone-based digital planimetry on wounds in different body locations to assess its overall utility. Additionally, further studies are required to evaluate the intra- and inter-rater reliability of smartphone-based digital planimetry to confirm its reproducibility across different users and settings.

Conclusion

Smartphone-based digital planimetry was more time-saving than manual wound area measurement, with a mean measurement time of less than one minute per wound. It is a reliable and accurate wound area measurement method similar to ImageJ-based digital image analysis. The smartphone-based digital planimetry, imitoMeasure, is a reliable and efficient alternative to traditional manual planimetry (wound tracing) for wound area measurement in animal wound healing research. Researchers can confidently use smartphone-based digital planimetry for consistent and accurate wound area assessments across various wound sizes. This technology's convenience and accessibility make it a valuable tool in advancing wound healing research. Further studies are required to validate its application in specific experimental conditions and wound types.

Ethics approval

All experimental protocols used in the study were approved by the Institutional Animal Ethics Committee (IAEC), ICAR-Indian Veterinary Research Institute, vide order No. 26-1/2022-23/JD(R)/IAEC.

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

Declaration of artificial intelligence use

We hereby confirm that no artificial intelligence (AI) tools or methodologies were utilized at any stage of this study, including during data collection, analysis, visualization, or manuscript preparation. All work presented in this study was conducted manually by the authors without the assistance of AI-based tools or systems.

How to cite

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