Comparing different ulcer measurement techniques: a pilot study

Brown D

Abstract

The aim of this pilot study was to compare interrater and intrarater reliability and to provide analysis of difference of common measurement tools used in podiatry. The tools used to measure the surface area in this study were ruler, tracings and photographic methods. Ten volunteers participated in the study. The surface area for the tracing was determined by counting the squares on graph paper and using a computerised program called UTHSCSA Image Tool program (version 2)[1]. The surface area for the two cameras was determined by using the UTHSCSA Image Tool program and the length and width measurements were calculated for the ruler method.

The one way ANOVA intraclass correlation coefficient ICC(1,1) indicated good reliability for both podiatrists with an ICC(1,1) >0.8. Wilcoxon signed rank test was used to compare tracing, counting of squares from tracing, ruler, digital camera and SLR camera. The p value for ruler measurements were statistically significant when compared to the other methods, while the comparison of the other methods was more varied. In addition, the ruler method had values that were consistently larger than all other methods. It was concluded that this study was unable to provide one statistically significant reliable measurement tool, therefore further investigations were required to strive for a gold standard in measurement techniques.

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Introduction

In a podiatry clinical setting, subjective and objective data are collected to evaluate the progress of ulcer healing. Subjectively, the clinician evaluates the ulcer's base colour, the presence of callus, granulation or epithelisation tissue, any odour and the amount of exudate. This information is usually documented in descriptive terms based on the clinician's perception and experience[2]. Objectively, the clinician evaluates the area and/or volume with a measurement tool.

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The measurement tool is one area that has created the most interest among clinicians, especially in the field of research. There appears to be no general consensus on which measurement tool provides the most valid and reliable data[3,4]. Plassman[5] stated that ulcers are three dimensional, dynamic structures and this causes problems when measuring them objectively. In addition, healing is often complicated by many variables and this can make achieving the ultimate outcome a long and frustrating process.

The measurement of foot ulcers or wounds is essential for podiatrists to evaluate or assess the effectiveness of dressings, debridement, pressure-relieving techniques and footwear modifications. Measurement techniques vary greatly and may range from rulers to newly developed sophisticated methods involving computer vision technology[4-6].

This article is focused on comparing the reliability and systematic differences of common objective measurement tools in regard to ulcer management in a clinical setting.

Literature review

Measurement techniques

Contact and non-contact measurement techniques are two ways of measuring wound or ulcers. Both measurement techniques are able to measure the area and volume of ulcers. The major problem with the contact technique is contamination and wound disturbance by the measuring device as it comes in contact with the wound [7-10]. Non-invasive or non-contact techniques are therefore becoming more popular due to the prevention of wound contamination and discomfort to patients [10]. Unfortunately, it has been argued that these techniques can be time consuming, expensive and not practical for a clinical setting [6]. Examples of the two different measurement techniques are summarised in Table 1.

Reliability of data

Haas [11] defined reliability as "a measure of concordance, consistency or repeatability of experimental outcomes". Reliability studies have been used to evaluate the effectiveness of a number of measurement tools. Table 2 summarises some intrarater and interrater reliability studies.

As seen from the studies, there is a variation of experimental designs and statistical analysis. Other studies were not included due to a more diverse design in producing reliability or comparison of techniques. Because of this diversity, it has been difficult to compare this study with other reliability studies. Even taking into account all diverse forms of recent studies, there still seems to be some confusion as to which tool provides the most accurate and reliable data such as a gold standard in measurement techniques.

Table 1. Examples of measurement tools.

Contact
Ruler (linear)-based
Wound gauge e.g. Kundin
Geometric shapes e.g. shape factor
Transparency film tracings
Saline method
Impression material e.g. alginate cast
Graduated swab stick
Non contact
Photography
Structured light techniques/MAVIS
Stereophotogrammetry
Laser triangulation
Alfred/Medseed Wound Imaging System (AMWIS)

Each measurement technique or tool has its own strengths and limitations for a variety of different reasons. It is acknowledged that both volume and surface area measurements are necessary to effectively evaluate the progress of wound healing. For simplicity of this study, only the surface area was used to evaluate wound measurement techniques in a podiatry clinical setting.

Methodology

Aim

The aim of the pilot study was to compare interrater and intrarater reliability and to provide analysis of difference of common measurement tools used in podiatry to measure foot ulcers.

In this study the tools used to measure the surface area were:

- Ruler-based assessment.
- Transparency tracings.
- Photographic methods.

Participants

A convenience sample of 11 subjects (n=11) who had a foot ulcer volunteered to be part of this study. The inclusion criteria basically included any subject with a foot ulcer or wound seen by The Queen Elizabeth Hospital (TQEH) podiatry out-patient department. The exclusion criteria involved the following:

- In-patients.
- Non-English speaking patients due to the need for the subject to understand and sign the consent form.
- Ulcers that were sinused, undermining, tracking or hypergranulated.

Approval

Approval was obtained from TQEH ethics committee. An inservice for the podiatrists was given prior to the study to ensure data collection time was kept to a minimum. All subjects involved in the study gave informed written consent prior to data collection. It was also made clear that non participation or withdrawal from the study would not prejudice any future treatments in the department.

Table 2. Summary of reliability studies.

Study	Measurement method	Analytical technique	Findings
Houghton & Kippen [3] pilot study	Linear measurements were used on a life size photograph of a venous ulcer. Six raters used a ruler to measure the photograph six times over a two day period	Analysis of variance	There was poor interrater and intrarater reliability using linear measurements
Brown-Etris, Pribble & LaBrecque [6]	Used a multi-centre, double-blind, parallel, randomised, placebo-controlled clinical trail. Wound size was determined prior to and during patient treatment using photography and the tracing method. They obtained the surface area from the two methods by using a digitising pad	Mean, median and analysis of variance	The mean, median and variance for both methods were similar and there was a high correlation coefficient between them. This concluded that the photo method (SLR camera) and the tracing method were accurate and reproducible
Thomas & Wysocki [7]	Compared the acetate, photo image and Kundin© method. Two measurements were taken of each ulcer	Pearson correlation and ANOVA	There was a high correlation among the measurements and each was significantly different from each other. It was concluded that all three methods can be used to measure wound area but, for more accuracy, tracings or photo images were recommended
Majeski [12]	Compared four methods of measuring wound area from transparency film. The methods were ruler, counting squares from graph paper, hand-held planimeter and digitiser. Three physical therapists made two tracings of each wound	One way ANOVA	Intrarater reliability (ICC=0.99) and interrater reliability (ICC=0.97-0.99) were high. This demonstrated good reliability of all methods. The study concluded that the graph paper technique was the preferred method due to cost and availability of equipment
Santamaria, Austin & Clayton [13]	Planimetric testing using digital photography was used to test AMWIS. This involved test re-test measurements in a laboratory setting and clinical measurements using standardised calibration procedures in a clinical setting	Measurement error rates and Pearson's product moment correlation coefficients	It was concluded that the AMWIS was a reliable and accurate system where the accuracy rate for laboratory testing was 98.72% and 94.9% for the clinical setting

Method

Callus was debrided from the surrounding border prior to taking measurements. For measurement purposes, callus debridement provides a clearer boundary between epithelium and granulating tissue [14], especially for plantar neuropathic ulcers or post-operative wounds. All ulcers were cleaned with normal saline to remove any residual exudate and to provide a clear vision of the border.

Sequentially, two podiatrists measured each ulcer by ruler and then traced it. The same two podiatrists repeated this procedure after a period of time and documented each result on a separate piece of paper. Another podiatrist took photographs using a digital camera and a single lens reflex (SLR) camera.

The same type of equipment was used for each subject. A sterilised metal ruler was used to measure the widest and longest dimensions of the ulcer. The surface area was determined by calculating the length and width of each ulcer (Ruler). A clear piece of acetate was used to trace the ulcer. This was placed over the ulcer and the outline was drawn by an indelible marking pen. The surface area for the tracing was determined by counting the squares on graph paper (Counting Squares) and using a computerised program called UTHSCSA *Image Tool* [1] (version 2) where the analysis is performed on a Gateway 2000 computer (Tracing). It is a program that uses selected shapes such as rectangular, polygonal or elliptical, to determine the surface area of other images. The tracings were scanned onto this program which calculated the surface area.

The digital camera was an Olympus® Camedia C-1400XL with software for the photos to be downloaded on to the computer. The SLR camera was a manual 35mm Nikon FM2 loaded with colour photo film and equipped with a built-in ring flash and reproduction ratio imprinting feature. This type of camera was able to achieve the precise framing of the ulcer, necessary for repetition at a later date and to enable accurate close-up views to be taken [15]. For both the digital and SLR camera a white calibrated ruler was placed beside each ulcer.

To determine the surface area, the photographs from the digital camera (Photo) were loaded onto the UTHSCSA Image Tool program. This was similar to the SLR camera but the negatives were provided to produce the surface area of the ulcer (Negative). A technician from the University of South Australia was used to determine the surface area from the UTHSCSA program. The author [D Brown] counted the squares from the tracing using graph paper and calculated the length and width for the ruler method. The counting of squares from graph paper was repeated three times and an average was obtained for the surface area.

Table 3. Subject information.

Subject	Age	Gender	Primary diagnosis	Site	Shape	Type of ulcer/wound
1	80	M	PVD	Left 4th distal apex toe	Circle	Ischaemic
2	66	M	NIDDM	Right 1st apex toe	Circle	Neuropathic
3	56	M	Idiopathic neuropathy	Left 1st apex toe	Elliptical	Neuropathic
4	46	M	IDDM	Left 2nd submetatarsal plus amputation 1st &2nd toes	Elliptical	Post-operative (gangrene)
5	72	M	IDDM	Right 5th submetatarsal	Irregular	Post biopsy
6	56	F	NIDDM	Right heel	Irregular	Neuropathic
7	42	M	NIDDM	Right 1st & 2nd submetatarsal	Elliptical	Post-operative (gangrene)
8	37	M	IDDM	Right 1st submetatarsal	Elliptical	Post-amputation
9	86	M	NIDDM	Right 1st distal apex toe	Irregular	Ischaemic
10	70	M	PVD	Left 1st medial side Interphalangeal joint	Circle	Ischaemic

Statistical analysis

Intrarater and interrater reliability data were analysed using the one way ANOVA intraclass correlation coefficient ICC (1,1). It is the statistic of choice for reliability studies with continuous data [11]. Good reliability is valued at ICC (1,1) >0.8.

The results incorporated an ICC (1,1) with and without Subject 7. This was to see if Subject 7's large surface area and its large variation of measurements made any difference to the reliability results. To test the analysis of difference for Tracing, Counting Squares, Ruler, Photo and Negatives, the Wilcoxon signed rank test was applied instead of a t-test due to the skewed distribution of the results. The $p<0.05$ made the result statistically significant.

Results

There were a total of 11 subjects who volunteered to be part of the study. During data collection one subject withdrew from the study due to a long hospital admission. Information obtain from the subjects is summarised in Table 3.

As seen from the subject information, 90% of the subjects were males. The subjects' age ranged from 37 to 86 years, with a mean age of 61.1 years. Seventy per cent of the subjects had diabetes, 20% peripheral vascular disease and 10% idiopathic neuropathy. There was a variety of different types and shapes of ulcers located and a variety of different sites on the foot.

Reliability

Intrarater reliability

Intrareliability involved Podiatrist 1 and Podiatrist 2 measuring the ulcer or wound for each subject twice; the measurements were then compared (Table 4).

Podiatrist 1 had shown good reliability, with ICC (1,1)=0.996 with Subject 7 and ICC (1,1)=0.984-0.99 without Subject 7. This was similar with Podiatrist 2 with ICC (1,1)=0.987-0.9995 with Subject 7 and ICC (1,1)=0.99-0.999 without Subject 7, indicating a good reliability with an ICC (1,1)>0.8. Therefore there is a high correlation between Tracing, Counting Squares and the Ruler method for intrarater reliability.

Interrater reliability

Interrater reliability involved Podiatrist 1 and Podiatrist 2 measuring each subject's ulcer or wound and comparing the results (Table 5).

Table 4. Intrarater reliability.

Measurement	Podiatrist 1 ICC (1,1)		Podiatrist 2 ICC (1,1)	
	with	without Subject 7	with	without Subject 7
Tracing	0.996	0.984	0.987	0.99
Counting Squares	0.996	0.99	0.989	0.999
Ruler	0.996	0.99	0.9995	0.995

Podiatrist 1 and Podiatrist 2 ulcer measurements for Tracing and Counting Squares had ICC (1,1)=0.997 with and without Subject 7. The Ruler method had an ICC (1,1)=0.994 with Subject 7 and ICC (1,1)=0.997 without Subject 7. All three methods indicate a good reliability with an ICC (1,1)>0.8.

Analysis of difference

Comparison of Tracing, Counting Squares and Ruler

As seen in Table 6, both podiatrists produce very similar results when comparing Tracing, Counting Squares and Ruler method. Due to the non-parametric nature of this test, the Wilcoxon test produced essentially the same results, with a p value of 0.006 for each comparison for Podiatrist 1 and Podiatrist 2 (Table 7). This p value indicates statistically significant evidence of a difference between the two sets of measurements. The statistical difference in the data between the two podiatrists is very similar in magnitude.

In each pairwise comparison of the methods, one method had all values higher than the other. The Ruler method had a consistent higher value than Tracing and Tracing had a higher value than Counting Squares for both Podiatrist 1 and Podiatrist 2.

Table 5. Interrater reliability: Podiatrists 1 and 2.

Measurement	ICC (1,1)	ICC (1,1) without Subject 7
Tracing	0.997	0.997
Counting Squares	0.997	0.997
Ruler	0.994	0.997

Table 6. Comparison of Tracing, Counting Squares and Ruler.

Measurement	Median	
	Podiatrist 1	Podiatrist 2
Tracing	77	76
Counting Squares	66	66
Ruler	104	162

Comparison of Tracing, Ruler, Counting Squares, Photo and Negative

The median of measurements for Ruler, Tracing and Counting Squares made by the Podiatrist 1 and Podiatrist 2 were calculated and compared with the results from Photos and Negatives (Table 8).

When comparing Tracing, Counting Squares, Ruler, Photos and Negatives there was some variation in the p value (Table 9). The Ruler method had a p value of 0.006 which indicated a statistically significant difference from the other methods, while the other measurement tools indicated no statistically significant difference to each other. The p value ranged from 0.31 for Tracing-Photo and Photo-Negative to 0.76 for Tracing-Negative.

Discussion

As seen from Table 3, there were a variety of different types of ulcers. The subjects ranged from people with diabetes having ischaemic or neuropathic ulcers to post-operative surgery from a complication of gangrene.

The description involving the shape of the ulcer did require some imagination. Not one ulcer was truly elliptical or

Table 7. Statistical analysis of Tracing, Counting Squares and Ruler.

Comparison of techniques	Wilcoxon Test (p=)		Statistically significant difference (p< 0.05)	
	Pod. 1	Pod. 2	Pod. 1	Pod. 2
Counting-Ruler	0.006	0.006	Yes	Yes
Ruler-Tracing	0.006	0.006	Yes	Yes
Tracing-Counting	0.006	0.006	Yes	Yes

Table 8. Comparison of Tracing, Ruler, Counting Squares, Photo and Negative.

Measurement	Median
Tracing	78
Counting	66
Ruler	136
Photo	86
Negative	83

circular in shape. Mayrovitz [16] and Mayrovitz, Smith & Ingram [17] have stated that neuropathic and ischaemic ulcers are "round-like" and venous ulcers are "irregular" in shape. Cutler *et al.* [18] approximated all the ulcers as elliptical. Johnson [19] stated that most plantar ulcers were round; dorsal foot wounds and venous ulcers were elliptical; but there was no mention of what site the irregular shaped ulcers came from. Even among different studies there is no general consensus on what shape is true for all types of ulcers.

This provides some doubt on how effective the UTHSCSA Image Tool program was in the study in providing accurate data. The program uses a formula for certain shapes to calculate the surface area of other shapes such as images of ulcers. If an ulcer was not exactly or very close to a rectangle, elliptical or polygonal, then there could be some overestimation or underestimation of surface area for Tracing, Photo (digital camera) and Negative (SLR camera). Therefore this program will need to be compared to other computerised programs to ascertain its accuracy.

During the study, counting the squares from the tracings was a long and tedious task. Majeske [12] also acknowledge this fact but overcame this by using 1cm squares that were centrally located within the wound tracing. With this in mind, Majeske concluded that counting the squares via graph paper was a preferred method in the absence of a planimeter or digitizer. From experience, Counting Squares from graph paper had a number of potential errors, especially with large, irregular ulcers due to the large variation of counting. A decision had to be made about the tracing margins when they crossed half, three-quarters or quarter of a square. If the border was thick, there was a possibility that this may add to the area measurement [14]. Therefore counting the squares from graph paper were repeated three times to provide an average number.

Photography provides a non-contact method of measuring ulcers. During the study, a lot time was spent in perfecting the art of using both digital and SLR cameras. Brown-Etris, Pribble & LaBrecque [6] found the photo method was more versatile than the tracing method. It provided a better visual recording of the wound and more information such as wound base tissue composition, wound margin attachment and depth. However, as discussed in that paper, skills were required to set and operate the camera equipment; if the clinician does not have those skills, valuable information would be lost in poor quality photography.

From the results of the study it was thought that Subject 7 with its large variation of results would provide a false ICC.

Table 9. Statistical analysis of Tracing, Ruler, Counting Squares, Photo and Negative.

Comparison of techniques	Wilcoxon Test (p=)	Statistically significant difference (p< 0.05)	Comments	
Photo-Negative	0.31	No	2 largest wounds Negative gave quite a larger value for the wound area	
Tracing-Photo	0.31	No	2 largest wound area Tracing is much larger in wound area	
Counting-Photo	0.41	No	Small wound areas Photo is larger than Counting	2 largest wound areas Counting is larger than Photos
Ruler-Photo	0.006	Yes	All wound areas Ruler is a lot larger than Photo	
Tracing-Negative	0.76	No	2 largest wound areas Tracing is larger in wound area	
Counting-Negative	0.36	No	Small wound areas Negative is larger than Counting	2 largest wound areas Counting is larger than Negative
Ruler-Negative	0.006	Yes	All wound areas Ruler is a lot larger than Negative	

It was decided to delete Subject 7 to see if this would have a large impact on the intrarater and interrater reliability. As seen from the statistical analysis, there was little variation on intrarater and interrater reliability with or without Subject 7. Therefore the two podiatrists provided good intrarater and interrater reliability with the ICC (1,1)>0.08 for Tracing, Counting Squares from tracing and the Ruler method.

The Ruler method provided the most interesting results from the study. For intrarater and interrater reliability it provided good reliability (>0.08), indicating that consistency is present when the podiatrist repeated this measurement tool. However, Houghton & Kippen [3] found poor intrarater and interrater reliability for linear measurements and concluded that the technique was unreliable. Öien *et al*. [20] concluded that the ruler method was less reliable than other methods such as planimeter and grid tracing, especially when ulcers had an area greater than 5cm^2.

When comparing it to other methods, the ruler had a consistently larger value and provided a statistically significant difference of p=0.006. Majeske [12] and Öien *et al*. [20] also found the ruler method overestimated or provided larger values than other measurement techniques. Calculating length and width measurements that produces the surface area of a rectangle is bound to overestimate the area of ulcers, especially when they are rarely this shape.

According to the results, if a podiatrist uses the Ruler method it would show a consistently high value every time the tool is used but is reliable enough to provide a result indicating change in the healing process. This provides the question of what does a clinician want from a measurement tool. Ideally, every clinician would use a tool that provides accurate and reliable data but, in the absence of such a tool, a clinician must decide what is sufficient for their clinical practice.

When comparing the other methods such as Tracing, Counting Squares from Tracing, Photo (digital camera) and Negative (SLR camera) to each other, there was some variation in the p value. Counting Squares from graph paper and Tracing using the Image tool program were statistically different, with p=0.006. When comparing these two methods with Photo (digital camera) and Negative (SLR camera), there was no statistical difference with p>0.05. Also, when comparing Photo and Negative p values, there was no statistical significance, with p=0.31.

Even among the comments provided in Table 8, there was some variation. All other methods had larger values for the two largest ulcers than Photo (digital camera) but the photo value was larger for the two smallest ulcers when compared to Counting Squares from Tracing. The analysis from the study indicates that there is not one measurement technique that stands out as the best tool for podiatrists to use in a clinical setting. Many articles conclude that the availability of resources, time, cost, clinical or research purpose, and convenience are factors that clinicians should think about when pursuing the most appropriate and accurate measurement tool [5-7]. Therefore, it was felt that more investigations were required to conclude whether one method was more clinically significant than the others.

To truly compare the results of this study with other studies there needs to be an identical experimental design and statistical analysis, but this is not so. As stated by Haas [11], it is "imperative that some standardisation of methodology be developed to abate the current confusion and ambiguities associated with reliability research".

At this stage this pilot study raises more questions than answers, especially in regard to future experimental designs such as:

- Should only real ulcers or wounds be used, or photographs, computerised hypothetical ulcerations or plaster cast moulds?
- What measurement tools should be studied?
- Do ulcer or wound sites influences what measurement tool should be used?
- Is the study for research purposes or practical use in a clinical setting?
- What type or size of ulcer should be included or excluded?
- Should surface area or volume or both be evaluated in the study?

All these questions raise the fact that wound healing is a complex process that cannot be resolved by one simple study. Many factors need to be taken into account and this explains why there is such a variation among reliability studies. Regardless of this variation, it is generally agreed that there needs to be an accurate measurement technique to effectively evaluate the size of wounds or ulcers in order to assess the progress of healing [4, 5, 21].

Limitations

The limitation of this pilot study was the small sample size; this was due to the sample of convenience and time frame of the study. This may produce results interpreted as chance alone rather than a real reproducible result [22].

Recommendations

It is recommended that more clinicians repeating more measurements over an extended period of time would improve the intrarater reliability study design. For interrater reliability, it would be an interesting exercise to see if experience makes a difference; this may involve comparing an inexperienced clinician such as a third year podiatry student or new graduate with a more experienced high risk podiatry clinician.

For further studies, the methodology would need to involve a power analysis to provide a sample size that is large enough to provide a more valid statistical and clinical significance when evaluating measurement tools.

Conclusion

This study provided more questions than answers on what is the best measurement technique that should be used in a podiatry clinical setting. It has been concluded that a better experimental design and therefore more useful statistically analysis could provide a better conclusion on the reliability of measurement tools.

The results of this pilot study suggests it doesn't matter what tool is used as long as it provides consistent measurements that can be used by a clinician to evaluate the progress of healing. A standardisation approach to reliability studies is important in providing a gold standard that all measurement tools can be compared to. Until this occurs, little debate on effectiveness of different measurement tools can be pursued in research or in a clinical setting.

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