Investigating the Most Suitable Imaging Modality to Accurately Record Wounds for Clinical Records and Remote Assessments

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Background

Reviewing a wound in person always yields greater understanding of its severity or progress; stereo eyesight, 360^0 perspective and physical contact, provide additional information to that displayed within a single 2D image. Conversely, one quality wound image, provides the remote clinician or expert assessor with far more understanding than words alone could achieve.

Objective

Through practical investigation identify which; robust, simplistic and cost effective imaging system should be employed to accurately photograph 'all' skin surface wounds within the clinical environment. Wounds from 1cm to 1m in length were selected as those most numerous, whilst avoiding the extremes which incur greater cost; for macro equipment to capture <1cm wounds, or the time and complexity required to combine multiple images for >1m length wounds which, due to body curvature, could not be recorded within one 2D image. In addition, multiple imaging systems could be employed to capture specific wound characteristics; colour only, surface texture and blood flow. Such specialist imaging systems are not considered; they significantly increase cost, complexity and protract both the image capture, handling and wound assessment processes.

Method

The practical evaluation criteria for such a wound capture system was divided into the following areas for investigation:

1. Determine the preferred method for lighting a diverse range of wound types, bodily locations and sizes; changes in illuminate area, spectral composition and intensity profoundly alter the appearance of all images.
2. Which imaging modalities are compatible with the preferred lighting? The range of capture devices is immense and includes dedicated clinical imaging systems.
3. Which combination of settings balances ease of use and image consistency? From predictive auto focus and exposure to Wi-Fi image transfer, the flexibility and range of capture options available can unnecessarily add complexity and time if not evaluated.

Determine the preferred methods of wound lighting

Wounds within the ranges of <10cm (close-up), 10-30cm (head) and 30-100cm (torso) were captured using the lighting systems listed below. Having first assessed the wounds in person, 5 clinicians scored the accuracy of wound detail from each lighting system and capture area combination, the results are shown in Table 1.

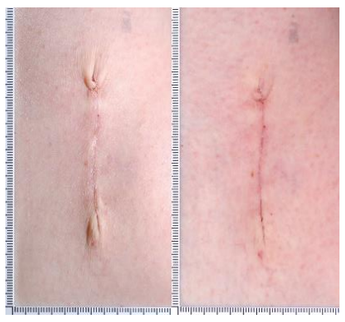
Rationale for choice of lighting tested/not considered:

- On-camera flashes (both direct and diffused) are simplistic and require no additional power source, flash proximity to the lens means if a restricted access wound can be seen through the camera then it can be photographed.
- Lens mounted ring-flashes (both two-tube and one continuous tube varieties) increase cost and complexity but with greater power and skin tone rendition. The on-lens position allows greater access to wounds with restricted access.

Those lighting systems not investigated, include:

- Specular, in-line polarised and oblique lighting; these systems identify surface texture at the expense of colour by emphasising surface glare or shadow detail, see Figure 1.
- Cross-polarised lighting captures colour only, at the expense of any surface texture, see Figure 1.
- 360^0 diffuse and copy lighting are excellent standard lighting techniques for small wounds, the size and weight of the diffusers or copy lights -which are positioned all-round or at 45^0 to the wound respectively- would prove wholly impractical for daily use within the clinical environment.
- Ambient and bounced (hammerhead flash) lighting, cannot provide the consistency of colour balance, exposure or sufficient depth of field across the range of potential wound sizes, bodily locations or changing clinical environments.

Figure 1. (L-R) Oblique and cross polarised lighting.



Imaging modalities compatible with the preferred wound lighting

The lighting systems offered by trade photography, medical imaging and consumer web based suppliers were investigated and the available products reviewed. Low cost lighting and unbranded imports were not reviewed, from experience, product design and flash (power) consistency were not of sufficient quality. Table 2 classifies which imaging modalities, either incorporate or are compatible with those lighting systems favoured by the clinicians in Table 1.

Balancing ease of use with image consistency

In reference to the preferred lighting identified (B-C) within Table 2:

- The professional DSLR was not selected for further testing; it did not provide any additional functionality or image quality applicable to this wound capture process, in addition the extra weight and cost rendered it less practical for clinical acceptance.
- Those ring flashes which contain 2 separate lights within one unit were not investigated further; they resulted in highlight (and shadow) inconsistency when photographed between landscape and portrait orientation, as Figure 2. There was also potential for one tube to develop a fault or to be set differently without detection, whereas the single tube flash either worked or did not.

Figure 2. Ring flash with 2 tubes positioned above and below lens (top) and with tubes either side of lens (bottom).

A qualified medical photographer investigated those settings offered by an entry level DSLR and continuous ring flash, with emphasis on:

- Speed and ease of use, for both image capture and transfer within the clinical environment,
- Accuracy of exposure and colour, irrespective of skin tone or subject matter,
- Image consistency across the range of capture areas.

Manually fixing all the camera and flash settings prevents both user interference and the cameras' automatic settings miss-interpreting subject matter - then adjusting image content accordingly. In practice within every image capture Mode, the Sharpening, Contrast and Saturation of each image is automatically altered by the camera at point of capture, unless set manually the camera:

- lightens dark skin or darkens light skin to meet pre-set ideals,
- reduces high contrast burn images or expands the colour of subtle bruising, to best fit the available dynamic range.

Results

Table 1. Clinical staff ranked the lighting techniques in order of preference and scored each image: preferred = 3, good = 2, tolerable = 1 and not acceptable = 0. Averaged scores from the 5-strong clinical team are shown for each lighting.

Preferred wound lighting	Close-up (<10cm)	Face (10-30cm)	Torso (30-100cm)	Total
On-camera flash – direct (A)	1	2	2	5
On-camera flash – diffused (B)	2	2	3	7
Lens mounted ring flash - 2 tubes (C)	2	2	3	7
Lens mounted ring flash – 1 tube (D)	2	3	3	8

Figure 3. Wound lighting examples (L-R) for flashes A – D, from Table 1.

Table 2. Identifies which imaging modalities are available and compatible with the top 2 preferred lighting methods from Table 1.

Preferred lighting	Mobile phone	Compact camera	DSLR <£1000	Professional DSLR >£1000
On-camera flash diffused	Not available	Not available	Suitable	Suitable
Lens mounted ring flash - 2 tubes	Not available	Not available	Suitable	Suitable
Lens mounted ring flash – 1 tube	Not suitable *	Not suitable *	**Suitable**	Suitable

*Continuous (LED) lighting units are available but lack sufficient power.

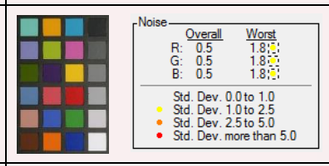
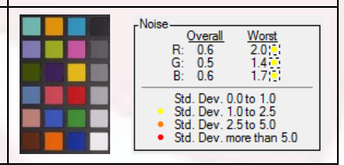
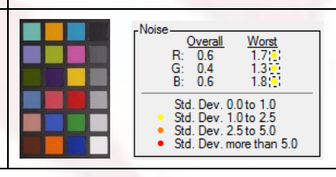
As discussed within **Balancing ease of use with image consistency** an entry level DSLR was selected for practical testing within the clinic. Every setting within the Nikon D3100, Tamron 18-200mm lens with manual limiter and Pentax AF160FC ring flash was investigated and referenced against an industry standard colour chart. Table 3 identifies the manual settings that were derived to ensure optimized image accuracy and consistency across the range of capture areas.

Table 3. Derived imaging settings and reasoning:

System Settings	Main Setting	Sub Menu/Setting	Reasoning
Flash	Full power	-	Sufficient to achieve required exposure for 100cm wound.
Lens	Manual, with focus point locked at 1.5m	VR ON, minimises risk of image blur	Distance to subject allows bed and theatre photography. Lens barrel marked (at focal lengths) for Close-up (135mm), Head (70mm) and Torso (24mm) settings for guidance.
	F22 aperture	-	Maximum depth of field achievable with flash, negates impact of ambient lighting.
Camera (exposure)	1/200 exposure	400 ISO	Fastest synchronised flash shutter reduces image blur and influence of ambient lighting. ISO to achieve exposure.
Camera (image size)	Large	4608X3072 (14.2MP)	Allows 2-3x image enlargement at each capture area without screen pixilation.
	JPG format	Fine detail	The increased size and post capture processing renders RAW format impractical.
Camera (white balance)	Flash setting	B2 adjustment	Manually set sensor to match flash, using Macbeth colour checker and Adobe Photoshop.
Camera (picture control)	Portrait mode, with sub menus manually set to:	Sharpening 4 Contrast 0 Brightness 0 Saturation +2 Hue 0	Image characteristics manually set against Macbeth colour checker to prevent within camera image processing.
Camera (image adjust's)	Noise reduction OFF	Distortion correction OFF	Not required for settings employed, turned off to avoid possible changes to images.

As part of the camera configuration, system accuracy was validated against a Macbeth Colour Checker for each capture area. As lens aperture can be set throughout the zoom range for this lens, any focal length in-between the extremes below could be captured with the same confidence.

Table 4. Shows colour checker images and delta values across entire capture range, with example Torso image.

Preferred configuration	Delta between colour chart and resultant image data	Example Torso image
Close-up (<10cm)		
Face (10-30cm)		
Torso (30-100cm)		

Conclusion

Numerous imaging systems seek to provide simplicity and robust patient/wound capture. Unfortunately, the importance of accurate wound lighting is often neglected due to the increased cost, power usage and perceived complexity. Only consistent flash can over-ride changing ambient light levels and consistently provide sufficient power to achieve sharp images – in combination with fast shutter speeds and sufficient depth-of-field.

The inclusion of white scale tape and patient identification labels as standard, ensures both a visual colour reference and scale check are retained for subsequent assessments. If reviewing/assessing images via an uncalibrated display, the inclusion of white (scale) provides a (standardising) comparator for the eye to reference.

The research goal was to evaluate imaging options for accurate wound capture, whilst balancing the numerous practical constraints associated with clinical imaging. The resultant imaging system provides:

1. Image accuracy and consistency -demonstrated by clinical consensus and industry colour chart comparison- shows images as acceptable for medical notes and remote clinical assessment.
2. At £750 for a configured camera, the cost is noticeable when compared to compact cameras but significantly lower than dedicated imaging systems, so considered cost effective. All settings being fixed makes for a robust and easy to use device - where only the zoom lens requires user intervention to fill the viewfinder with the wound.
3. Images (approx. 5MB each) recorded on the camera SD memory card are transferred to the respective patient/assessment folders – image meta data provides audit trail. Image transfer options also include; SD card/reader, write once or password protected memory cards, tethered camera to computer transfer or direct to device via camera Wi-Fi adaptor.