

ONLINE FIRST

## Early Depth Assessment of Local Burns by Dermoscopy

### *A New Frontier of Dermoscopic Evaluation*

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**Objective:** To investigate the effectiveness of early depth assessment of local burns, the depth of which is difficult to assess with the naked eye, by dermoscopy.

**Design:** The morphological findings of burn wounds were prospectively evaluated by dermoscopy and videomicroscopy. Prior to dermoscopic and videomicroscopic measurement, clinical assessment was performed. All patients received conservative treatment for 21 days after injury.

**Setting:** A burns unit at a primary care hospital.

**Participants:** Thirty-two patients with 41 intermediate-depth local burn wounds were included. Inclusion criteria were time to presentation greater than 24 hours after injury and total burn size greater than 1% and less than 10% of the total body surface area.

**Main Outcome Measures:** Primary healing within 21 days (superficial partial thickness) and failure of primary healing within 21 days (deep partial thickness). The accuracy, sensitivity, and specificity of the assessment ac-

ording to the algorithm proposed in this study were evaluated by dermoscopy, and the accuracy of the dermoscopic measurements was compared with videomicroscopic measurements and clinical assessments.

**Results:** The results of dermoscopic measurements according to the proposed algorithm showed an accuracy of 93%, sensitivity of 86%, and specificity of 100%. The dermoscopic measurements were significantly more accurate compared with clinical assessment ( $P = .01$ ).

**Conclusions:** Dermoscopy is a noninvasive, portable, relatively inexpensive, and effective approach for assessment of the burn wound healing potential. It is more accurate if compared with clinical observation in burn depth assessment. It has a broader utility and is equally or more accurate compared with the more expensive videomicroscopy.

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IT HAS BEEN REVEALED BY LITERATURE reviews that the burn healing outcome is usually considered to be a function of blood flow to the wound. A number of techniques to evaluate the dermal capillary integrity of burn wounds have been reported to predict the clinical course, to avoid unnecessary surgery and burdens on both patients and medical professionals, and to reduce the medical cost.<sup>1-8</sup>

Dermoscopy has been reported to improve the diagnostic accuracy of skin tumors, especially pigmented skin lesions.<sup>9-13</sup> The usefulness of dermoscopy was also reported in the evaluation of vascular structures in skin tumors,<sup>14</sup> nonpigmented skin lesions such as amelanotic melanoma,<sup>15</sup> and pyogenic granuloma<sup>16</sup>

and in the differentiation of psoriasis and seborrheic dermatitis.<sup>17</sup> In addition, it is reportedly useful to identify microvascular damage of scleroderma spectrum disorder.<sup>18</sup> It has also been shown to be a useful tool to examine the vascular structure of the superficial dermis.

Both videomicroscopy and dermoscopy are types of epiluminescence microscopy and work according to the same principle. The considerable utility of videomicroscopy was previously shown in the assessment of burn depth in its early acute phase.<sup>1-3</sup> In the same way, early depth assessment of burn wounds by dermoscopy is thought to be possible; in fact, it makes early burn depth assessment easier, is possible over a wider area, and benefits both patients and medical professionals.

## METHODS

This investigation was implemented at the Burns Unit, Nagasaki Hospital, Hiroshima, Japan. The hospital's ethical committee approved this study, and written informed consent was obtained from each patient. Patients with intermediate-depth burns, the depth of which was difficult to assess with the naked eye, who were admitted to the Burns Unit at Nagasaki Hospital were prospectively assessed. Inclusion criteria for the study were presentation time greater than 24 hours after injury, total burn size greater than 1% and less than 10% of the total body surface area (TBSA), and older than 15 years. Exclusion criteria were presentation time less than 24 hours after injury, total burn size less than 1% or greater than 10% of total body surface area, younger than 15 years, facial and head burns, and concomitant illness such as diabetes and other known vascular problems, as well as psychiatric disease. Larger burns were excluded because dynamic evaluation of the depth is also related to vaso-active circulating metabolic substances in such cases.<sup>1,2</sup>

Patients presenting less than 24 hours after injury were excluded from this study. That was because burn wound conversion, the process in which a change of depth may occur, has been shown to be completed by 24 hours after injury<sup>1</sup>; thus, the assessment is thought to be conducted accurately later than 24 hours after injury without being influenced by the process of burn wound conversion.

For videomicroscopy, transcutaneous microscopy with a compact handy videomicroscope (Bscan-pro; Toku Corporation) was used in this study, and the dermal capillary integrity of the burn wounds was directly visualized. This system has a zoom of  $\times 95$  to  $\times 300$  magnification and can obtain a digital image for real-time display on a monitor.

For dermoscopy, the dermoscope Derma9500 with a polarization filter (Derma Medical Inc) was used in this study. The system consists of a close-up adapter unit mounted on a Canon Powershot G11 digital camera (Canon Inc). It can obtain a digital image for real-time monitoring and recording. The system is factory calibrated and ready to use at  $\times 10$  magnification. Videomicroscopy requires an assistant to screen, is not easily portable, and is relatively expensive. However, videomicroscopy and dermoscopy are basically the same, but the magnifying power is different.

Prior to dermoscopic and videomicroscopic measurement, clinical assessment was performed according to the classification of burns by the International Society for Burn Injuries in collaboration with the World Health Organization.<sup>19</sup> Then, videomicroscopic measurement was performed according to the classification previously proposed by Mihara et al,<sup>2</sup> and dermoscopic measurement was conducted according to the algorithm proposed in the present study.

The first author (K.M.), who is experienced in burn depth assessment using videomicroscopy and dermoscopy, examined the burn surface by videomicroscopy and dermoscopy with care not to contact the wound. The wound was cleaned well under running water and covered with thin transparent polyvinylidene chloride film (Kurewrap; Kureha Corporation). The first few centimeters of it were discarded,<sup>20</sup> and it was laid on the wound with care not to compress the wound to avoid the possibility of transmitting infection through videomicroscopy and dermoscopy. Then, investigation of the dermal capillary integrity over the entire wound was conducted rapidly. At clinically, videomicroscopically, and dermoscopically interesting areas, such as areas that appeared to exhibit a clinically different depth, that seemed to be the deepest clinically, or that were indicative of the overall burn depth, the operator investigated the area with extreme caution and a digital photograph was taken. The burn wound depth was classified into each grade consensually

**Table 1. The Classification for the Videomicroscopic Measurement Used in the Present Study Compared With Previous Studies**

Studies	Category	Main Findings	Burn Depth
Present study and Mihara et al <sup>2</sup>	Dots	Dot patterns	SDB
	Dots and reticular	Dot and reticular patterns	
	Reticular	Reticular patterns	
	Sparse	Apparent destruction of capillary plexus	DDB
Mihara et al <sup>1</sup> and McGill et al <sup>3</sup>	Avascular	No vascular patterns	
	Grade 0	Intact capillary	SDB
	Grade 1	Minor capillary destruction	
	Grade 2	Large amount of capillary destruction, hemoglobin deposition	DDB
	Grade 3	Complete capillary destruction, absent capillaries	Full thickness

Abbreviations: DDB, deep dermal burn; SDB, superficial dermal burn.

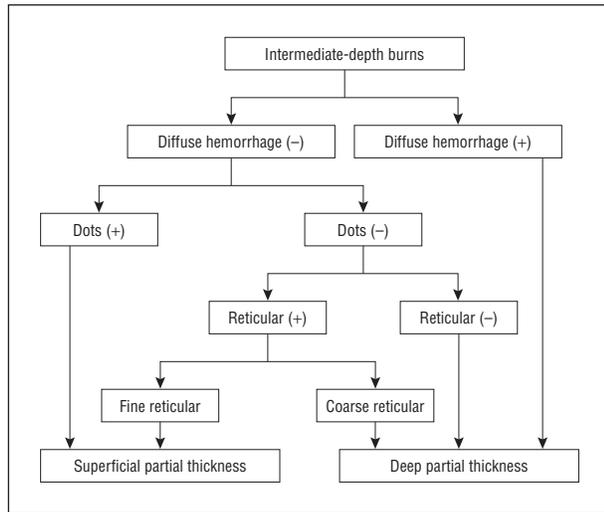
by 3 of the members of the Burns Unit (K.M., M.O., and K.N.), who had more than 15 years experience in burn care. Following the assessment, thorough cleaning of the wound under running water was conducted, and all patients received conservative treatment for 21 days after injury according to the protocol to treat local burns at Nagasaki Hospital. This protocol is as follows: the wound is thoroughly cleaned under running water, after that, topical administration of tretinoin tocoferil, 0.25% cream (POLA-pharma Corporation) is performed, and then the wound is covered with white petrolatum-impregnated gauze and dry gauze. Two end points were set in this study: primary healing within 21 days (superficial dermal burn [SDB]) and failure of primary healing within 21 days (deep dermal burn [DDB]). These end points are widely accepted in the literature on burn wounds.<sup>1-5</sup> For cases with delayed healing, the indications of surgery (excision and skin graft) were evaluated. The burn wound was assessed as soon as possible after the first visit; the accuracy, sensitivity, and specificity of the assessment were evaluated according to the algorithm proposed in this study.

## CLASSIFICATION FOR VIDEOMICROSCOPY

The classification used for videomicroscopic measurement in this study is given in **Table 1**, in comparison with previous studies. We used the classification proposed by Mihara et al,<sup>2</sup> and it is different from the one proposed by McGill et al.<sup>3</sup> The former involves pattern analysis, and the latter, degree of expression (Table 1). The ambiguity of the classification by McGill et al<sup>3</sup> means that the operator must be proficient. The classification by Mihara et al<sup>2</sup> is easier to use and makes it easier to understand the pathological condition of the wound. Therefore, the classification by Mihara et al<sup>2</sup> was used in this study.

## PROPOSED ALGORITHM FOR DEMOSCOPY

The algorithm used for dermoscopic measurement in this study is shown in **Figure 1** and **Table 2**. This algorithm is based on the classification for videomicroscopy by Mihara et al<sup>2</sup>; however, it is modified only for dermoscopy because of the lower magnification power of dermoscopy. In the proposed algorithm for dermoscopy, "diffuse hemorrhage" is set for the first



**Figure 1.** Proposed algorithm. + Indicates positive; -, negative.

**Table 2. Findings and the Meaning of Each Step of the Proposed Algorithm**

Dermoscopic Finding	Feature/Meaning	Burn Depth
Diffuse hemorrhage	The majority is covered by hemorrhagic maculae/severe damage to superficial dermal capillary integrity	DDB
Dots	Top of capillary loop; shallowest component of dermal capillary/heat damage to wound is limited to shallow part of upper dermis	SDB
Fine reticular	Delicate and ordered reticular pattern/viability of superficial plexus	
Coarse reticular	Rough and disordered reticular pattern/severe damage to superficial plexus	DDB
No particular pattern	No vascular patterns/very severe damage to superficial plexus	

Abbreviations: DDB, deep dermal burn; SDB, superficial dermal burn.

step. This is because diffuse hemorrhage is clearly observable, masks the findings behind it (Figure 2A), and requires careful attention to detect the dermal capillary integrity. “Diffuse hemorrhage” is, however, an important finding suggesting severe damage to the superficial dermal capillary integrity and indicates a deep partial thickness burn. A “dots” pattern is denoted as the top of the capillary loop, which is the shallowest component of the dermal capillary (Figure 2B). Therefore, recognition of the dots pattern indicates that the heat damage to the wound is limited to the shallow part of the upper dermis, that is to say, it was denoted as a superficial partial thickness injury. Therefore, the dots pattern was set for the second step of the algorithm. There is, however, one important problem in detecting the dots pattern. When a number of small patchy hemorrhages are recognized, they may lead to incorrect assessment as dots. This can be avoided with careful attention to the pattern of the whole image. A dots pattern is a physiological one, so one can see regularity in its order and shape, which is not the case in small patchy hemorrhages (Figure 2C). A “reticular” pattern was denoted as the superficial plexus, which

is the lower component of the superficial dermal capillary. Its destruction means the disruption of capillary flow to the upper dermis, denoted as a deep partial thickness injury. Two reticular patterns were found: “fine reticular” and “coarse reticular.” A fine reticular pattern is delicate and ordered (Figure 2D); on the other hand, a coarse reticular pattern is rough and disordered (Figure 2E). It seemed to be caused by heat damage. A fine reticular pattern represents viability of the superficial plexus and was denoted as a superficial partial thickness injury. In contrast, coarse reticular represents severe damage to the superficial plexus and was denoted as a deep partial thickness injury. A wound in which no particular pattern was detected reflects the presence of marked capillary destruction or the absence of capillaries in the upper dermis (Figure 2F), denoted as a deep partial thickness injury.

## STATISTICAL ANALYSIS

The  $\chi^2$  test was used for 2-group comparisons.  $P < .05$  was considered significant. Data analysis was performed using SPSS statistical software, version 12.0 (SPSS Inc).

## RESULTS

Thirty-two patients (21 women and 11 men) with 41 intermediate-depth burn wounds were included (27 of the 41 burns were already reported in a previous study by Mi-hara et al<sup>2</sup>). The characteristics of the patients are given in Table 3. Patients had a mean (SD) age of 54.8 (18.8) years. The mean (SD) percentage of total body surface area of burns was 2.4% (1.7%), minimum and maximum assessment times after injury were 25 and 208 hours, respectively, and the mean (SD) assessment time was 78.2 (47.2) hours after injury. The clinical outcomes of burns were SDB in 20 burns (49%) and DDB in 21 burns (51%). The majority of burns were located on the lower extremities, and the most common cause of injury was scalding.

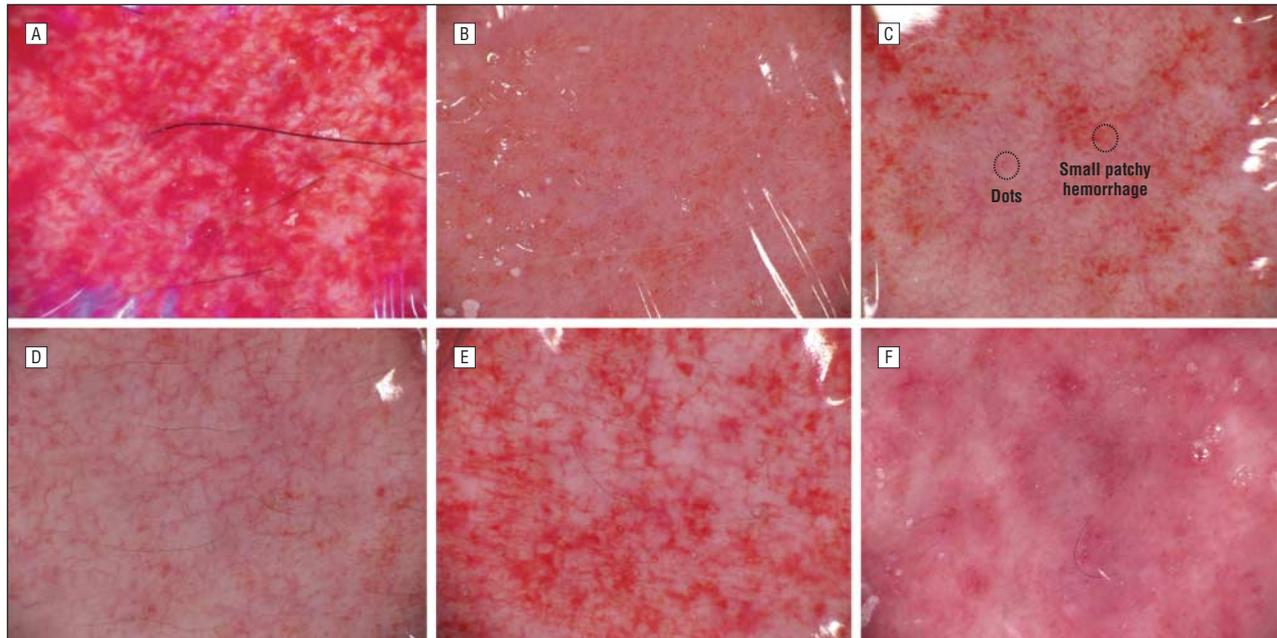
## ASSESSMENT ACCORDING TO PROPOSED ALGORITHM

The numbers of burns placed into each category according to the algorithm proposed in this study are shown in Figure 3. The burns that showed diffuse hemorrhage included only DDBs (5 burns), dots pattern included 14 SDBs and 3 DDBs, fine reticular pattern included 6 SDBs, coarse reticular pattern included 1 DDBs, and the burns that did not show a reticular pattern included 12 DDBs.

The results of measurements according to the proposed algorithm showed an accuracy of 93% (38 accurate vs 3 inaccurate). The sensitivity was 86%, specificity was 100%, positive predictive value (PPV) was 100%, and negative predictive value (NPV) was 87% (Table 4).

## CLINICAL ASSESSMENT VS VIDEOMICROSCOPY VS DERMOSCOPY

The results of the 3 procedures are given in Table 5. The results of clinical assessment showed an accuracy of 71% (29 accurate vs 12 inaccurate), and that of videomicroscopic measurement showed an accuracy of 85% (35 accurate vs 6 inaccurate). The  $\chi^2$  test demonstrated that the accuracy of clinical measurements was signifi-



**Figure 2.** Dermoscopic findings. A, Diffuse hemorrhage. The majority is covered by hemorrhagic maculae and the capillary integrity is not detectable. This indicates severe damage to capillaries in the upper dermis. B, Dots. Regularly ordered and uniform sized dots denote the top of the capillary roof. C, Dots and punctate hemorrhage. A “dots” pattern is a physiological one, with regularity in its order and shape, which is not the case in small patchy hemorrhages. D, Fine reticular. Delicate and ordered reticular pattern indicates viability of the superficial plexus. E, Coarse reticular. Rough and disordered reticular pattern indicates severe damage to the superficial plexus. F, No particular pattern. No capillary pattern detected indicates very severe damage to the superficial plexus.

**Table 3. Patient Profile (41 Burns)**

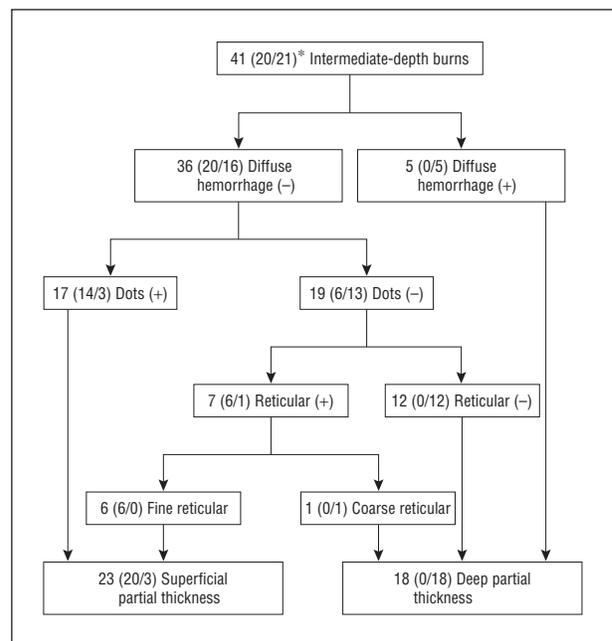
Characteristic	Value
Age, mean (SD) [range], y	54.8 (18.8) [22-89]
TBSA, mean (SD) [range], %	2.4 (1.7) [1.0-8.0]
Assessment time, mean (SD) [range], h	78.2 (47.2) [25-208]
Clinical outcome, No.	
SDB	20
DDB	21
Location, No.	
Lower extremity	25
Upper extremity	9
Trunk	7
Cause of injury, No.	
Scald	33
Flame	8

Abbreviations: DDB, deep dermal burn; SDB, superficial dermal burn; TBSA, total body surface area.

cantly lower than that of dermoscopic measurements ( $P=.01$ ) (**Table 6**). Three DDBs were diagnosed inaccurately by videomicroscopy but accurately by dermoscopy. All of the findings were “reticular” by videomicroscopy and “diffuse hemorrhage” by dermoscopy (**Figure 4**).

## COMMENT

Whether the burn wound is to heal within 21 days is of paramount clinical importance. The patient’s prognosis, including morbidity, is determined by the burn wound. Recently, laser Doppler imaging has been the most frequently reported to assess burn depth, and its accuracy



**Figure 3.** Results of assessment by dermoscopy according to the proposed algorithm. \*Number of cases (superficial dermal burn/deep dermal burn: clinical outcome). + Indicates positive; -, negative.

was reported to be between 90% and 100%.<sup>3,4,6,8</sup> Regional and institutional differences in the usefulness of laser Doppler imaging are mainly due to its high cost and cumbersome nature of the procedure; therefore, the effectiveness of videomicroscopy in early burn depth assessment was reported because of its lower cost and simpler handleability.<sup>1-3</sup> Videomicroscopy is, however, not as popular as dermoscopy in clinical use; dermoscopy is

**Table 4. Results of Assessment by Dermoscopy According to the Proposed Algorithm**

Variable	Value
Accurate, No. of burns	38
Inaccurate, No. of burns	3
Accuracy, %	93
Sensitivity, %	86
Specificity, %	100
PPV, %	100
NPV, %	87

Abbreviations: NPV, negative predictive value; PPV, positive predictive value.

**Table 5. Comparison of the Accuracy of Each Procedure**

Variable <sup>a</sup>	Clinical Assessment	Videomicroscopy	Dermoscopy
Cases, accurate/inaccurate, No.	29/12	35/6	38/3
Accuracy, %	71	85	93
Sensitivity, %	76	71	86
Specificity, %	65	100	100
PPV, %	70	100	100
NPV, %	72	77	87

Abbreviations: NPV, negative predictive value; PPV, positive predictive value.

<sup>a</sup>Accuracy, % = number of burns that were assessed as deep dermal burn (DDB) and failed to heal within 21 days and number of burns that were assessed as superficial dermal burn (SDB) and healed within 21 days/total number of burns assessed in this study (n = 41). Sensitivity, % = number of burns that were assessed as DDB and failed to heal within 21 days after injury/number of burns that failed to heal within 21 days after injury; specificity, % = number of burns that were assessed as SDB and healed within 21 days after injury/number of burns that healed within 21 days after injury; PPV, % = number of burns that were assessed as DDB and failed to heal within 21 days after injury/number of burns that were assessed as DDB; and NPV, % = number of burns that were assessed as SDB and healed within 21 days after injury/number of burns that were assessed as SDB.

**Table 6.  $\chi^2$  Test, Between Each Procedure<sup>a</sup>**

	Dermoscopy vs Clinical Assessment	Dermoscopy vs Videomicroscopy	Clinical Assessment vs Videomicroscopy
P value	.01	.29	.11

<sup>a</sup>Three cases of deep dermal burn were diagnosed inaccurately by videomicroscopy but accurately by dermoscopy. All findings were "reticular" by videomicroscopy and "diffuse hemorrhage" by dermoscopy.

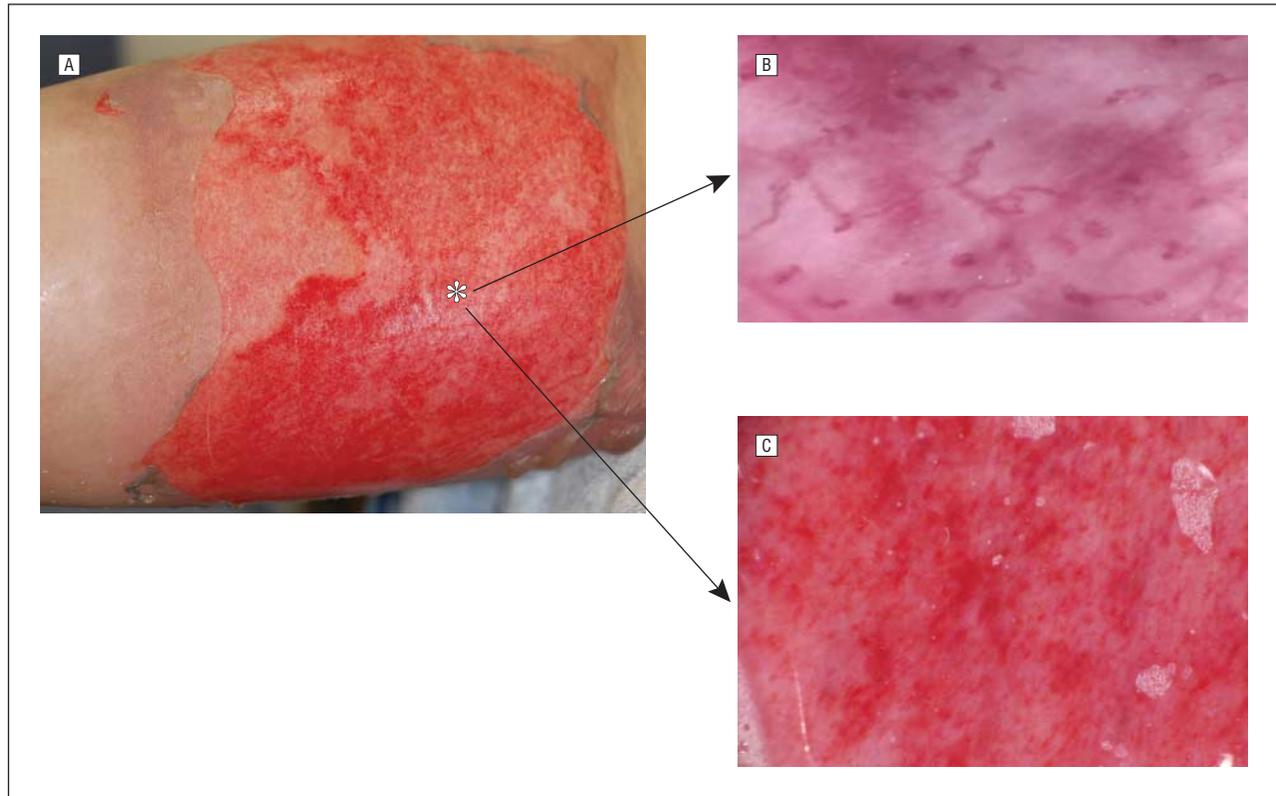
less expensive, more portable, and more versatile than videomicroscopy. The intention of this study was to investigate the potential relevance of the technology in the assessment of wound depth. In this study, dermoscopy was shown to be significantly more accurate than clinical assessment and more accurate than videomicroscopy. Dermoscopy is useful not only in the evaluation of skin tumors and inflammatory skin disease, but also in the evaluation of the wound healing potential of a burn wound. The dermal capillary integrity of an intermediate-depth burn, a kind of skin ulcer, can be clearly assessed by dermoscopy. In the present study, the use of a sim-

plified, easy-to-understand algorithm was proposed. With this algorithm, the pathological condition of the wound can be easily recognized with baseline knowledge of the skin microvascular system. The proposed algorithm is composed of 6 findings. It is based on classification by videomicroscopy<sup>2</sup>; however, the lower magnification power of dermoscopy necessitated some modifications. With dermoscopy, a larger view of wounds can be obtained than with videomicroscopy at one time, and the dermal capillary integrity of the wound can be better recognized.

Puppin et al<sup>21</sup> examined whether a higher magnification provided any improvement of features in the analysis of patterns previously described in pigmented skin lesions. They concluded that amplified surface microscopy is a time-consuming procedure and dermoscopy is more appropriate for routine use. That is also the case in reports by Akasu et al<sup>22</sup> and Saida et al.<sup>23</sup> Saida et al<sup>23</sup> reported the usefulness of videomicroscopy at  $\times 25$ ,  $\times 50$ , and  $\times 100$  magnification for determining the clinical diagnosis of pigmented skin lesion, and a much higher magnification did not show clear features. In the present study, 3 DDBs were diagnosed inaccurately by videomicroscopy but accurately by dermoscopy. All of the findings were "reticular" by videomicroscopy and "diffuse hemorrhage" by dermoscopy. This is thought to be because the higher magnification of videomicroscopy might be misleading and prevent the viewing of the total picture of wounds. Diffuse hemorrhage is easily recognized by dermoscopy but not by videomicroscopy. The higher magnification of videomicroscopy enables the detection of the vascular pattern among hemorrhagic maculae, and then the wide field of view is missed. However, the lower magnification of dermoscopy is thought to be useful to capture the entire picture of wounds.

In this study, the assessment time was limited to greater than 24 hours after injury. Because this is, to our knowledge, the first study of burn wound depth assessment by dermoscopy, wounds in which the changing process of burn depth had not completed were excluded to evaluate the essential utility of dermoscopy in the assessment of the burn depth. In addition, the dermoscopy findings have not been validated by biopsy. Biopsy was not conducted because it is invasive, and its application was thought to be impractical in a clinical setting. It gives information only about the small site where a biopsy is performed. One of the biggest concerns of patients regarding local burns is to prevent scarring. Biopsy might leave an additional scar, and the effectiveness of videomicroscopy in the assessment of the burn depth has already been reported in the literature.<sup>1-3</sup> Therefore, comparing clinical assessment and videomicroscopy with dermoscopy is acceptable to validate dermoscopy findings in clinical settings.

Dermoscopy has been widely used to detect findings that indicate malignant pigmented skin lesions and is a guiding method for diagnosing skin tumors clinically and identifying microvascular damage of scleroderma spectrum disorder. To our knowledge, this is the first study to evaluate the wound healing potential, one of the most important functions of skin, morphologically by dermoscopy. The usefulness of dermoscopy is not limited to mor-



**Figure 4.** Scald on the right thigh assessed 77 hours after injury (A); videomicroscopy (original magnification  $\times 300$ ) (B); and dermoscopy (original magnification  $\times 10$ ) (C). This wound failed to heal in 21 days. This wound was inaccurately assessed as “reticular” by videomicroscopy but was accurately assessed as “diffuse hemorrhage” by dermoscopy.

phological assessment; it can also aid in evaluating the function of skin. This study may open up a new dimension in dermoscopy.

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**Author Contributions:** Dr K. Mihara had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* K. Mihara, Shindo, H. Mihara, Ohtani, Nagasaki, and Katoh. *Acquisition of data:* K. Mihara and Shindo. *Analysis and interpretation of data:* K. Mihara and Shindo. *Drafting of the manuscript:* K. Mihara, Shindo, H. Mihara, Ohtani, and Nagasaki. *Critical revision of the manuscript for important intellectual content:* K. Mihara and Katoh. *Administrative, technical, and material support:* Shindo, H. Mihara, Ohtani, and Nagasaki. *Study supervision:* Katoh.

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