Received: 14 March 2022 | Revised: 13 June 2022 | Accepted: 14 June 2022

DOI: 10.1111/iwj.13880

ORIGINAL ARTICLE

IWJ WILEY

Relationship between items of DMIST and healing of diabetic foot ulcers

Sayumi Tsuchiya[1] | **Suriadi**[2] | **Hiromi Sanada**[3,4] | **Junko Sugama**[5] | **Makoto Oe**[1]

[1]Department of Clinical Nursing, Division of Health Sciences, Institute of Medical, Pharmaceutical, and Health Sciences, Kanazawa University, Ishikawa, Japan

[2]Kitamura Wound Care Clinic Pontianak, West Borneo, Indonesia

[3]Global Nursing Research Center, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

[4]Department of Gerontological Nursing/Wound Care Management, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

[5]Research Center for Implementation Nursing Science Initiative, School of Health Sciences, Fujita Health University, Aichi, Japan

Correspondence
Makoto Oe, Department of Clinical Nursing, Division of Health Sciences, Institute of Medical, Pharmaceutical, and Health Sciences, Kanazawa University, 5-11-80 Kodatsuno, Kanazawa, Ishikawa 920-0942, Japan.
Email: moe-tky@umin.ac.jp

Abstract

A monitoring tool for the wound-healing process of diabetic foot ulcers (DFUs) was developed. It comprises seven domains, namely, depth, maceration, inflammation/infection, size, tissue type of the wound bed, type of wound edge, and tunnelling/undermining. It was named "DMIST" based on the initials of its domains. Although DMIST is useful for assessing wound-healing processes, the monitoring items related to wound healing remain unclear, thereby making the selection of optimal care based on the assessment difficult. We identified the relationship between the DMIST items and wound healing. This study was a secondary analysis of five previous investigations and was conducted using DMIST based on the diabetic foot ulcer assessment scale score and DFU images. Multivariate logistic regression was used to calculate odds ratios (ORs) and 95% confidence intervals (95% CIs) after simultaneously controlling for potential confounders. The examined DFU healing status revealed that some DFUs healed at 4 weeks from baseline, whereas some DFUs did not. Variables considered in the models were the scores of each DMIST domain. The study population comprised 146 Indonesian patients and 33 Japanese patients. Depth, maceration, and size were associated with DFU healing at 4 weeks from baseline [depth: OR = 0.317 (95% CI: 0.145-0.693, $P = 0.004$); maceration: OR = 0.445 (95% CI: 0.221-0.896, $P = 0.023$); size: OR = 0.623 (95% CI: 0.451-0.862, $P = 0.004$)]. Our findings suggest that appropriate management of maceration promotes DFU healing.

KEYWORDS

diabetic foot ulcers, maceration, wound healing

Key Messages

- This study revealed the relationship between the items of DMIST and wound healing
- Depth, maceration and size were associated with diabetic foot ulcer healing at 4 weeks from baseline
- Our findings suggest that appropriate management of maceration promotes diabetic foot ulcer healing

1 | INTRODUCTION

Diabetes mellitus (DM) is one of the global health issues. Approximately 463 million people were living with DM in 2019, and this number is expected to increase to 578 million in 2030 and 700 million in 2045.[1] Various chronic complications of DM are known, and diabetic foot ulcers (DFUs) are one of the serious complications of DM that deteriorate patients' quality of life. Global DFU prevalence is reported to be 6.3% (95% confidence interval [CI]: 5.4%-7.3%),[2] with an estimated lifetime incidence of 15%.[3]

The assessment of the wound-healing process, which is necessary to recommend continued or modified treatments, is essential for managing DFUs. Recently, a monitoring tool for the wound-healing process of DFUs was developed. It comprised of seven domains, namely, depth, maceration, inflammation/infection, size, tissue type of wound bed, type of wound edge, and tunnelling/undermining. Its scoring range is from 0 to 34. It was named "DMIST" based on the initials of its domains.[4]

A previous study revealed that DMIST is a reliable and content-valid tool for DFU.[4] Although DMIST is useful for assessing wound-healing processes across specialisations and nations, the monitoring items related to wound healing remain unclear, thereby making the selection of optimal care based on the assessment difficult. This study aimed to reveal the relationship between the items of DMIST and wound healing. We believe that the findings of this study will help in the selection of the most appropriate care for DFUs based on assessments.

2 | MATERIALS AND METHODS

2.1 | Materials and methods

This study was the secondary analysis of five previous investigations, which had already been published. The investigations involved a prospective cohort study of the effects of wound, ostomy and continence nursing care on the outcomes in patients with wounds[5]; an evaluation of the validity of the new diabetic foot ulcer assessment scale in Indonesia[6]; a randomised controlled trial for evaluating the effects of understanding wellbeing on psychological aspects and wound healing in patients with DFU recurrence[7]; a prospective cohort study for evaluating wound healing of DFUs using sea cucumber[8]; and a prospective observational study of the effects of a date and honey mixture in promoting recurrent DFU healing.[9] These studies were conducted in Indonesia and Japan from April 2013 to March 2019. Wound progression was assessed using the diabetic foot ulcer assessment scale (DFUAS)[6] for 4 weeks based on the actual DFUs in these investigations. For secondary analysis, wound progression was assessed by researchers using DMIST based on the DFUAS scores and DFU images. Healing is defined as complete epithelialization of the wound at 4 weeks from baseline based on observations using DMIST (total score = 0).

Data regarding patient characteristics, including demographic and clinical data, were collected at the beginning of each investigation. Collected data included age, sex, DM type, DM duration, type of DM treatment, HbA1c, and ankle brachial index (ABI) retrieved from medical records or currently available data. Data on wound characteristics included wound location, trigger of wound onset, and severity of wound (as assessed by the Wagner Ulcer Classification System).[10]

2.2 | Statistical analysis

The Mann–Whitney *U* test or independent *t*-test and chi-square test were used to compare patient characteristics between the groups. Before multivariate logistic regression analysis, multicollinearity was assessed using the correlation coefficients among each DMIST items. No item showed a correlation of ≥0.5. Multivariate logistic regression was used to calculate the odds ratios (ORs) and 95% CIs after controlling for potential confounders. Moreover, DFU healing status was examined. The examination revealed that some DFUs healed at 4 weeks from baseline, whereas some DFUs did not. Variables considered in the models were scores of each DMIST domain (depth, maceration, inflammation/infection, size, tissue type of wound bed, type of wound edge, and tunnelling/undermining). The model was adjusted for age and nationality. A *P*-value of <0.05 was considered significant. We conducted all analyses using the IBM SPSS Statistics for Windows version 25 (IBM Corp., Armonk, NY, USA).

2.3 | Ethical consideration

This study was conducted in accordance with the Declaration of Helsinki. The Medical Ethics Committee of Kanazawa University approved the previous studies (no. 549-3, 643-1, 652-1, 417, 49-1).

3 | RESULTS

Of the 256 potential subjects in the five investigations, 179 patients were included in the analysis. The reason for

TABLE 1 Participant characteristics

	n = 179	
Age (years) (n = 177)	56.6 ± 10.7	
Sex (n = 178)		
Male	70	(39.3)
Female	108	(60.7)
Nationality		
Indonesia	146	(81.6)
Japan	33	(18.4)
Type of DM (n = 175)		
Type 1	1	(0.6)
Type 2	174	(99.4)
Duration of DM (years) (n = 173)	7.9 ± 7.2	
Treatment of DM (n = 127)		
Insulin	22	(17.3)
Oral	92	(72.4)
Insulin and oral	13	(10.2)
HbA1c (%) (n = 134)	10.9 ± 2.5	
ABI (n = 159)	1.0 ± 0.2	

Note: n (%), mean ± SD.
Abbreviations: ABI, ankle brachial pressure index; DM, diabetes mellitus.

TABLE 2 Wound characteristics

	n = 179	
Trigger of wound onset (n = 130)		
Trauma	69	(53.1)
Burns	1	(0.8)
Callus	13	(10.0)
Unknown	47	(36.2)
Wound location		
Toe	57	(31.8)
Dorsal	25	(14.0)
Plantar	55	(30.7)
Lateral	9	(5.0)
Heel	18	(10.1)
Malleolus	13	(7.3)
Ankle	2	(1.1)
Wagner classification		
Grade 1	63	(35.2)
Grade 2	77	(43.0)
Grade 3	25	(14.0)
Grade 4	13	(7.3)
Grade 5	1	(0.6)
DMIST score		
Depth	2.5 ± 1.1	
Maceration	0.7 ± 0.9	
Inflammation/infection	1.2 ± 1.2	
Size	4.1 ± 2.4	
Tissue type of wound bed	1.7 ± 0.7	
Type of wound edge	2.6 ± 1.1	
Tunnelling or undermining	0.0 ± 0.3	
Total	12.9 ± 4.6	

Note: n (%), mean ± SD.

patient exclusion was that DFU healing could not be observed 4 weeks after the baseline. Healing was achieved in 4 weeks for 39 ulcers (21.8%). Baseline characteristics of the participants are summarised in Table 1. The average age of the patients was 56.6 years, and 60.7% were females. Moreover, 146 participants (81.6%) were Indonesian. The average duration of DM was 7.9 years, and 72.4% patients were receiving oral treatment. The characteristics of the wounds are listed in Table 2. Moreover, 57 (31.8%) wounds were located on the toe, and Wagner grade 2 or 3 (full-thickness) occurred in 57.0%.

The results shown in Table 3 indicate that HbA1c was significantly lower in the healing group (10.4 [8.7-12.2], n = 31) than in the non-healing group (11.7 [9.9-13.6], n = 103; $P = 0.012$, Mann–Whitney U test). Table 4 reports the partial regression coefficient, P-value, ORs, and 95% CIs from the multivariate logistic regression model, which was adjusted for age and nationality. The result of the Hosmer–Lemeshaw test was $P = 0.669$, and the percentage of correct classifications was 85.3%. Depth, maceration, and size were associated with DFU healing at 4 weeks from baseline [depth: OR = 0.317 (95% CI 0.145-0.693, $P = 0.004$); maceration: OR = 0.445 (95% CI 0.221-0.896, $P = 0.023$); size: OR = 0.623 (95% CI 0.451-0.862, $P = 0.004$)].

4 | DISCUSSION

To the best of our knowledge, this is the first study to report that depth, maceration, and size among DMIST items were associated with DFU healing at 4 weeks from baseline.

Among items of DMIST, we found that DFU healing was most significantly affected by maceration. Maceration can reduce skin barrier function. Without barrier protection, it is difficult to sustain physical injuries and thus skin breakdown.[11] Moreover, when tissue is macerated, it can become infected by organisms that prefer an environment with a high water activity.[12] Hence, the condition of the skin surface can be worsened. Another study showed that maceration can cause inner tissue damage of

TABLE 3 Comparison of participants' characteristics between healing and non-healing group

	Healing		Non-healing		*P*
Sex					
Male	18	(46.2)	52	(37.4)	0.323
Female	21	(53.8)	87	(62.6)	
Nationality					
Indonesia	31	(79.5)	115	(82.1)	0.705
Japan	8	(20.5)	25	(17.9)	
Type of DM					
Type 1	1	(2.6)	0	(0.0)	0.057
Type 2	37	(97.4)	137	(100.0)	
Treatment of DM					
Insulin	2	(9.5)	20	(18.9)	0.563
Oral	17	(81.0)	75	(70.8)	
Insulin and oral	2	(9.5)	11	(10.4)	
Age (years)	(n = 38)		(n = 139)		
	57.3 ± 12.0		56.5 ± 10.4		0.690
Duration of DM (years)	(n = 39)		(n = 134)		
	7.0	(0.5-13.5)	5.0	(0.5-9.5)	0.089
HbA1c (%)	(n = 31)		(n = 103)		
	10.4	(8.7-12.2)	11.7	(9.9-13.6)	0.012
ABI	(n = 34)		(n = 125)		
	1.0	(0.9-1.1)	1.0	(0.9-1.1)	0.695

Note: n (%), mean ± SD, median (IQR).
Abbreviations: ABI, ankle brachial pressure index; DM, diabetes mellitus.

TABLE 4 Results of the multivariate logistic regression model adjusted for age and nationality

	B	*P*	OR	95% CI
Depth	−1.148	0.004	0.317	0.145 to 0.693
Maceration	−0.809	0.023	0.445	0.221 to 0.896
Inflammation/infection	−0.171	0.694	0.843	0.359 to 1.976
Size	−0.473	0.004	0.623	0.451 to 0.862
Tissue type of the wound bed	−0.550	0.202	0.577	0.248 to 1.343
Type of wound edge	−0.314	0.194	0.731	0.455 to 1.173
Tunnelling or undermining	−9.390	0.999	0.000	0.000
Constant	6.008	0.027		

Note: Adjustment for age and nationality. Percentage of correct classifications: 85.3%.
Abbreviations: B, partial regression coefficient; CI, confidence interval; OR, odds ratio.

the skin.[13] Therefore, in the present study, maceration had a huge effect on DFU healing. A previous study examined the relationship between maceration and wound healing. It revealed that non-macerated wounds healed faster than macerated wounds.[14] Similar to the results of the previous study, the results of our study indicated that maceration affected DFU healing.

The results of the correct study regarding depth were as expected. In a previous study of the assessment scale for the healing process of pressure injuries, depth was excluded from the analysis because it showed multicollinearity with several other assessment items.[15] Although multicollinearity was not confirmed in this study, it was included in the analysis. The presence of the effect of wound healing on depth is an easily predictable result as it directly indicates the wound status until healing.

Moreover, regarding the size, the results of this study were as we had expected. The relationship between

wound healing and wound size of pressure injury has been reported in previous studies.[15,16] The pathology of DFU is different from pressure injuries. However, the effect of wound healing on size is also an easily predictable result as it directly indicates the wound status until healing as with depth.

The results of this study suggested that appropriate management of maceration promotes DFU healing. It is important to eliminate the causes leading to excess exudate. Wound infection can cause an increase in exudate volume.[17] A high blood glucose level is associated with increased infection rates.[18] Therefore, the management of infection and blood sugar is necessary to control the amount of exudate. Moreover, selecting appropriate external medicines or dressing materials based on the level of exudate is important.[19] Dressing replacement at the appropriate time is essential for managing maceration.

This study has two limitations. First, data were lacking for several variables, although this was a limitation of the secondary analysis from previous studies. Second, this study was conducted in Indonesia and Japan. The treatment procedure of DFU varies according to country; therefore, this must be considered when interpreting the present result to other countries. Despite these limitations, the results clarified that each item of DMIST has a different degree of influence on DFU healing. As a future study, a score weighting of each item on DMIST is needed to compare the wound-healing process between different DFUs in different patients.

In conclusion, this study investigated the relationship between items of DMIST and wound healing by secondary analysis of the previous five investigations. Depth, maceration, and size were associated with DFU healing at 4 weeks from baseline. Appropriate management of maceration was suggested to promote DFU healing.

ACKNOWLEDGEMENTS

We thank Enago, Crimson Interactive Pvt. Ltd. (www.enago.ip) for English language editing.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Sayumi Tsuchiya https://orcid.org/0000-0002-0204-7772

Suriadi https://orcid.org/0000-0001-5794-7826

REFERENCES

1. Saeedi P, Petersohn I, Salpea P, et al. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: results from the international diabetes federation diabetes atlas, 9th edition. *Diabetes Res Clin Pract*. 2019;157:107843.
2. Zhang P, Lu J, Jing Y, Tang S, Zhu D, Bi Y. Global epidemiology of diabetic foot ulceration: a systematic review and meta-analysis. *Ann Med*. 2017;49(2):106-116.
3. Schaper NC, Apelqvist J, Bakker K. The international consensus and practical guidelines on the management and prevention of the diabetic foot. *Curr Diab Rep*. 2003;3(6):475-479.
4. Oe M, Yotsu RR, Arisandi D, et al. Validity of DMIST for monitoring healing of diabetic foot ulcers. *Wound Repair Regen*. 2020;28(4):539-546.
5. Sakai Y, Yokono T, Mizokami Y, et al. Differences in the working pattern among wound, ostomy, and continence nurses with and without conducting the specified medical act: a multicenter time and motion study. *BMC Nurs*. 2016;15:69.
6. Arisandi D, Oe M, Roselyne Yotsu R, et al. Evaluation of validity of the new diabetic foot ulcer assessment scale in Indonesia. *Wound Repair Regen*. 2016;24(5):876-884.
7. Imran AD, Haryanto S, Oe M, et al. Effects of understanding wellbeing on psychological aspects and wound healing in patients with diabetic foot ulcer recurrence: a pilot randomized controlled trial. *Diabetic Foot J*. 2018;21(2):119-126.
8. Haryanto OK, Suriadi NG, Oe M, et al. A prospective observational study using sea cucumber and honey as topical therapy for diabetic foot ulcers in Indonesia. *J Wellness Health Care*. 2018;41(2):41-56.
9. Imran OK, Supriadi H, Oe M, et al. Date and honey mixture compared with honey alone for diabetic foot ulcer healing. *J Jpn Soc Wound, Ostomy Continence Manag*. 2021;25(3):597-610.
10. Wagner FW. The diabetic foot. *Orthopedics*. 1987;10(1):163-172.
11. Cutting KF, White RJ. Maceration of the skin and wound bed 1: its nature and causes. *J Wound Care*. 2002;11(7):275-278.
12. Troller JA, Stinson JV. Influence of water activity on the production of extracellular enzymes by Staphylococcus aureus. *Appl Environ Microbiol*. 1978;35(3):521-526.
13. Mugita Y, Minematsu T, Huang L, et al. Histopathology of incontinence-associated skin lesions: inner tissue damage due to invasion of proteolytic enzymes and bacteria in macerated rat skin. *PLoS One*. 2015;10(9):e0138117.
14. Haryanto H, Arisandi D, Suriadi S, et al. Relationship between maceration and wound healing on diabetic foot ulcers in Indonesia: a prospective study. *Int Wound J*. 2017;14(3):516-522.
15. Matsui Y, Furue M, Sanada H, et al. Development of the DESIGN-R with an observational study: an absolute evaluation tool for monitoring pressure ulcer wound healing. *Wound Repair Regen*. 2011;19(3):309-315.
16. Bergstrom N, Smout R, Horn S, Spector W, Hartz A, Limcangco MR. Stage 2 pressure ulcer healing in nursing homes. *J Am Geriatr Soc*. 2008;56(7):1252-1258.
17. Cutting K, White R, Mahoney P, Harding K. Clinical identification of wound infection: a Delphi approach. In: Association EWM,

ed. *Position Document: Identifying Criteria for Wound Infection*. Vol 32. London: MEP Ltd; 2005:6-9.
18. Martin ET, Kaye KS, Knott C, et al. Diabetes and risk of surgical site infection: a systematic review and meta-analysis. *Infect Control Hosp Epidemiol*. 2016;37(1):88-99.
19. Hollinworth H. Challenges in protecting peri-wound skin. *Nurs Stand*. 2009;24(7):53-54, 6, 8 passim.

How to cite this article: Tsuchiya S, Suriadi, Sanada H, Sugama J, Oe M. Relationship between items of DMIST and healing of diabetic foot ulcers. *Int Wound J*. 2023;20(2):345-350. doi:10.1111/iwj.13880