

Indicators of a moist wound environment and care to maintain a moist environment for early healing: A scoping review

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SUMMARY: Although maintaining a moist environment is important for wound healing, excess moisture can delay wound healing. Furthermore, recommended assessment methods for moist environments in the latest consensus guidelines are subjective. This scoping review aimed to map indicators to assess the moist environment in a wound and summarize the effectiveness of wound healing care in maintaining a moist environment, as assessed using these indicators. We searched four databases, the Medical Literature Analysis and Retrieval System On-Line, Cumulative Index to Nursing and Allied Health Literature, PubMed, and the Japan Medical Abstracts Society database, using a combination of chronic wound- and moisture-related terms. Independent researchers screening the articles based on the inclusion criteria and extracting relevant data afterward. After screening 2,727 articles, eight met the inclusion criteria: original articles/case studies, studies involving patients with chronic wounds, studies on care to maintain a moist wound environment, and studies assessing wound healing and moist wound environment. The articles included in this review demonstrated that dressings that absorb or hydrate exudates and care decisions based on the moisture content of the wound surface were effective care strategies for wound healing. Additional research is required to determine the best objective indicator for the assessment of a moist wound environment because despite the numerous existing indicators, only few reference values for healing have been reported.

Keywords: Chronic wounds, hard-to-heal wounds, maceration, exudate, wound healing

1. Introduction

A chronic wound fails to progress through the normal phases of healing in an orderly and timely manner (1). The condition has a high prevalence, estimated at 2.21 per 1000 individuals (2). In addition, chronic wounds exert significant effects on patients, including prolonged hospitalization (3), decreased quality of life (4), increased medical costs (4), and increased risk of death (5). Thus, preventing delayed wound healing is important in wound management.

In recent years, moist wound treatment has gained widespread acceptance as the gold standard for wound management. Moreover, a moist wound environment leads to faster and better healing. Specifically, it facilitates autolytic debridement, activates collagen synthesis, facilitates and promotes keratinocyte migration over the wound surface, and supports the presence and function of nutrients, growth factors, and other soluble

mediators in the wound microenvironment (6). However, excess moisture causes maceration (skin softening and breakdown due to prolonged moisture exposure) of the peri-wound skin (7). Maceration of the peri-wound skin has a significant effect on wound healing (8,9), and it can reduce the skin barrier function, leading to skin breakdown due to decreased susceptibility to physical injuries (10). Therefore, it is necessary to implement wound care that can maintain a moist environment suitable for wound healing, without insufficient or excess moisture.

The consensus document on wound exudate recommends assessing wound exudates based on gross findings on the wound surface and dressings and considering changes in care accordingly, such as using a more absorbent dressing or more frequent dressing changes (11). However, these assessment methods are generally quite subjective and vary in complexity and ease of use; consequently, no one approach is ideal (12).

In addition, for inexperienced caregivers, making care choices based on the results of these assessments can be difficult.

The questions that guided this scoping review were: "Which indicators can be used to assess moist wound environments?" and "To what extent does the maintenance of a moist environment, as assessed using the evaluated indicators, lead to effective wound healing?" The objectives of this scoping review were to 1) map indicators for assessing the moist environment and 2) summarize the effectiveness of wound healing care in maintaining a moist environment, as assessed using these indicators.

2. Materials and Methods

2.1. Protocol and registration

This review protocol was not registered. This scoping review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (13).

2.2. Eligibility criteria

The eligibility criteria for this review were as follows: 1) studies investigating patients with chronic wounds; 2) studies on care to maintain a moist wound environment; 3) studies assessing wound healing; and 4) studies assessing a moist wound environment. We included studies that included participants of all ages, regardless of the clinical setting and publication year. The study languages were limited to English and Japanese, and only original articles and case reports were included in the scoping review.

2.3. Information sources

The following bibliographic databases were searched for unlimited periods: Medical Literature Analysis and Retrieval System On-Line, Cumulative Index to Nursing and Allied Health Literature, and PubMed. In addition, we searched the Japan Medical Abstracts Society (JAMAS) database for articles in Japanese.

2.4. Search terms

The following search terms were used: (1. chronic wound, 2. hard-to-heal wound, 3. pressure injuries, 4. pressure injury, 5. leg ulcer, 6. diabetic foot ulcer, 7. ischemic ulcer, 8. ischemic preconditioning, 9. stasis dermatitis, 10. stasis ulcer) AND (1. moist environment, 2. moisture, 3. moist). The same combination of keywords in Japanese was used to search the JAMAS database.

2.5. Selection of sources of evidence

The search results were imported into Rayyan (Qatar Computing Research Institute, Doha, Qatar) and duplicates were eliminated (14). Article titles and abstracts were independently screened by three groups of researchers (KI, YK, KT, and RYa; KN, HH, YM, and RYo; and MK and AY). Articles that did not meet the eligibility criteria were excluded. Subsequently, the remaining full-text articles after the first screening were independently evaluated according to the inclusion criteria by three groups of researchers. Disagreements regarding the study selection were resolved through a discussion.

2.6. Data charting process

A data chart was developed to determine the data items to be extracted through a discussion. Eight authors were divided into pairs (KI and HH, YK and YM, KT and KN, and RYa and RYo), and data were extracted from the selected studies by the authors. Thereafter, the data were verified by 10 authors, including MK and YN. Discrepancies in the extracted data were resolved through discussions.

2.7. Data items

The following data were extracted: (a) study authors, year of publication, and country; (b) study design/participants; (c) wound type; (d) indicator of a moist environment; (e) evaluation methods of the indicators; (f) details of wound care; and (g) outcomes related to wound healing and a moist environment.

2.8. Synthesis of results

Data on study authors, year of publication, country, study design/participants and wound type were shown in Table 1. Studies were grouped according to the type of wound care. These data are presented in Tables 2 and 3.

3. Results

3.1. Selection of sources of evidence

The initial search yielded 2,727 studies, and after the removal of the duplicate studies, 2,265 studies remained. After subsequent title and abstract screening, 2,197 articles were excluded. Sixty studies were further excluded because they failed to meet the inclusion criteria for full-text screening. Thus, eight articles were included in the scoping review. Figure 1 presents the PRISMA-ScR flowchart used in this review.

3.2. Characteristics of sources of evidence

Table 1. Characteristics of the included studies

Study author/year/country	Study design	Participants	Wound type
Furuta <i>et al.</i> , 1997, Japan (in Japanese) ¹⁹	Case report	N = 4 A 75-year-old male, 58-year-old male, 61-year-old male, and 60-year-old female	Pressure injuries on the sacrum
Nagata <i>et al.</i> , 2000, Japan (in Japanese) ²⁰	Case report	N = 2 A 50-year-old male and an 86-year-old female (Both with poor respiratory and nutritional conditions)	Pressure injuries, classified as stage IV (IAET classification), on the sacrum
Meuleneire <i>et al.</i> , 2007, Germany ¹⁵	Prospective observational study	N = 74 The mean age was 69.5 years (± 18); 45 women (61%) and 29 men (39%) participated.	Venous leg ulcers, arterial leg ulcers, mixed leg ulcers, pressure injuries, diabetic foot ulcers, tumors, acute traumatic wounds, burns, and others (e.g. split-thickness skin graft donor site)
Tachi <i>et al.</i> , 2008, Japan (in Japanese) ²²	Pre-post comparison study	N = 50 The average age was 77.3 years (SD = 13.22); 29 women (58%) and 21 men (42%) participated.	Pressure injuries on the sacrum Venous leg ulcers, arterial leg ulcers, mixed leg ulcers, pressure injuries, and diabetic foot ulcers.
Ivins <i>et al.</i> , 2018, Germany ¹⁶	Prospective observational study	N = 15 The average age was 64.6 years (SD = 15.2); five women (33.3%) and 10 men (66.7%) participated.	Wound exudation was "heavy" in three (20%), "moderate-to-low" in 11 (73.3%), and "light" in one (6.7%) wound.
Koyanagi <i>et al.</i> , 2019, Japan ²¹	Prospective cohort study	N = 16 The mean age of three groups ranged from 78 to 86 years; 50% or more of participants were male.	Pressure injuries (at a depth deeper than the dermis) diagnosed as being in a critical colonization state by a dermatologist or wound ostomy continence nurses. Critical colonization is a condition characterized by the absence of evident symptoms of infection and an intermediate state between colonization and overt infection.
Forde <i>et al.</i> , 2020, Poland ¹⁷	Pre-post comparison study	N = 53. There is no data on the characteristics of the participants.	Pressure injuries, diabetic foot ulcers, leg ulcers, surgical wounds, trauma wounds, and burns.
Zahel <i>et al.</i> , 2022, Germany ¹⁸	Prospective observational study	N=44 The average age was 66.9 years (SD = 15.94); 22 women (50%) and 22 men (50%) participated.	Venous leg ulcers, mixed leg ulcers, and diabetic foot ulcers

IAET, International Association for Enterostomal Therapy; SD, Standard deviation.

Table 2. Care decision based on wound moisture content

Study author	Objective indicators for a moist environment	Subjective indicators for a moist environment	Evaluation methods of the indicators	Wound care	Outcomes
Furuta <i>et al.</i> ¹⁹	Moisture content of the wound surface	NA	During wound care, the moisture content was measured by applying the Moisture Checker® (Scalar Corporation, Japan) to the wound surface.	Based on the moisture content, a prescription was selected from seven types of topical agents capable of absorbing or supplying moisture. Film dressings (Bioclusive®, Smith & Nephew, UK) or polyurethane foam dressings (Hydrocoll®, Paul Hartmann AG, Germany) were used and generally replaced once daily.	By maintaining the moisture content at about 70%, the wound area of Case 1 (category 3) went from 7.0 cm × 5.0 cm to 2.0 cm × 2.0 cm after 1 month of treatment; Case 2 (category 4) healed from 10.0 cm × 7.5 cm in 4 months; Case 3 (category 4) healed from 10.0 cm × 8.0 cm in 4 months; and Case 4 (category 4) improved from 12.0 cm × 6.7 cm to 6.0 cm × 7.5 cm in 4 months.
Nagata <i>et al.</i> ²⁰	Moisture content of the wound surface	The degree of exudate absorption by the gauze	The moisture content was measured immediately after removing a wound dressing by applying the Moisture Checker® (Scalar Corporation, Japan) to the wound surface.	Based on the amount of wound exudate, the moisture content of the topical agents, moisture absorption capacity of the base material of the topical agents, and moisture content of the wound surface, a prescription was selected from seven types of topical agents capable of absorbing or supplying moisture. After cleaning the wound with saline and disinfecting with iodine, Bescitin WA (Kobayashi Pharmaceutical Co., Ltd., Japan) was applied, followed by the application of ointment, gauze, and film dressing (Bioclusive®, Smith & Nephew, UK).	In Case 1, the wound area reduced from 8.0 × 6.0 cm to 3.5 × 2.5 cm after 5 months of treatment selected based on the degree of exudate. In Case 2, by maintaining the moisture content at 60–70%, the wound area decreased from 11.0 × 8.0 cm to 1.0 × 0.5 cm after 5 weeks of treatment.

NA, Not Applicable; UK, United Kingdom of Great Britain and Northern Ireland.

Table 3. Application of dressings to manage wound exudates

Study author	Objective indicators for a moist environment	Subjective indicators for a moist environment	Evaluation methods of the indicators	Wound care	Outcomes
Meuleneire <i>et al.</i> ¹⁵	Maceration	NA	At each dressing change, the investigators evaluated the condition of the wound and perilesional skin. Overall, five dressing changes were documented, or until complete healing occurred.	Hydroactive-impregnated dressing (Hydrotul, Paul Hartmann AG, Germany) was used in accordance with the manufacturer's recommendations. In the majority, there was a 2–3 day interval between the dressing changes.	The wound size decreased from 4.7cm (SD±4.3) × 3.2cm (SD±3.4) to 2.9cm (SD±4.1) × 2.1cm (SD±2.9). Twenty-two (29%) wounds were completely healed by the observational period. The percentage of perilesional skin without maceration increased from 43% (32 wounds) to 66% (49 wounds) at the final examination.
Tachi <i>et al.</i> ²²	NA	Level of lateral leakage of wound exudate from the wound dressing	If there was no lateral leakage from the wound dressing, it was classified as a "marked effect." If there was minimal leakage, it was classified as "effective." If there was frequent leakage, it was classified as "ineffective." The researcher evaluated and recorded this every week.	After cleaning with sterile saline, Carboxymethylcellulose Sodium Silver (Aquacel® Ag, ConvaTec, USA) was applied and covered with gauze or a film dressing. The dressing was changed according to the amount of exudate (ranging from daily changes to a maximum of 7 days). Surgical debridement was performed as an adjunctive therapy when necessary. The treatment period was 8 weeks.	During the observation period, 14 cases (35.9%) healed. The average wound area contraction rate was 63.9%, with an average contraction area of 0.64 cm ² per week. The level of lateral leakage of wound exudate from the wound dressing was rated as effective or marked effective in 44 of 49 cases (89.7%).
Ivins <i>et al.</i> ¹⁶	Maceration	Level of exudate absorption and wound hydration by dressing	The clinician conducted a visual assessment for maceration; a relative score was used to score maceration of 0 (no maceration), 1 (minimal maceration), 2 (moderate maceration), and 3 (excessive maceration and need to withdraw patient from study). In addition, they evaluated the effectiveness of the dressing, and presence of copious wound exudates was monitored at each dressing change.	After wound cleansing and sharp debridement if necrotic tissue was present, a gelling fiber dressing, which is made from sodium carboxymethyl cellulose and strengthening cellulose fibers (Biosorb, Acelity, UK) was applied in addition to standard of care. Wounds were treated until healing or for a maximum of 4 weeks.	During 4 weeks of treatment, granulation was completed in eight wounds (53.3%), 75% coverage in two wounds (13.3%), 50% coverage in three wounds (20.3%), and 25% coverage in two wounds (13.3%). No maceration was found in 10 (66.7%) wounds and minimal maceration in five (33.3%) wounds. Dressing's ability to absorb and retain wound exudates was rated "excellent" or "very good" in 80% of cases, "moderate" in 10%, and "poor" in 10%.

NA, Not Applicable; UK, United Kingdom of Great Britain and Northern Ireland; USA, the United States of America.

Table 3. Application of dressings to manage wound exudates (continued)

Study author	Objective indicators for a moist environment	Subjective indicators for a moist environment	Evaluation methods of the indicators	Wound care	Outcomes
Koyanagi <i>et al.</i> ²¹	Change rate of exudate volume; change rate of the difference in the stratum corneum hydration between healthy skin and ulcer-surrounding skin	NA	Exudate volume was measured by the ESTimation method, which estimates daily exudate volume (mL) using a regression equation utilizing several sub-scores of DESIGN-R®, which is a tool to score the severity of pressure ulcers. The stratum corneum hydration of the skin surrounding wounds was measured using a portable moisture meter (Mobile Moisture HP10-N®, Integral Co., Japan).	Group A, hydrating ointment with infection control or low exudate-absorption dressing material; Group B, high exudate-absorption dressing material; and Group C, hydrating ointment with exudate-absorption and infection control. Wounds were assessed at two time points: at baseline and after 1 week.	The total score of DESIGN-R was lower in Group C than in the other groups, indicating a lower effect on wound healing (Group A: -0.12 vs. Group B: -0.11 vs. Group C: -0.01). The median change rate of exudate volume was 0 in each group. Regarding the change rate of the difference in the stratum corneum hydration, the sum of the negative values in Group A was 0.52, and the sum of the values in Groups B and C were different (-0.97 and -0.87, respectively).
Forde <i>et al.</i> ¹⁷	Maceration	Level of moist environment maintenance <i>via</i> dressing	NA	After evaluating the wound, silicone-form dressing was used based on the exudate level (ActivHeal® Silicone Foam [Advanced Medical Solutions Ltd., Cheshire, UK] was used for wounds with moderate to heavy exudate levels, and ActivHeal® Silicone Foam Lite [Advanced Medical Solutions Ltd.] was used for wounds with low exudate levels.) Wound healing was evaluated after 6 weeks.	The number of macerated cases decreased. More than 90% of users rated the maintenance of moist environment as "satisfied" or "very satisfied." [ActivHeal® Silicone Foam] The mean wound length, width, and depth were 4.2 cm, 2.6 cm, and 0.2 cm, respectively at baseline; at the end of the evaluation the values were 3.4 cm, 1.8 cm, and 0.2 cm, respectively. The number of macerated cases decreased. [ActivHeal® Silicone Foam Lite] The mean wound length, width, and depth were 3.4 cm, 1.9 cm, and 0.2 cm, respectively, at baseline; at the end of the evaluation the values were 2.7 cm, 1.4 cm, and 0.1 cm, respectively.
Zahel <i>et al.</i> ¹⁸	Maceration	Level of exudate absorption and wound hydration <i>via</i> dressing	Exudation and wound hydration were evaluated through interviews with participating physicians and care specialists.	Patients used bacterial cellulose hydrogel dressings (hydroactive BC wound dressing, Smith & Nephew, UK). There are no details regarding the application method.	There was a significant reduction in the mean wound size and depth over the study period of 28 days ($p < 0.006$). The case of healthy peri-wound skin was significantly increased. Users rated the exudate uptake as "good" to "satisfactory" and wound hydration as "good."

NA, Not Applicable; UK, United Kingdom of Great Britain and Northern Ireland; USA, the United States of America.

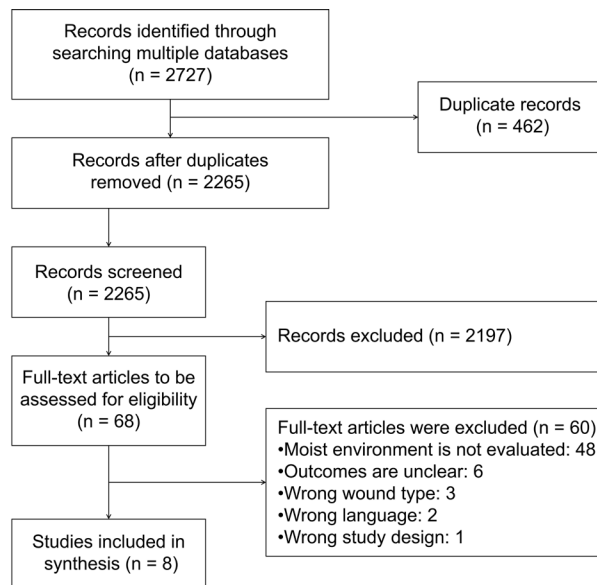


Figure 1. Flow chart of the present scoping review.

The characteristics of the included studies are summarized in Tables 1. Six of the studies were original articles and two were case studies. The included studies were published between 1997 and 2022, and they were conducted in Japan (four studies), Germany (three studies), and Poland (one study).

The number of participants in the studies was 2–74 (Table 1). Regarding wound types, seven studies focused on pressure injuries, four on diabetic foot ulcers, three on venous leg ulcers, and three on mixed leg ulcers. Some studies focused on more than one wound type (15–18).

3.3. Synthesis of results

3.3.1. Indicators of a moist environment

Four objective indicators were reported (Tables 2 and 3): the moisture content of the wound surface (19,20); number of maceration cases (15–18); change rate of exudate volume (21); and change rate of the difference in the stratum corneum hydration between healthy and ulcer-surrounding skin (21). In addition, five subjective indicators were reported: the degree of exudate absorption by the gauze (20); level of lateral leakage of wound exudate from the wound dressing (22); level of exudate absorption by dressing (16,18); level of moist environment maintained *via* dressing (17); and level of wound hydration *via* dressing (16,18). These indicators were evaluated by raters such as clinicians. Among these indicators, only the moisture content of the wound surface was mentioned as effective for wound healing, which was recommended to maintained at approximately 60–70% (19,20).

3.3.2. Care decision based on wound moisture content

Two studies evaluated the moisture content of the wound surface, and medications were selected to either supply or absorb moisture to regulate wound surface moisture (Table 2). Consequently, it was confirmed that maintaining a moisture content of approximately 70% led to reduced wound area (19,20).

3.3.3. Application of dressings to manage wound exudates

Six studies were conducted on dressings for the management of wound exudates (Table 3). The dressings investigated were a hydroactive triglyceride-based carboxymethylcellulose granules-containing dressing (15); sodium carboxymethylcellulose silver-containing dressing (22); gelling fiber dressing made from sodium carboxymethylcellulose and strengthening cellulose fibers (16); dressing made of polyurethane foam pad and hydrophobic soft silicone layer (17); and carbohydrate polymer bacterial cellulose dressing (18). The use of these dressings resulted in a reduction in wound size (15,17,18), improvement in wound area contraction rate (22), and granulation formation (16). In addition, a decrease in maceration cases associated with the use of these dressings was reported (15–18). Furthermore, users rated high the lateral leakage of wound exudates from the wound dressing (22), exudate absorption and wound hydration (16,18), and maintenance of a moist wound environment (17).

4. Discussion

4.1. Summary of evidence

This is the first scoping review summarizing the available evidence on indicators for assessing moist wound environments and its effectiveness on wound healing. We identified six original studies and two case studies published between 1997 and 2022. Nine objective and subjective indicators were used to evaluate the moist environment. In addition, two categories of care for maintaining a moist wound environment were reported: care decisions based on wound moisture content and the application of dressings to manage wound exudates, both of which were highly effective in wound healing.

4.2. Indicators of a moist wound environment

In the studies included in this review, the indicators of a moist wound environment included not only subjective assessments, which may vary among raters, but also objective assessments. In particular, the measurement of the moisture content of the wound surface allows easy real-time and non-invasive assessment by anyone who learns how to use the measurement device (19). Furthermore, the moisture content of the wound surface was the only indicator for which a reference value suitable

for healing was mentioned (19,20). Thus, it is likely to be highly useful for wound management. However, because a wide variety of indicators were reported in the literature, this review alone cannot determine the most effective indicator for moist environment assessment. Moreover, because most indicators lack reference values for healing, it is difficult to incorporate them into treatment decisions. Therefore, it is necessary to compare objective indicators to clarify the most useful indicators for maintaining a moist wound environment and investigate the reference values of these indicators.

4.3. Care to maintain a moist wound environment

Two studies investigated topical agents that supply or absorb moisture based on the measurement of the moisture content of the wound surface (19,20). These studies confirmed wound reduction and healing, indicating the appropriateness of the care decision. In addition, wearable devices have recently been developed to measure the moisture content of the wound surface and wound dressing (23,24). Based on these results, the moisture content of the wound surface will increasingly become a simple and effective indicator for assessing a moist wound environment. However, the number of individuals investigated in these studies was four in one study (19) and two in the other study (20). Thus, there is insufficient evidence to suggest that moisture content is the best indicator for assessing a moist wound environment. Therefore, measurement of moisture content and care protocols based on this assessment need to be established in studies with larger sample sizes.

Dressings have been investigated as the primary method of wound care for maintaining a moist environment and promoting early wound healing. In the studies included in this review, the use of dressings incorporating materials with exudate absorption and hydration functions, such as carboxycellulose (15,22), gelling fibers (16), polyurethane foam (17), and bacterial cellulose (18), prevented complications, such as maceration, and delayed healing owing to excess moisture in the wound environment. Thus, as recommended by a previous consensus document (11), the use of dressings with high absorbency and excellent moisture hydration are likely to be effective in maintaining a moist environment. However, the studies included in this review focused on comparisons with standard treatments; thus, the criteria for dressing selection were not clear. Therefore, studies that compare dressings that absorb and hydrate exudates to identify the dressing that is most effective in maintaining a moist environment are warranted.

4.4. Limitations of the included literature

Most studies included in this review were case reports, cohort studies, or pre-post comparison studies with small

sample sizes, yielding relatively low levels of evidence. Therefore, randomized controlled trials with high levels of evidence are required to validate the identified indicators that can assess moist environments suitable for early wound healing. As such, no specific indicators or care methods can currently be recommended based on the existing literature.

Furthermore, the studies span a long time period, from 1997 to 2022; caution is therefore warranted regarding potential variations in results due to differences in study periods and advances in wound care technologies. Notably, studies reporting care selection based on indicators of a moist environment were limited to only a few early studies published in 1997 (19) and 2000 (20); as such, whether similar results would be obtained with current wound care products and assessment devices remains unclear. Therefore, further validation using modern products and technologies is warranted.

In addition, the included studies were geographically concentrated in Japan ($n = 4$), Germany ($n = 3$), and Poland ($n = 1$), with no reports from other regions in Africa, the Americas, or Oceania. Given the potential differences in race, culture, and medical practices across regions, caution is required when generalizing these findings, and further studies from diverse countries are desirable.

4.5. Limitations of the review

This scoping review had some limitations. The review focused on studies in English and Japanese languages, therefore, results from studies in other languages were excluded. Thus, there may be bias in the race, healthcare system, and cultural background of the target population. In addition, the eligibility criteria in this review included that the study assessed both wound healing and the moist wound environment. Accordingly, studies that examined dressings to manage exudates were excluded except they did not assess the moist environment.

5. Conclusion

This scoping review summarized the indicators for assessing the moist environment and the effectiveness of wound healing care in the maintenance of a moist environment. The articles included in this review showed that the application of dressings that absorb or hydrate exudates and care decisions based on the moisture content of the wound surface are effective in wound healing. However, there are a variety of indicators for assessing a moist environment, and further studies comparing the objective indicators are warranted.

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