SYSTEMATIC REVIEW

An evaluation of the burden of periwound skin maceration in wound care and the identification of gaps in clinical evidence: a scoping review

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Abstract

Aim This scoping review seeks to evaluate the burden of periwound skin maceration in wound care and identify gaps in clinical evidence.

Methods A scoping review was conducted using Medline and manual searches (including in Google Scholar). Keywords related to maceration and acute/hard-to-heal wounds were used. Outcomes focused on identifying periwound maceration and its clinical consequences

Results In all 59 articles were included: eight randomised controlled trials (Oxford Centre of Evidence-Based Medicine (OCEBM) Level 2), 22 non-randomised trials or observational studies (Level 3), and 24 case series/case reports (Level 4). Five articles involved surveys or image-based assessments. Evidence suggests that maceration negatively affects healing time, pain, quality of life and treatment costs. Few studies considered maceration as a primary outcome, and there is a lack of validated assessment tools.

Conclusion Periwound maceration remains a major challenge in managing hard-to-heal wounds. Evidence is limited by methodological and clinical variability, alongside generally low study quality. Inconsistent study designs and outcome measures create further gaps. A key gap is the absence of a validated tool to identify and measure maceration. Developing and adopting such a tool would greatly support clinicians in managing this issue.

Keywords maceration, periwound skin, quantification tool.

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Introduction

Effective management of wound exudate is crucial in wound care, as it significantly impacts treatment outcomes, patient comfort, and overall treatment efficiency.[1,2] Wound exudate plays an important role in acute wound healing, as it helps maintain a moist environment that encourages cellular activity and tissue regeneration.[1] However, if exudate is not managed properly – especially in hard-to-heal wounds – it can lead to various complications, such as periwound maceration.[3,4]

Exudate management presents several challenges across wound healing, patient quality of life, and clinical efficiency (Table 1). Poorly managed exudate can lead to maceration, periwound skin damage, and a heightened risk of infection, all of which delay healing.[5] For patients, excessive or poorly controlled exudate contributes to pain, malodour, social isolation, and psychological distress, including feelings of helplessness.[6,7] Clinically, ineffective exudate control results in increased dressing changes, product wastage, higher treatment costs, prolonged healing times and greater demands on nursing time.[7-9]

Table 1. Challenges of exudate management

Wound healing	Quality of life	Clinical efficiencies
• Maceration • Skin damage • Increased infection risk	• Mental health • Pain • Social isolation • Malodour • Helplessness	• Increased waste • Increased costs • Delayed healing • Increased nursing time

Periwound maceration is the softening and breakdown of healthy skin around a wound caused by prolonged exposure to moisture.[10] (The periwound area is defined as the area of skin between the wound's edge to 4cm beyond the edge[11]). A recent consensus definition describes the appearance of maceration in skin of lighter tones as the wrinkled, soggy, and/or soft periwound skin occurring due to exposure to moisture, usually presenting as white or pale colouration (shiny, grey, purple or darker discolouration in darker skin tones).[11] This condition not only compromises the skin's integrity making the skin likely to breakdown[12] but also delays healing by damaging wound margins, enlarging wound area, and increasing susceptibility to infection.[1,2] Moreover, when the skin becomes macerated, it loses its natural barrier function, providing a more suitable environment for bacteria and increasing the risk of complications, such as cellulitis or further wound deterioration.[13,14] In addition, patients with macerated periwound skin often experience elevated discomfort, itching and/or pain, which can negatively affect their quality of life and limit their mobility.[15]

There are several factors that can lead to maceration. The most common cause is excessive wound exudate, particularly when dressings fail to effectively manage the fluid – whether that's due to inadequate absorption or leakage from poor sealing at the wound edges.[16] Other contributing factors include improper dressing choices, prolonged wear times, or frequent changes without adequate skin protection.[17,18] These challenges highlight not only the physiological aspects of wound management but also potential shortcomings in clinical practices, such as insufficient wound assessments or suboptimal treatment planning.

Maceration is particularly prevalent in hard-to-heal wounds, such as venous leg ulcers, diabetic foot ulcers, and pressure injuries — conditions often associated with high levels of exudate.[15] Wound exudate is frequently excessive in leg and foot ulceration, particularly in venous leg ulcers, due to a combination of physiological and pathological processes.[19] Venous hypertension, a hallmark of chronic venous insufficiency, leads to elevated hydrostatic pressure within the capillaries increasing capillary filtration, causing plasma and proteins to leak into the interstitial tissues and wound bed. This process is compounded by the persistent release of inflammatory mediators, including histamine and pro-inflammatory cytokines, which enhance capillary permeability and further exacerbate fluid leakage. Such alterations in microvascular dynamics contribute to the sustained production of exudate commonly observed in chronic wounds.[19] In addition, although wound healing requires proteinase (protein-degrading) activity, the balance between tissue breakdown and repair seen in acute wound healing is disturbed.[20] Proteinase levels become abnormally elevated in chronic wound exudates leading to elevated peri-wound tissue irritation and potential for tissue destruction of already-susceptible maceration peri-ulcer skin.[21] The prevalence of periwound maceration is not well documented, but is noted to be "substantial",[13] with one study suggesting approximately 30% with diabetic foot ulceration.[22] Despite its frequency, maceration tends to be overlooked and under-reported, which underscores the importance of consistent assessment, effective prevention strategies, and better education in clinical settings.

Periwound maceration can be variable and sometimes difficult to identify. It often presents as a whitening or paleness of the skin, which can be challenging to assess in individuals with dark skin tones[23] although it has been suggested that maceration may be easier to identify.[24] The degree of maceration can vary from mild skin softening to significant breakdown. It tends to be localised to the immediate wound edge or may extend further into the surrounding skin, depending on the source and duration of moisture exposure.[15] The periwound skin is at greater risk from damage as compared with healthy skin because it is affected by tissue inflammation.[25]

Once an assessment of the level of exudate produced by a wound has been conducted, effective exudate management is facilitated by choosing the most appropriate wound dressing able to handle the level of exudate being produced.[26] This is particularly important as the wound's characteristics vary between patients which will influence the appropriate dressing choice, and usage (such as dressing change intervals). Together, appropriate dressing choice and usage reduces exudate-related problems, including periwound maceration.[27] Various dressing types — such as superabsorbent, hydrofiber, and foam — have been used to manage moderate to high levels of exudate across different clinical scenarios, with reports indicating that skin maceration in the surrounding area is improved or prevented.[28-32]

Current assessment methods are largely subjective, relying on visual cues and clinician experience,[33] and although current assessment tools offer a standardised approach to wound assessment, they are not as useful for the periwound region.[34] Skin variations can influence how maceration appears,[23,24] making it harder to recognise. Figure 1 illustrates the variations in maceration, indicating the difficulty of identification and accurate assessment.

Periwound maceration is more than just a local skin issue. It can be a sign of inappropriate wound management[1] that increases the risk of infection and contributes to prolonged

Figure 1. Variability of maceration found in different clinical situations (Image copyright held by Mid Yorks NHS Trust: Patients written consent obtained to share.)

healing times and higher healthcare costs.[15] Tackling this issue requires a comprehensive approach that focuses on maintaining moisture balance, choosing the right dressings, and taking proactive steps to protect the skin. All these elements are crucial for enhancing patient outcomes and easing the overall burden of wound care.[1,15]

There are several guidance documents related to exudate management, though these are not maceration specific. The National Institute for Health and Care Excellence (NICE) provides guidance on wound care for hard-to-heal wounds, that recommends keeping skin dry and clean and protected, particularly for wounds producing exudate.[35,36] A Best Practice Statement on exudate management highlights the importance of moisture balance and holistic wound assessment, encouraging clinicians to use exudate classification tools and dressing selection algorithms and suggests regular monitoring for early signs of maceration and adjusting care plans accordingly.[1] The Wound, Ostomy and Continence Nurses Society emphasises routine skin assessment and use of barrier products to protect periwound skin and recommends selecting dressing types based on exudate level. It also supports the use of moisture management protocols in patients at high risk for maceration.[37]

This scoping review seeks to evaluate the burden of periwound skin maceration in wound care and identify gaps in clinical evidence.

Methods

The review was undertaken according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] and Meta-Analyses extension for Scoping Reviews Checklist (PRISMA-ScR).[38]

Research question

The primary aim is to synthesise evidence exploring the clinical challenges for the management/prevention, identification and scaling of periwound maceration and associated costs.

Search strategy

A literature search of the MEDLINE database (date range, from inception of database to 31-March-2025) was performed in March 2025 relating to the development of maceration/excoriation in patients with acute and hard-to-heal wounds. We feel that searching only MEDLINE (PubMed), a powerful search tool for medical literature,[39] as our main source of articles (in conjunction with Google Scholar) is appropriate for this review. Access to literature databases is often limited and only available on a subscription basis.[40] Studies have concluded only one database can be sufficient[41,42] particularly in cases of reviews that are not systematic reviews[43] as the majority of relevant studies appear within a limited number of databases.[44] A systematic review of the combined use of MEDLINE (PubMed) and Google Scholar in bioscience suggests that up to 98% coverage of the relevant literature.[45] Furthermore, selective searching may not introduce bias[44] and it is not always necessary to find all relevant references to draw valid conclusions.[40] Table 2 details the Medline search process highlighting the keywords used, as well as details such as the Medline MeSH terms adopted.

A manual search was conducted among references of included articles, and in relevant journals known not to be indexed in Medline. The keywords were used to search for additional references using the Google Scholar search engine. The top 200 search results of most relevant returns were screened for inclusion using the same eligibility criteria as the primary literature search. Prior to study selection duplicates were removed. Study selection was based on the

Table 2. Search strategy in MEDLINE

Search strategy details	Keywords “skin”, “wound”, “periwound”, and “maceration” were searched with the Boolean operator ‘OR’. The search was as follows: “(skin OR wound OR (periwound OR peri-wound)) macerat*) OR (“skin macerat*” OR “wound macerat*” OR “periwound macerat*””
Medline advanced search	((“skin”[MeSH Terms] OR “skin”[All Fields] OR (“injuries”[MeSH Subheading] OR “injuries”[All Fields] OR “wounds”[All Fields] OR “wounds and injuries”[MeSH Terms] OR (“wounds”[All Fields] AND “injuries”[All Fields]) OR “wounds and injuries”[All Fields] OR “wound s”[All Fields] OR “wounded”[All Fields] OR “wounding”[All Fields] OR “woundings”[All Fields] OR “wound”[All Fields]) OR (“periwound”[All Fields] OR “peri-wound”[All Fields])) AND “macerat*”[All Fields]) OR (“skin macerat*”[All Fields] OR “wound macerat*”[All Fields] OR “periwound macerat*”[All Fields])

inclusion and exclusion criteria (Table 3). Two researchers (MR and AR) independently screened titles, abstracts, and then full texts. Any disagreements were resolved by discussion and consensus. The description of the study selection was presented as a flow diagram following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) statement (Figure 2).[38] The OCEBM's (Oxford Centre of Evidence-Based Medicine) 'Levels of Evidence' guidelines[46] were utilised to assess and grade the methodological quality of the articles included within this review.

Results from the included articles were tabulated in Excel to present the general characteristics and findings of studies.

Results

Overview of study selection

The study selection process is presented in Figure 2. Overall, 1470 articles were identified from the literature search. Following removal of duplicates, 1413 articles remained that progressed to screening. Reading the titles and abstracts 1215 were considered irrelevant to this review, and a further 95 were excluded as no full-text option was available. In all, 103 articles were included for full-text analysis, and a subsequent 59 articles met the inclusion criteria and were included in this review.

Table 3. Inclusion and exclusion criteria for articles

Inclusion criteria	
Inclusion criteria	*Description and/or rationale*
Original peer reviewed primary literature	• Want to investigate the broad range of original clinical studies being conducted across all levels of clinical evidence
Any date	• Want no time limitation of clinical studies included
Paper authors must report on maceration	• Aligns with our review research question
In English	• Due to the abilities of the reviewers, and English being the most accessible language, widely spoken
Exclusion criteria	
Exclusion criteria	*Description and/or rationale*
Articles not of primary clinical origin (such as reviews, letters, commentaries, editorials, protocols)	• Due to lack of peer review, and potential for duplication of assessed clinical evidence in reviews
Not in English	• Due to lack of abilities of the reviewers to assess evidence contained within

Overview of included articles

The 59 articles included in this review are summarised in Table 4. They include 32 articles where maceration was described evaluated wound healing progression (Figure 3); 16 articles that evaluated patient quality of life of which maceration was an observed component, and 17 maceration-observed articles that evaluated pain experienced by patients or the wound-associated infection. Only two articles discussed the cost implications in relation to maceration, or tools for the identification, measurement or grading of maceration , this including articles that reported user-defined maceration grading. There was no indication of standardisation of these assessment tools between articles, with only one study quantifying maceration grading.

Study designs included: RCTs (OCEBM Level 2), these were 8/59 (13.6%) of the studies[28,47-53]; non-randomised controlled trials or non-comparative observational studies (OCEBM Level 3), these were 22/59 (37.3%) of the studies[30-32,54-72]; and case series or case report studies (OCEBM Level 4), these were 24/59 (40.7%) of the studies.[29,73-95] Three articles (5.1%) were surveys conducted with healthcare or wound care

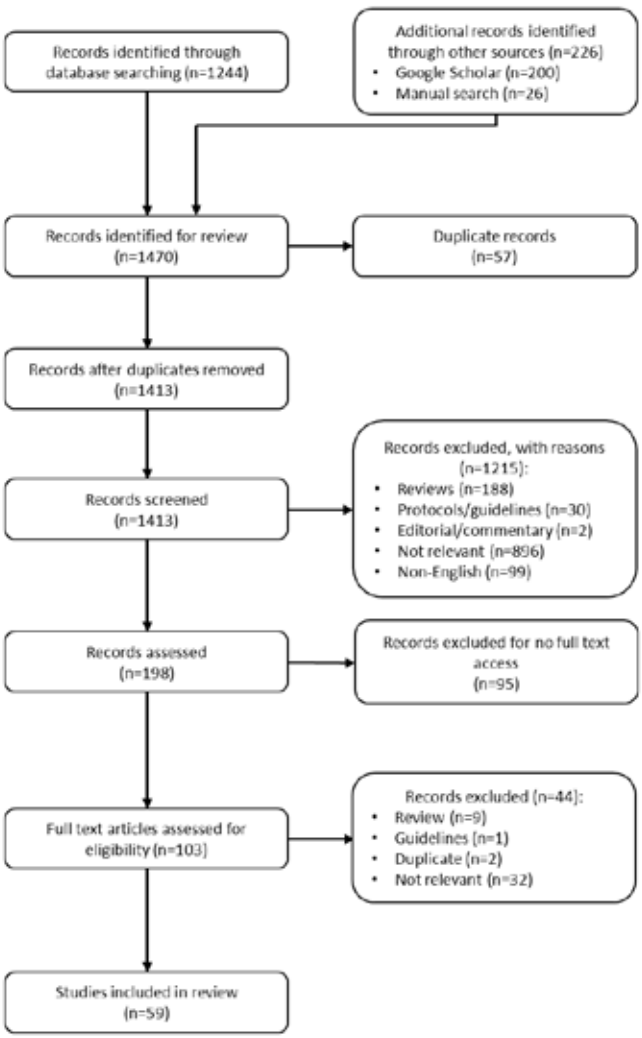

Figure 2. Flow diagram of maceration literature search process

Table 4. Articled identified in review

	Reference first author (date)	Design of study	Number of patients	Tissue type	OCEBM Level of evidence	Maceration involvement
1	Abbade et al (2021)[54]	Phase I/II non-randomised, single-arm	31 (69 wounds)	Venous leg ulcers	Level 3	An assessment primary outcome
2	Al-Mualla et al (2025)[29]	Case studies	8	Acute and hard-to-heal wounds	Level 4	Observation in clinical case(s)
3	Atkin (2017)[73]	Case study	1	Venous leg ulcer	Level 4	Observation in clinical case(s)
4	Barnea et al (2004)[55]	Prospective comparative study	23	Donor sites	Level 3	Observation in clinical case(s)
5	Bateman (2015)[56]	Observational evaluation	150	Acute and hard-to-heal wounds	Level 3	Assessment as an outcome
6	Beeckman et al (2024)[96]	Survey of community-based HCPs	12	Acute and hard-to-heal wounds	N/A	Observation in clinical case(s)
7	Benbow et al (2004)[74]	Descriptive, non-comparative observational study	22	Acute and hard-to-heal wounds	Level 4	An assessment primary outcome
8	Callaghan et al (2018)[75]	Case studies	8	Acute and hard-to-heal wounds	Level 4	Observation in clinical case(s)
9	Chalwade et al (2023)[76]	Case studies	26	Burn wounds	Level 4	An assessment secondary outcome
10	Charlesworth et al (2014)[97]	Survey of wound care specialists	30	Acute and hard-to-heal wounds	N/A	Noted as specific "dressing-related trauma concept"
11	Coutts et al (2005)[32]	Open-label case studies	30	Acute and hard-to-heal wounds	Level 3	An assessment primary outcome
12	Degenhardt et al (2024)[57]	Observational, uncontrolled post-market study	42	Acute wounds (lacerations and surgical wounds)	Level 3	An assessment primary outcome (as part of MARSI)
13	Giri et al (2020)[47]	Prospective, RCT	48	Hard-to-heal wounds	Level 2	Observation in clinical case(s)
14	Hansen et al (2013)[58]	Pilot cohort study	109	Surgical wounds	Level 3	An assessment primary outcome
15	Haryanto et al (2017)[59]	Prospective longitudinal cohort study	62 (70 wounds)	Diabetic foot ulcers	Level 3	Maceration a primary focus of study
16	Haycocks (2017)[77]	Case studies	3	Diabetic foot ulcers	Level 4	Observation in clinical case(s)
17	Hüsers et al (2022)[99]	Case studies	416 (wound images)	Diabetic foot ulcers	N/A	Maceration a primary focus of study
18	Janssen et al (2021)[78]	Case studies	10	Acute and hard-to-heal wounds	Level 4	Observation in clinical case(s)
19	Jones et al (2014)[98]	Survey of HCPs	33	Acute and hard-to-heal wounds	N/A	Observation in clinical case(s)
20	Jørgensen et al (2005)[48]	Prospective, open RCT	129	Venous leg ulcers	Level 2	An assessment primary outcome
21	Joshi et al (2022)[49]	Prospective RCT	80	Decubitus ulcers	Level 2	An assessment secondary outcome
22	Karaca et al (2018)[60]	Quasi-experimental two-arm controlled study	60	Surgical wounds	Level 3	An assessment primary outcome
23	Kücking et al (2024)[100]	Quantitative intervention study	210	Hard-to-heal wounds	N/A	Maceration a primary focus of study

	Reference first author (date)	Design of study	Number of patients	Tissue type	OCEBM Level of evidence	Maceration involvement
24	Lohmann et al (2004)[61]	Open, non-comparative prospective study	35	Diabetic foot ulcers	Level 3	An assessment secondary outcome
25	Malige et al (2021)[50]	Prospective RCT	52	Traumatic wounds	Level 2	Maceration a primary focus of study
26	Marcuello et al (2021)[79]	Case studies	9	Acute and hard-to-heal wounds	Level 4	Observation in clinical case(s)
27	Martin et al (1990)[62]	Non-comparative study	21	Burn wounds	Level 3	Maceration a primary focus of study
28	Meaume et al (2005)[51]	Prospective RCT	91	Hard-to-heal wounds	Level 2	An assessment secondary outcome
29	Meaume et al (2011)[63]	Open, non-comparative study	44	Acute and hard-to-heal wounds	Level 3	An assessment secondary outcome
30	Metcalf et al (2017)[31]	Open, non-comparative study	111 (112 wounds)	Acute and hard-to-heal wounds	Level 3	An assessment primary outcome
31	Milne et al (2024)[80]	Case studies	6	Hard-to-heal wounds	Level 4	Observation in clinical case(s)
32	Nair et al (2024)[81]	Case studies	5	Hard-to-heal wounds	Level 4	An assessment primary outcome
33	Nair et al (2020)[82]	Case studies	4	Hard-to-heal wounds	Level 4	An assessment primary outcome
34	Nair et al (2021)[64]	Non-comparative study	61	Hard-to-heal wounds	Level 3	An assessment primary outcome
35	O'Keeffe (2024)[83]	Case study	1	Hard-to-heal wound	Level 4	Observation in clinical case(s)
36	Osti (2006)[65]	Non-comparative study	44	Burn wounds	Level 3	An assessment primary outcome
37	Parish et al (2008)[66]	Prospective, open, non-comparative study	23	Decubitus ulcers	Level 3	An assessment secondary outcome
38	Pillai et al (2023)[84]	Case studies	6	Hard-to-heal wounds	Level 4	Observation in clinical case(s)
39	Pramod et al (2023)[85]	Case studies	10	Hard-to-heal wounds	Level 4	Observation in clinical case(s)
40	Probst et al (2022)[28]	Open RCT	77	Hard-to-heal wounds	Level 2	An assessment secondary outcome
41	Qi et al (2024)[67]	Prospective observational non-comparative study	340	Surgical wounds (catheter insertion)	Level 3	An assessment primary outcome (as part of MARSI)
42	Recio et al (2012)[86]	Retrospective case studies	3	Decubitus wounds	Level 4	Observation in clinical case(s)
43	Roberts (2023)[87]	Case studies	2	Hard-to-heal wounds	Level 4	Observation in clinical case(s)
44	Romanelli et al (2013)[88]	Case studies	6	Acute and hard-to-heal wounds	Level 4	Observation in clinical case(s)
45	Ryan et al (2023)[89]	Case studies	4	Acute and hard-to-heal wounds	Level 4	Observation in clinical case(s)
46	Sakurai et al (2024)[68]	Randomised, comparative, parallel-group study	26	Volunteer skin	Level 3	An assessment secondary outcome
47	Scheithauer et al (2014)[69]	Comparative, non-randomised study	34 (40 infections)	Surgical wounds (catheter insertion)	Level 3	Observation in clinical case(s)

	Reference first author (date)	Design of study	Number of patients	Tissue type	OCEBM Level of evidence	Maceration involvement
48	Si'Ai (2023)[90]	Case studies	2	Diabetic foot ulcers	Level 4	Observation in clinical case(s)
49	Stephen-Haynes et al (2012)[30]	Non-comparative study	40	Hard-to-heal wounds	Level 3	An assessment primary outcome
50	Suzuki et al (2014)[91]	Retrospective case studies	14	Surgical wounds	Level 4	Observation in clinical case(s)
51	Tan et al (2016)[92]	Case study	1	Hard-to-heal wound	Level 4	Observation in clinical case(s)
52	Terrill et al (2000)[52]	Prospective RCT	99	Surgical wounds	Level 2	An assessment primary outcome
53	Tiwari et al (2024)[93]	Case studies	7	Hard-to-heal wounds	Level 4	Observation in clinical case(s)
54	Tong (2009)[94]	Case studies	4	Diabetic foot ulcers	Level 4	Observation in clinical case(s)
55	Tsuchiya et al (2023)[70]	Prospective non-comparative study	179	Diabetic foot ulcers	Level 3	Maceration a primary focus of study (as part of an assessment tool)
56	White et al (2007)[71]	Prospective non-comparative study	82	Acute and hard-to-heal wounds	Level 3	Observation in clinical case(s)
57	Wongkietkachorn et al (2019)[95]	Case study	1	Hard-to-heal wound	Level 4	Observation in clinical case(s)
58	Zakka Bajjani et al (2025)[72]	Observational study	391	Various skin conditions	Level 3	Observation in clinical case(s)
59	Zhao et al (2022)[53]	RCT	156	Surgical wounds (catheter insertion)	Level 2	An assessment primary outcome (as part of MARSI)

specialists,[96-98] and two articles (3.4%) involved the analysis of wound images from an unknown number of patients.[99,100] The median sample size was 26 patients (IQR 55.75, range 1–391). Thirteen articles (22%) included hard-to-heal wounds with a variety of different aetiologies,[28,30,47,51,64,80-85,87,92,93,95,100] and there were several articles featuring a variety of acute and hard-to-heal wounds (15/59, 25.4%).[29,31,32,56,63,71,74,75,78,79,88,89,96-98] Diabetic foot ulcers were the most frequent wound type (7/59, 11.9%)[59,61,70,77,90,94,99]; followed by surgical wounds (4/59, 6.8%)[52,58,60,91]; venous leg ulcers (3/59, 5.1%)[48,54,73]; decubitus/pressure ulcers (3/59, 5.1%)[49,66,86]; burn wounds (3/59, 5.1%)[62,65,76]; and surgical wounds (catheter insertion sites) (3/59, 5.1%).[53,67,69]

While our intention was to prioritise articles representing the highest levels of evidence,[101] the limited availability of such publications necessitated the inclusion of lower-tier evidence, including descriptive studies, case series, and case reports. Only eight articles (14.8%) met the criteria for high-quality clinical evidence, namely randomised controlled trials (Figure 4), prompting the need to broaden our inclusion criteria to encompass non-comparative observational designs and other lower-level study types.

Maceration in acute and hard-to-heal wounds — how common?

No articles were identified in this review examining the incidence of periwound maceration in wounds. However, a surrogate indicator of how common a problem maceration is to note the baseline maceration levels reported in articles observing periwound skin conditions, including the presence or absence of maceration. Probst et al[28] demonstrated in a RCT (n=77) of patients with hard-to-heal wounds that periwound maceration was observed at baseline in 75.3% (n=58) of patients. In two further RCTs, Jørgensen et al[48] (n=129) reported the development of maceration in 55% control dressing-treated patients after one week compared with 34% in the patients group receiving the test treatment, and Meaume et al[51] (n=129) observed periwound maceration in 29% of dressings changes in an RCT assessing a lipido-colloid dressing in patients with VLUs.

Several uncontrolled clinical and case series observe a range of periwound maceration. For example, Coutts and Sibbald[32] observed maceration in 54% of 30 participants with hard-to-heal wounds, Metcalf et al,[31] as part of an assessment of safety and efficacy of an antimicrobial absorbent dressing

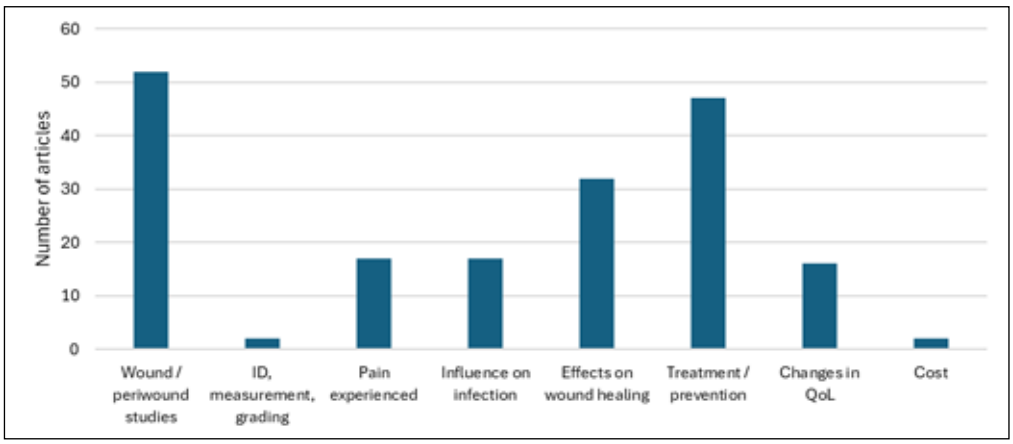

Figure 3. Subject areas evaluated in maceration-related articles

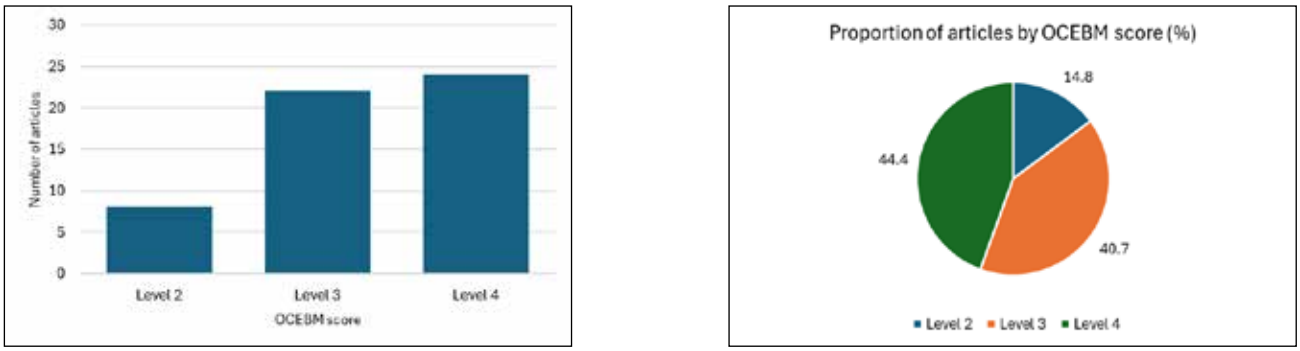

Figure 4. Distribution (left) and proportion (right) of OCEBM scores in maceration-related articles (n=54)

in patients with a variety of acute and hard-to-heal wounds, observed 36.9% (n=41) patients had maceration at baseline, and White et al[71] observed that 19.5% (16/82) of their patients had maceration at baseline. In a case series study of ten patients with fungating wounds treated with a gelling wound dressing, three presented at baseline with periwound maceration.[85] In addition, in a survey of six wound care specialists (WCSs) maceration was mentioned as a 'trauma concept' elicited during the wearing or removal of a dressing by half (3/6). In a subsequent survey of 30 WCSs, 97% reported that they had observed maceration.[97]

Maceration and high levels of wound exudate

Eight articles described wounds with moderate to high exudate levels that were associated with periwound maceration and its management. Jørgensen et al[48] reported an RCT study in patients with moderately or highly exuding hard-to-heal venous or mixed venous/arterial leg ulcers, comparing two foam dressings, that leakage was noted in 27% (14/52) dressing changes in a silver-releasing foam compared with 44% (25/57) in a comparative foam dressing. Maceration after 1 week was 34% in the silver foam dressings compared with 55% in the foam dressing. At the end of treatment, 37% of silver foam dressing-treated patients and 48% of the foam dressing-treated patients had some degree of periwound maceration. Metcalf et al[31] observed a shift from predominantly high (n=43, 38%) or moderate (n=54, 48%) exudate production at baseline, to predominantly low (n=48, 43%) or moderate (n=44, 39%) in patients (n=111) with a variety of challenging wounds treated with a hydrofiber dressing in a safety and effectiveness study. The number of wounds with high levels of exudate reduced from 43 (38%) to 10 (9%). Reduction in exudate levels were accompanied by improvements in skin health: macerated skin reduced from 41 at baseline to 27 and end of evaluation. Stephen-Haynes and Stephens[30] demonstrated excellent (n=24) and good (n=14) exudate and fluid handling in patients (n=40) with various hard-to-heal wounds treated with a superabsorbent wound dressing with a high absorbing capacity. The authors reported only one case where maceration developed. A number of case series or case report studies demonstrated that effective wound exudate management by absorbent wound dressings reduced periwound maceration[73,75,79,85] or prevented its development.[29]

What is the impact of maceration?

Wound healing

Among the articles evaluating wound dressings, 32 specifically examined maceration. Several of these reported a reduction in maceration that coincided with wound healing progression. For example, Probst et al[28] conducted a multicentre, open-label randomised controlled trial involving 77 patients with hard-to-heal wounds. The study found that wound area decreased more rapidly in the polyacrylate wound pad group compared with the control group, and

this was accompanied by a more pronounced reduction in maceration. Tsuchiya et al[70] demonstrated that appropriate management of maceration was associated with healing of diabetic foot ulceration (n=179) at 4 weeks. Osti[65] evaluated patients with burn wounds treated with a hydrogel and a semipermeable adhesive film and found the most frequent complication as skin maceration (15 of 44 patients, 34%), reporting a reduction over the course of therapy. White et al[71] reported a reduction in periwound maceration in a cohort of patients (n=82) with a variety of acute and hard-to-heal wounds treated with a foam dressing.

Haryanto et al[59] evaluated the impact of maceration on the healing of diabetic foot ulcers (n=62). Classifying patients into two cohorts (patients with or without periwound maceration), the authors demonstrated that the non-macerated wounds healed significantly faster than the macerated wounds (P=0.000) and demonstrated that maceration is a significant and independent predictor of wound healing (adjusted hazard ratio, 0.324; 95% CI, 0.131-0.799; P=0.014).

Pain

Seventeen articles examining wound maceration also assessed pain outcomes; however, none specifically explored a direct correlation between maceration levels and patient-reported pain. Marcuello et al[79] observed a reduction in periwound maceration in nine patients with wounds of varying aetiology following the use of an absorbent dressing, accompanied by decreased pain during dressing changes. Nonetheless, the authors did not attribute the pain reduction to changes in maceration. Similarly, Pramod and Rice[85] reported reduced periwound maceration and lower mean pain scores in a cohort of 10 patients with malignant fungating wounds treated with a gelling dressing, without establishing a causal link between the two outcomes.

Quality of life

Sixteen articles related to assessing maceration in periwound skin reported several outcomes related to quality of life (QoL). In a case series study Callaghan et al[75] evaluated the performance of an absorbent dressing in eight patients with a variety of acute and hard-to-heal wounds, reporting that effective exudate management reduced maceration levels and resulted in an improvement in the patients' quality of life. Stephen-Haynes and Stephens[30] demonstrated the use of a superabsorbent wound dressing in patients (n=40) with acute and hard-to-heal wounds minimised the risk of the development of maceration. The authors concluded that effective exudate management, among other outcomes, also improved the quality of life of patients. Jones and Barraud[98] evaluated a superabsorbent wound dressing on moderate-to-highly exuding wounds of varying aetiology (n=33) observing that there was a reduction in levels of maceration in 16 patients. Reductions in maceration were observed alongside improvements in 'patient experience' (such as patient comfort).

Infection-related aspects

Seventeen articles related to periwound skin maceration reported infection-related findings, although no articles reported on direct associations between the incidence of maceration-related infection, and none of them crosslinked maceration-enabling infection. Probst et al[28] reported wound infection present in only three participants at the start of a RCT study (n=77) assessment of a superabsorbent charcoal dressing versus a silver foam dressing. As well as a reduction in maceration over the course of the assessment period, all cases of infection were resolved during treatment. Lohmann et al[61] demonstrated stable levels or improvement of maceration and exudate management in a non-comparative prospective evaluation of a non-adhesive foam dressing in diabetic patients (n=35) with foot ulcers. Nine patients were being treated with systemic antibiotics for an ulcer/periwound infection, and no patients developed a new infection in their ulcer during the study. Nair et al[81] observed a resolution or reduction of infection in four of five patients with a variety of hard-to-heal wounds treated with a collagen-containing gel formulation, with the reduction in infection corresponding with a resolution of periwound skin maceration.

Cost

Two articles examining periwound maceration addressed the associated cost implications. Terrill and Varughese[52] reported only on dressing costs, limiting broader economic insight. In contrast, Charlesworth et al[97] used qualitative interviews with wound care specialists to explore the direct financial impact of maceration on wound care services. The authors estimated the average cost of managing a typical case of maceration at £175, identifying in-patient care and material use as the primary cost drivers among components, such as pharmaceuticals and healthcare professional time.

Assessment of maceration in periwound skin

Six articles used a number of 3–5 point grading systems for the assessment of periwound maceration. Meaume et al[51] used a subjective 4-point maceration level scale ('none', 'slight', 'moderate', 'severe') in an RCT comparing maceration in patients with venous or mixed-aetiology ulcers treated with a lipido-colloid dressing versus a control dressing. Lohmann et al[61] also used a 4-point scale ('none', 'little', 'moderate', 'severe') for measuring periwound maceration in a non-comparative study of a foam dressing in 35 patients with diabetic foot ulcers. Meaume et al[63] evaluated periwound maceration in patients (n=44) with acute and hard-to-heal wounds treated with a lipido-colloid wound dressing using a 3-point scale ('none', 'moderate', 'severe') with the authors acknowledgement that the subjective/qualitative nature of some of the data affects result reliability, and there is the potential for reporting to be variable. Benbow and Iosson[74] also used a 3-point scale ('none', 'minimal', 'moderate') as part of a clinical evaluation of periwound maceration in patients with acute and hard-to-heal wounds treated with a lipido-colloid dressing. Sakurai et al[68] evaluated maceration

in a healthy volunteers (n=26) study treated with a film dressing and using a 5-point scale ('no findings', 'slight', 'mild', 'moderate', 'severe'). In each of these articles there was no indication of a definition of the various parameters in the scaling systems used. Chalwade et al,[76] evaluating a superabsorbent diaper-based wound dressing in 26 patients with burn wounds, used a 4-point scale ('no', 'minimal', 'moderate', 'severe'). These authors attempted to quantitate maceration by measuring the extent of the unhealthy skin around the wound as a measure of the level of maceration ('no' (0cm), 'minimal' (<1cm), 'moderate' (1–3cm), 'severe' (>3cm)).

Four articles used semi-quantitative monitoring tools to assess maceration, often as part of a broader wound status evaluation. Tsuchiya et al,[70] conducting a secondary analysis of five prior studies, analysed data from 179 patients with diabetic foot ulcers using the DMIST tool (depth, maceration, inflammation/infection, size, tissue type of wound bed, type of wound edge, and tunnelling/undermining)[102] to explore the relationship between individual components and wound healing. Two articles applied the Harikrishna Periwound Skin Classification (HPSC) tool[103] (Table 5), which integrates peri-wound skin assessment with wound bed and edge evaluation, across a range of wound types. They used multiple assessment tools, including the HPSC, to evaluate 61 patients with wounds of varying aetiologies receiving skin cleanser treatment. In a separate study, Nair et al[82] used the HPSC tool to evaluate four patients with periwound maceration (classified as HPSC Class 2) who were treated with a barrier cream.

Table 5. The 2015 Harikrishna Periwound Skin Classification (HPSC)103

Class	Subtype	Periwound condition
0		Normal
1		Fibrous tissue/tissue at risk
2	A	Exudate centred with desiccation
	B	Exudate centred with maceration
	C	Exudate centred with allergy
3		Inflammation without infection
4		Inflammation with infection
5		Atypical (senescent cells/cancer/ subcutaneous emphysema)

Haryanto et al[59] evaluated the relationship between maceration and wound healing of diabetic foot ulcers using image analysis of wound photos to measure areas of maceration (defined as areas of wet and opaque or white periwound skin). It assigned patients either to the macerated skin or non-macerated skin groups. Hüsers et al[99] evaluated a convolutional neural network (CNN) a form of artificial intelligence network that is primarily used for processing visual information, as a tool for automatically classifying maceration in images of diabetic foot ulcers. Having previously been trained on 326 images of diabetic foot ulcers to distinguish between macerated and non-macerated periwound skin, although the overall accuracy (0.69) was not high enough for real clinical scenarios to automatically classify macerations, the authors suggested that the CNN may aid semi-automatic classification by proposing maceration status of periwound skin to a clinician to accept or decline.

Gaps in literature

Figure 5 highlights that maceration as a focus of clinical studies was in only six (10.3%) of 58 articles, and maceration was noted as a specific outcome in 25/58 (43.1%) of study methodologies. The remaining articles reported maceration as a descriptive observation, usually in case series or case report studies. For example, Haryanto et al[59] assessed the impact of maceration and wound healing in a prospective longitudinal study in 62 patients observing that non-macerated wounds healed significantly faster than the macerated wounds. Tsuchiya et al[70] demonstrated an association between several parameters (including maceration) used in the DMIST monitoring tool and healing in patients with diabetic foot ulcers. Two articles used maceration as clinical parameter for the assessment of automated assessment tools. Kücking et al[100] used images of periwound wound maceration in hard-to-heal wounds to assess artificial intelligence (AI)-based decision bias. Hüsers et al[99] assessed an AI-based system for the classification of diabetic foot ulcer images for periwound maceration.

Discussion

Holistic care needs to commence with accurate and timely assessment and addressing the underlying cause of the

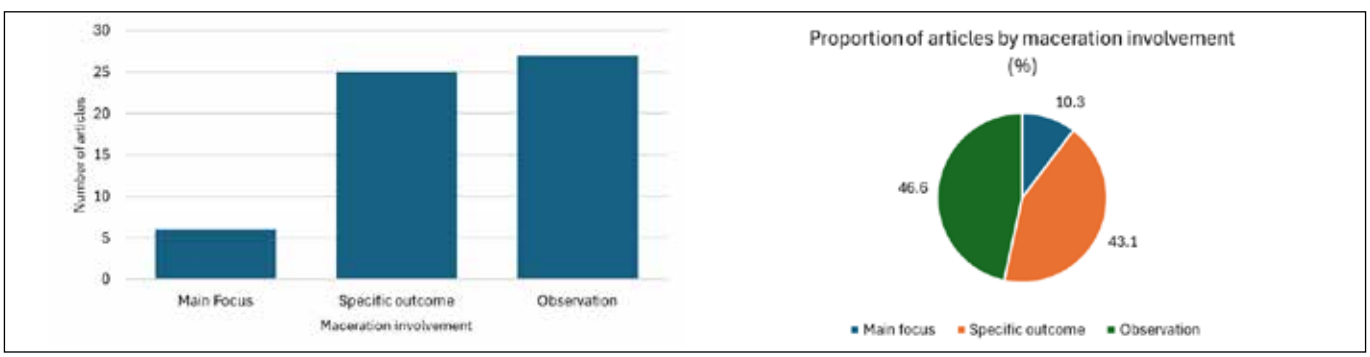

Figure 5. Distribution (left) and proportion (right) of articles with maceration involvement (n=58)

wound/reason for high exudate. Secondly, the individual's wound should be considered both in terms of choosing the most appropriate wound dressing (such as its exudate management capability), and their usage (for example dressing change frequency). These considerations have an important role to play in the response of the wound bed and surrounding skin. Periwound skin maceration remains a significant clinical concern, contributing to delayed wound healing, reduced patient quality of life, and increased risk of tissue breakdown and infection.[1,15]

While maceration is often cited in the literature as a factor associated with increased infection risk, our review identified no studies demonstrating a direct causal relationship. These gaps in the literature highlight lack of clinical evidence for the impact of maceration, and the need for further clinical research.

Despite growing interest in this area, the available evidence is limited and heterogeneous, with much of the literature comprising low-level study designs applied across diverse wound types. Additionally, few studies employ validated or standardised tools to assess maceration, further limiting comparability and generalisability. A central barrier to optimising intervention strategies lies in the absence of clear diagnostic criteria and standardised assessment frameworks for maceration. This lack of consensus contributes to variability in clinical judgement and may impede the timely implementation of appropriate therapeutic interventions. This scoping review identified a clear gap in the evidence focusing on periwound maceration. Notably, only eight clinical studies of high quality (RCTs, OCEBM Level 2) have been conducted, all of these in clinically heterogeneous environments and with variable outcomes of interest.[28,47-53] The limited number of RCT (OCEBM Level 2) studies compared with the total number of articles identified in this scoping review (Figure 5) highlights a gap between the provision of high-level clinical evidence and clinical application of evidence.

Our review highlighted the need for more high-quality research in the area of maceration in order to provide robust clinical evidence; there were no clinical studies where maceration was a primary outcome. In addition, there is a lack of evidence on what is currently perceived to be relationships between maceration and a number of clinical outcomes (such as the association between maceration and the increased risk of infection). Further investigation is required to determine whether peri-wound maceration contributes to risk of infection.

It is recommended that there needs to be better guidance on identifying maceration. Although this review identified several articles that used scaling and grading systems to measure periwound skin maceration,[51,61,63,64,68,70,74,76,82] there was little in the way of standardisation of grading systems between the various studies, and few studies where grading systems were defined.[76] This scoping review identified preliminary research exploring the use of artificial intelligence to support the standardisation of periwound maceration identification and grading. Notably, Hüsers et al[99] proposed an AI-driven approach as a potential step towards objective and reproducible maceration assessment in clinical practice. Although there are several sets of guidelines to aid in clinical choices related to exudate management[34,35] there is little related to maceration in terms of identification or assessment, as well as the appropriate interventions. Several assessment tools have been developed by clinicians[64,70,82] but their adoption has not been widespread. A lack of consensus with regards to the identification and measurement of maceration will help healthcare providers make appropriate treatment decisions.

Limitations

We aimed to focus on the data sources that provide the highest quality evidence, including RCTs and systematic reviews, and therefore, if these data sources were available, information on the effectiveness of first-line dressings based upon the findings from articles that provide lower level of evidence was excluded. Lower levels of evidence, however, were considered in the absence of higher quality evidence, including descriptive studies, case series studies and case reports.

Conclusions

Although maceration is widely recognised as a significant clinical challenge in patients with wounds, particularly hard-to-heal wounds, there is a notable absence of articles quantifying its prevalence. Maceration is a hidden problem in wound care, often overlooked but with significant implications for wound healing, patient quality of life, and clinical efficiencies (Table 1). While the literature offers substantial evidence on treatment strategies, typically involving the use of exudate-managing dressings, there remains a critical gap in the availability of validated tools to support consistent identification and grading of maceration. The lack of such instruments hinders clinicians' ability to align treatment choices with the severity and extent of maceration. As such the development and validation of such tools would be an extremely valuable resource to aid the clinician in managing this problem.

Conflict of interest

The authors declare no conflict of interest.

Ethics statement

An ethics statement is not applicable.

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Author contribution

All authors (MGR, AAR, LA) made significant contributions to the manuscript. MGR and AAR conceived the study design, including the review protocol and search strategy. MGR and AAR were involved in article screening and selection for eligibility. The article titles were assessed by two authors

(MGR and AAR) independently, and their abstracts were screened for the eligibility, according to the criteria for considering studies for this review. The free-to-view, full-text version of potentially relevant articles were obtained and two authors independently screened these against the inclusion criteria. Where discrepancies were identified a consensus between the two authors was reached through discussion. All authors (MGR, AAR, LA) provided critical revisions and feedback on the manuscript. LA provided the images of the illustrative clinical examples.

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