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Effectiveness of moist dressings in wound healing after surgical suturing: A Bayesian network meta-analysis of randomised controlled trials

Wenjing Sun | **Maojun Chen** | **Dan Duan** | **Wenjie Liu** | **Wenyao Cui** | **Li Li**

Department of Neurosurgery, West China Hospital, Sichuan University, Chengdu, China

Correspondence
Maojun Chen, BN, Department of Neurosurgery, West China Hospital, Sichuan University, Chengdu 610041, China.
Email: chenmaojunhl@163.com

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Abstract

The moist healing theory proves that a moderately moist and airtight environment is conducive to wound healing. However, different moist dressings have different functions. We aim to evaluate the effects of moist dressings on wound healing after surgical suturing and identify superior moist dressings. Randomised controlled trials investigating the application of moist dressings were retrieved from electronic databases, including PubMed, EMBASE, Web of Science, and the Cochrane Library. Wound healing, surgical site infection (SSI), and times of dressing change were assessed. The values of the surface under the cumulative ranking (SUCRA) curve were calculated based on the Bayesian network meta-analysis. Inconsistency tests and funnel plots were applied to analyse the consistency and publication bias. All the analysis complies with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 Checklist and AMSTAR (Assessing the Methodological Quality of Systematic Reviews) Guidelines. Sixteen randomised controlled trials involving 4444 patients were pooled in the network meta-analysis. The ionic silver dressing (SUCRA, 93%) ranked first in wound healing, the metallic silver dressing (SUCRA, 75.9%) ranked first in SSI, and the hydrocolloid dressing (SUCRA, 73.9%) ranked first in times of dressing change. Inconsistency was only observed in wound healing, and no publication bias was observed in this study. The effects of moist dressings are better than gauze dressings in the process of wound healing. The ionic silver dressing is effective in wound healing, whereas the metallic silver dressing is effective in SSI prevention. The hydrocolloid dressing requires the fewest times of dressing change. More high-quality RCTs are required to support the network meta-analysis.

KEYWORDS

network meta-analysis, occlusive dressings, surgical wound infection, sutures, wound healing

Key Messages

- the effects of moist dressings are better than gauze dressings in the process of wound healing
- the ionic silver dressing is effective in wound healing, whereas the metallic silver dressing is effective in SSI prevention
- the hydrocolloid dressing requires the fewest times of dressing change

1 | BACKGROUND

The skin suture technique, which includes sutures, staples, strips, and skin adhesives, is basically and commonly used in surgery.[1] From minor wounds such as lacerations to complex operations such as exploratory laparotomy and craniotomy, surgical suturing is in great need.[2] However, multiple complications such as surgical site infection (SSI), wound dehiscence, bleeding, and exudation often occur after suturing. SSI is the third most common nosocomial infection, occurring in 2 to 5% of surgical procedures.[3] Wound dehiscence is the separation of the incision layer, commonly occurring 7 to 14 days in high-tension skin after abdominal surgery, cardiothoracic surgery, orthopaedic surgery, etc.[4] These complications can hinder the healing of the postoperative incisions and prolong the length of hospital stay. Significant progress has been made in wound management to prevent complications after surgical suturing in recent years. One of the most representative is the moist healing theory.

In 1962, British zoologist George Winter put forward the theory of moist healing, which poses a robust challenge to the traditional concept of dry healing.[5] The moist healing theory states that a moderately moist and airtight environment is conducive to the rapid growth of epithelial cells and wound healing. Moist healing has several advantages: (i) it regulates the oxygen tension of the wound and promotes the formation of capillaries; (ii) it promotes the dissolution of necrotic tissue and fibrin; (iii) it preserves and releases the active substance in exudate; (iv) it promotes cell proliferation, differentiation, and migration; (v) it keeps the wound warm and moist; and (vi) it prevents wound infection.[6]

Covering gauze and bandage dressings on the surface of sutured wounds has been practiced for hundreds of years. Bandages and gauze dressings provide temporary protective physical barriers and absorb the exudate to promote wound healing. Although economical, the function of bandages and gauze dressings is limited. Multicomponent and multifunctional moist dressings have sprung up as a consequence. After surgical suturing, the most frequently used moist dressings include films, foams, hydrocolloids, hydrogels, alginates, etc.[7] Compared with gauze dressings, these moist dressings have improved the functions of antibacterial, haemostasis, exudate absorption, and wound healing to varying degrees.

Because of the different functions of moist dressings, it becomes more difficult for surgeons to decide which dressing is best to substitute for sterile gauze and bandages after surgical suturing. The Chinese expert consensus on emergency open wound debridement and suture suggests a lack of evidence regarding which dressings are suitable for all sutured wounds.[8] Therefore, we performed a network meta-analysis based on the Bayesian framework to compare the effects of different moist dressings in wound healing after surgical suturing and select superior moist dressings.

2 | METHODS

The network meta-analysis was registered on PROSPERO (https://www.crd.york.ac.uk/ prospero/) with an ID of CRD42021287928. This work complies with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 Checklist and AMSTAR (Assessing the Methodological Quality of Systematic Reviews) Guidelines.[9,10] More details can be found in Data S3.

2.1 | Search strategy

The PubMed, EMBASE, Cochrane Library, and Web of Science databases were searched up to November 1, 2021. No language restrictions will be applied. The search terms were composed of MeSH terms and free terms included “bandages, hydrocolloid”, “occlusive dressings”, “dressings”, “moist dressings”, “moist healing”, “foam”, “alginate”, “hydrogel”, “hydrofiber”, “film”, “silver”, “honey”, “wound healing”, “surgical wound”, “wound and injuries”, “wound infection”, “surgical wound infection”, “surgical wound dehiscence”, “sutures”, “stitch”, “seam”, and “closure.” The search strategies are listed in Table S1. All the search results were uploaded to Endnote X9 to delete duplicate records.

2.2 | Inclusion and exclusion criteria

The included articles were identified according to the following criteria: (i) patients were 18 years of age or older; (ii) moist dressings were applied in the intervention group when incisions were sutured after surgery; (iii) any dressings were applied in the control group; (iv) outcomes reported wound healing rate, SSI, or times of dressing change; and (v) randomised controlled trials. The exclusion criteria were as follows: (i) patients with sutures removed when dressings were applied; (ii) patients receiving skin grafts or wound drainage; (iii) trials with insufficient data; (iv) animal experiments; and (v) study protocol, reviews, case reports, conference abstracts, and posters.

2.3 | Data extraction and quality assessment

The study characteristics were extracted into Excel 2016 using data abstraction forms and were described from author name, year of publication, country, age, interventions and controls, sample size, and outcomes. The incidence of wound healing was identified as the primary outcome, while the incidence of SSI and times of dressing change were identified as the secondary outcomes.

Afterward, the Revised Cochrane Risk-of-bias Tool for Randomised Trials (ROB 2) was available to assess the overall bias and the quality of the included studies from five domains, including randomization process, deviations from the intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Two reviewers utilised an Excel tool containing macros provided by the Cochrane Collaboration to implement ROB 2 independently. The graph of risk bias was output using the Excel tool. All disagreements were resolved by a qualified reviewer expert in evidence-based medicine.

2.4 | Statistical analysis

The network meta-analysis was based on the Bayesian framework, with four Markov chains of Monte Carlo estimation. The simulation iterations were set to 200 000, with the first 5000 tuning iterations used for eliminating the set of initial values. Potential scale reduction factors (PSRFs) indicated the effects of convergence. When PRSF approaches 1, no more iterative process is required. In addition, relative ratios (RRs) and 95% confidence intervals (CIs) were calculated for dichotomous variables, while mean differences with 95% CIs were calculated for continuous variables. In addition, random or fixed effect models are selected depending on the smallest DIC value. The indicator I^2 was applied to calculate the study heterogeneity. The network connections were plotted according to the number of studies and sample size. The node size represents the sample size, and the thickness of the line segment represents the number of direct comparisons. Once the closed loops were formed in the network plot, the inconsistency test was used to compare the differences between direct and indirect evidence. The funnel plot was applied to assess publication bias when more than 10 studies reported outcomes. The values of the surface under the cumulative ranking curve (SUCRA) probabilities were estimated to rank the different dressings from wound healing, SSI, and times of dressing change. The values of SUCRA vary from 0% to 100%, and the high value suggests the greatest likelihood of being the best intervention.

OpenBUGS 3.2.3 was enabled for the network meta-analysis, and Stata 14.0 was conducted by calling data to plot statistical figures.

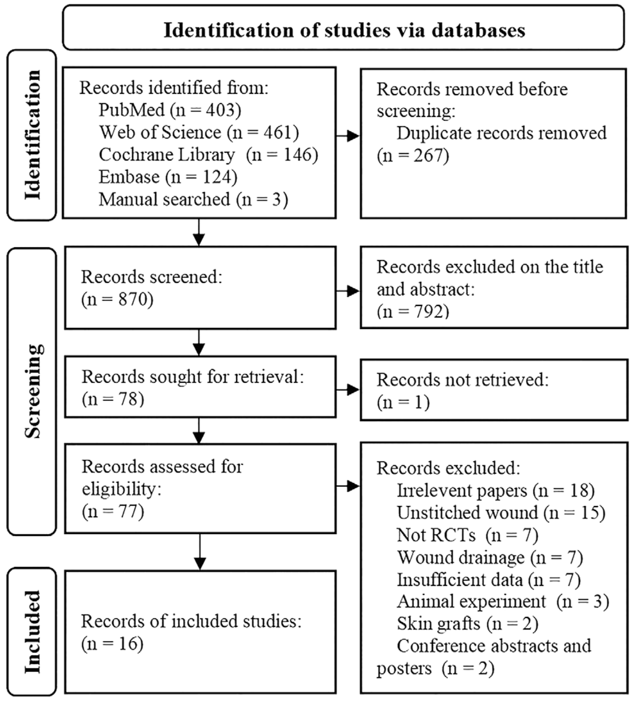

FIGURE 1 Flow diagram of study selection

3 | RESULTS

3.1 | Study identification process

We identified 1137 records via databases and manual retrieval (Figure 1). After duplicate records were removed and preliminary screening was performed, 78 studies were sought for retrieval. One study was not available full text after contacting the editorial department and the author. There were 61 studies excluded for several

TABLE 1 Study characteristics

Author (year)	Country	age	Interventions and controls	Sample size	Surgical site	Setting	Use and duration of each dressing	Outcomes
Arroyo 2015[11]	Spain	≥18	Film vs Gauze	411	Multiple surgical site	Orthopaedic; Cardiac Surgery; Urological-gynaecological surgery; Oncological surgery; Thoracic surgery; General surgery	15 days	SSI; Times of dressing change
Beele 2020[12]	Belgium	68.9 ± 10.5	Foam vs Hydrofiber	103	Hip and knee	Orthopaedics	4 days	SSI; Times of dressing change
Biffi 2012[13]	Italy	63.3 ± 9.0	Hydrofiber vs Foam	112	Abdomen	Abdomino-pelvic and minimally invasive surgery	7 days	SSI
Blazeby 2020[14]	United Kingdom	52 (34.7–66.9)	Glue vs Gauze	257	Abdomen	Obstetric surgery; General surgery	Before wound closure	SSI
Connery 2019[15]	United States	31 ± 5.6	Silver nylon vs Gauze	657	Abdomen	Obstetric surgery	7 days	SSI
Dickinson 2015[16]	United States	≥21	Metallic silver vs Ionic silver vs Foam	315	Heart	Cardiac surgery	Metallic and Ionic silver: 5 days or before discharge Foam: 2 days	Wound healing; SSI
Holm 1998[17]	Denmark	61.3 (25–90)	Hydrocolloid vs Gauze	73	Abdomen	Gastrointestinal surgery	Gauze: 1.9 days Hydrocolloid: 7.9 days	SSI
Michie 1994[18]	United States	60 ± 20.2	Hydrocolloid vs Gauze	56	Multiple surgical site	Surgery department	10 days	Wound healing; SSI
Ozaki 2015[19]	United States	67.6 ± 10.5	Alginate vs Gauze	500	Lower extremity	Vascular and endovascular surgery	3 days or clinical need to remove	SSI
Ruiz-Tovar 2019[20]	Spain	67.2 ± 10.4	Silicone vs Gauze	117	Abdomen	Surgery department	5 days	SSI
Shinohara 2008[21]	Japan	63.5 (31–91)	Hydrocolloid vs Gauze	134	Abdomen	Gastrointestinal surgery	Until sutures were removed	SSI; Times of dressing change
Stanirowski 2016[22]	Poland	30.9 ± 4.8	DACC vs Foam	543	Abdomen	Obstetric surgery	2 days	SSI
Teshima 2009[23]	Japan	67.9 ± 9.5	Hydrocolloid vs Foam	253	Heart	Cardiovascular surgery	7 days	Wound healing; SSI
Vogt 2007[24]	Denmark	69.5 (36–94)	Hydrofiber vs Foam	136	Abdomen; Groin; Lower limb	Vascular surgery	4 days	SSI; Times of dressing change
Wynne 2004[25]	Australia	66.2 ± 10.8	Hydrocolloid vs Foam vs Film	737	Heart	Cardiac surgery	Hydrocolloid and film: 5 days Foam: 2 days	Wound healing; SSI; Times of dressing change
Xue 2018[26]	China	35.4 ± 3.8	Alginate vs Gauze	40	Toes	Dermatology	3 days	SSI

Abbreviation: DACC, dialkylcarbamoyl chloride impregnated dressings.

FIGURE 2 Risk of bias graph

reasons. In particular, seven studies related to wound drainage were excluded because of compromised dressing integrity. Two studies related to skin grafts were excluded in that the compatibility of donor and recipient sites could affect wound healing. Ultimately, 16 studies[11-26] met the inclusion and exclusion criteria.

3.2 | Study characteristics and quality assessment

A total of 16 RCTs containing 4444 patients were pooled in this study (Table 1). The authors from 16 different countries applied 12 diverse dressings to sutured wounds. One of the arms in a three-arm study[14] was removed for no dressing was applied. In terms of risk and bias assessment, half of the studies retained some concerns in the randomization process, 37.5% of studies retained some concerns in deviations from intended interventions, and 75% of studies retained some concerns in the measurement of the outcome. Besides, high-risk bias was reported in the measurement of the outcome and missing outcome data. Overall, 12.5% of the studies were at low risk, 68.8% of the studies retained some concerns, and 18.8% of the studies were at high risk (Figure 2).

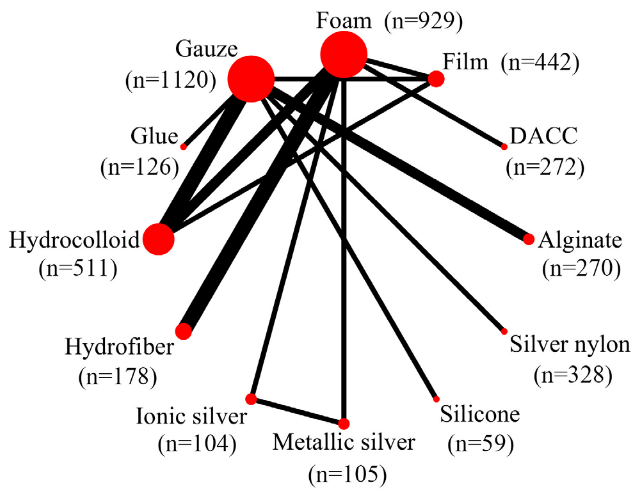

FIGURE 3 Network plot of 16 randomised controlled trials

TABLE 2 Inconsistency test

Parameter	Loop	IF	seIF	95% CI	*Z*-value	*P*-value
Wound healing	Hydrocolloid vs Foam vs Film	0.077	0.034	0.01, 0.14	2.292	0.022
SSI	Film vs Gauze vs Hydrocolloid	1.498	1.021	0.00, 3.50	1.466	0.143
	Film vs Hydrocolloid vs Hydrofiber	1.008	0.919	0.00, 2.81	1.097	0.273

Abbreviations: IF, inconsistency factor; seIF, standard error of inconsistency factor.

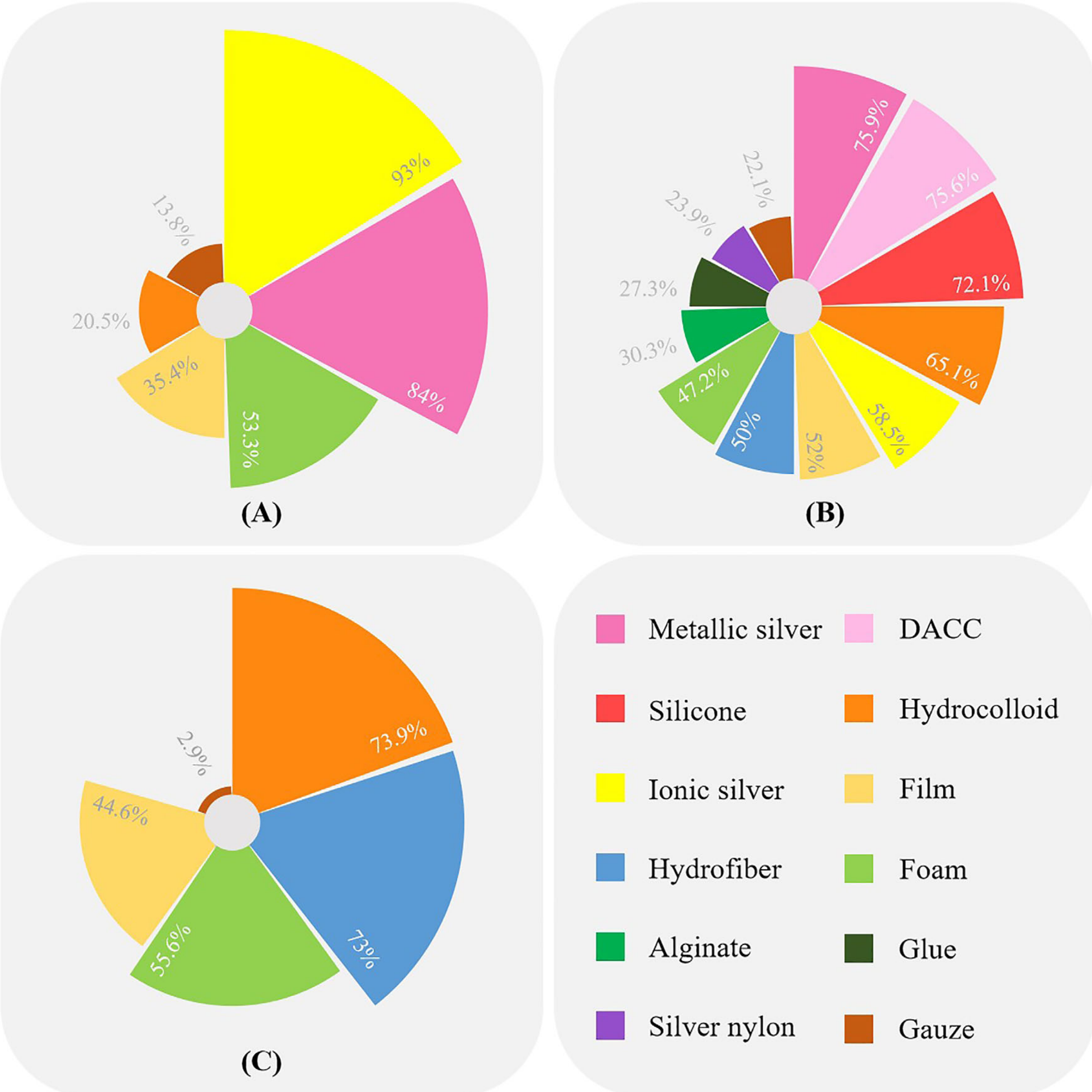

FIGURE 4 The values of the surface under the cumulative ranking curve. A, Wound healing; B, surgical site infection; C, times of dressing change

3.3 | Results of the network meta-analysis

The network plot of 16 RCTs containing 4444 patients is presented in Figure 3. As the control of moist dressing, the gauze dressing has the largest number of studies and sample size. There were three studies comparing the differences between hydrocolloid and gauze dressings, three studies comparing the differences between hydrofiber and foam dressings, two studies comparing the differences between hydrocolloid and foam dressings, and two studies comparing the differences between alginate and gauze dressings. The rest of the studies were compared only once.

3.3.1 | Wound healing

Four RCTs containing 1361 patients reported wound healing (Figure S1). There was no inconsistency or heterogeneity in comparisons between foam, ionic silver, and metallic silver dressings because the three interventions came from the same study. The inconsistency test in Table 2 shows that the direct comparisons between hydrocolloid, foam, and film dressings were inconsistent with the indirect comparisons ($P < 0.05$). Therefore, the inconsistency model was used for fitting. Direct meta-analysis related to foam dressing revealed lower heterogeneity ($I^2 = 0\%$, $P = 0.644$). Among the six dressings in Figure 4A, ionic silver dressing ranked first, with the SUCRA of 93%, followed by metallic silver (84%), foam (53.3%), film (35.4%), hydrocolloid (20.5%), and gauze dressings (13.8%).

3.3.2 | Surgical site infection

All 16 RCTs reported SSI. However, two studies[12,18] were excluded in that no SSIs occurred in either the intervention or control groups. Therefore, 14 RCTs containing 4210 patients were included. The network plot formed three closed loops (Figure S2). No inconsistency or heterogeneity existed in comparisons between foam, ionic silver, and metallic silver dressings because the three interventions came from the same study. Direct meta-analysis related to gauze dressing revealed lower heterogeneity in Figure S3 ($I^2 = 40.3\%$, $P = 0.11$). The inconsistency test in Table 2 shows that the direct comparisons between hydrocolloid, foam, and film dressings were consistent with the indirect comparisons ($P > 0.05$). Meanwhile, the comparisons between gauze, hydrocolloid, and film dressings were consistent with the indirect comparisons ($P > 0.05$). Among the 12 dressings in Figure 4B, metallic silver ranked first, with the SUCRA of 75.9%, followed by DACC (75.6%), silicone (72.1%), hydrocolloid (65.1%), ionic silver (58.5%), film (52%), hydrofiber (50%), foam (47.2%), alginate (30.3%), glue (27.3%), silver nylon (23.9%), and gauze dressings (22.1%). The publication bias of SSI-related studies was assessed using the funnel plot, which shows basically symmetrical and no publication bias (Figure S4).

3.3.3 | Times of dressing change

Five RCTs containing 1521 patients reported times of dressing change. The network plot formed two closed loops from 2 three-arm studies (Figure S5). No inconsistency or heterogeneity was observed in the two loops. The direct comparison results were in good agreement with those of the indirect comparison. Among the five dressings in Figure 4C, hydrocolloid dressings ranked first, with a SUCRA of 73.9%, followed by hydrofiber (73%), foam (55.6%), film (44.6%), and gauze dressings (22.9%).

4 | DISCUSSION

We searched 4 databases and obtained 16 RCTs to evaluate the effectiveness of moist dressings in wound healing after surgical suturing. Based on the Bayesian network meta-analysis, we compared the differences of 6 dressings in wound healing, 12 dressings in SSI, and 5 dressings in times of dressing change. The results demonstrated that the ionic silver dressing is the most effective in promoting wound healing. In addition, the metallic silver dressing is the most effective in preventing SSIs, while the hydrocolloid dressing has the least number of dressing changes.

Wound healing after surgical suturing is complicated and multifaced. Moist dressings promote wound healing by playing an important role in three stages, which involve the phases of haemostasis, inflammation, and repair.[27] In this study, the ionic silver dressing was the most effective in promoting wound healing and ranked in the top five in preventing SSIs. According to the antimicrobial activity of ionic silver, it can bind to the negative charge on the surface of bacterial proteins, change the cell structure, affect the replication of genetic material, and kill pathogens.[28] Meanwhile, loading ionic silver into wound dressings can promote the release of proteolytic enzymes and growth factors, as well as accelerate the proliferation of fibroblasts and wound healing.[29] In the inconsistency test of wound healing, we found that the direct evidence of two studies[23,25] was inconsistent with the indirect evidence. Since Wynne's[25] study is a three-arm study, there was no inconsistency or heterogeneity internal. Among the two studies, the main inconsistency comes from the differences between hydrocolloid dressings and foam dressings. In Wynne's study, only one person healed incompletely in each group, and the wound healing rate of both groups was 95.6%. Therefore, such a difference is not statistically significant. In Teshima's study,[23] 9% of patients failed to heal after applying hydrocolloid dressing because of massive exudation, bleeding, and other reasons. After all, foam dressings absorb exudation better than hydrocolloid dressings.

Surgical wounds eliminate pathogens such as Staphylococcus aureus and Escherichia coli mainly through phagocytosis of neutrophils and mononuclear macrophages.[30] However, relying on body protective mechanisms to prevent SSIs is not enough. We found that metallic silver dressing is the best dressing for preventing SSIs, and it has good efficacy in promoting wound healing. Metallic silver is an inert substance that cannot be absorbed into the human body. Compared with ionic silver, metallic silver has lower toxicity and better biocompatibility.[31] However, in a best practice, 93% of wound experts recommended that the decisive factor in choosing silver dressings is the release of silver ions, not the form of silver (e.g., ionic or metallic).[32] One RCT[14] creatively applied glue as a dressing on sutured wounds. According to our results, glue dressing was only better than silver nylon and gauze dressings in preventing SSIs. This is because the primary function of glue dressings is to prevent wound dehiscence and stop bleeding. Besides, glue dressings lack ingredients to promote wound healing and lack evidence of the wound healing rate.

The high frequency of dressing change increased dressing costs, nursing costs, and the potential risk of complications.[33] In this study, five RCTs reported the times of dressing change, making the hydrocolloid the best dressing in changing frequency. Hydrocolloid dressing is a new wound dressing made of hydrophilic polymer particles and rubber elastomers.[34] On the one hand, the inner layer of the hydrocolloid dressing forms gels by absorbing exudate. On the other hand, the outer layer creates a closed environment to protect the wound from pollution. The structure of the hydrocolloid dressing allows it to be worn for a week unless there is a large amount of exudation and severe infection.[35] In Wynne's study,[25] only one hydrocolloid dressing was applied on sternotomy wounds before sutures were removed, whereas 1.3 foam or film dressings were required on average. Frequent dressing changes can destroy new granulation tissue and increase the risk of wound exposure and infection.[33] A collaborative project applied the combination of Cadexomer iodine and foam dressing on chronic wounds and reduced the dressing change frequency by 48.8%.[36] However, this result remains to be confirmed in surgically sutured wounds.

Notably, the gauze dressings were used as an intermediary variable to compare the differences in moist dressings in this study. Interestingly, the gauze dressings performed worst in wound healing, SSI prevention, and changing times. Nevertheless, gauze dressings occupy most of the medical market because of their low price and versatile uses. The Chinese expert consensus on emergency open wound debridement and suture notes that although the moist dressings are more expensive than gauze dressings, their ease of healing and low frequency of replacement may reduce the overall costs.[8] Lindholm[33] considered wound healing, times of dressing change, and complications as the critical drivers of wound cost management. Among 16 RCTs, one study compared total dressing costs between hydrocolloid dressing and gauze dressing. Shinohara and colleagues[21] were surprised to find that the total cost of gauze dressing was even higher than that of hydrocolloid dressing. This result is because of the weak absorbability of gauze dressings and the frequent need for replacement.

By far, no moist dressings show the best performance in all categories. The metallic silver dressing is effective in wound healing and SSI prevention. However, few studies have reported the change frequency in metallic silver dressings. Moist dressings in sutured wounds compromise various functions to meet different needs. During the process, patients are required to participate in decision-making for choosing superior dressings. This action can not only improve patient compliance but also reduce their financial burden. Meanwhile, the location and size of wounds, amount and type of exudate, and surrounding skin condition should also be considered in dressing choice.[37]

Several limitations should be considered in this network meta-analysis. Firstly, a few studies reported wound healing and times of dressing change at the same time. Secondly, the differences in study characteristics could affect wound healing, resulting in inconsistency in the study. Thirdly, we compared three outcomes in this study, and outcomes such as wound healing time and total costs of dressings were not evaluated because of limited data. Thus, more high-quality RCTs are needed to support and supplement the conclusions.

5 | CONCLUSIONS

In conclusion, the effects of moist dressings are superior to gauze dressings in terms of wound healing, SSI prevention, and times of dressing change. The current evidence suggests that the ionic silver dressing is the most effective in wound healing, whereas the metallic silver dressing is the most effective in SSI prevention. Additionally, the hydrocolloid dressing requires the fewest times of dressing change. Different moist dressings show different advantages. To be sure, it is imperative to change the traditional concept of using gauze as a conventional dressing on sutured wounds. Finally, we look forward to developing moist dressings that perform well in all aspects in the near future.

AUTHOR CONTRIBUTIONS

Wenjie Liu and Maojun Chen designed methodology, Wenjing Sun, Dan Duan, and Wenyao Cui searched the literature and completed the quality assessment. Statistical analysis and data visualisation were performed by

Wenjing Sun and Li Li. The manuscript was written by Wenjing Sun and revised by Maojun Chen.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

ORCID

Wenjing Sun https://orcid.org/0000-0003-1865-0098

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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