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Negative Pressure Wound Therapy (NPWT) Impact in Burn Wounds Healing

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KEYWORDS	ABSTRACT
Negative Pressure Wound Therapy, burn wounds, wound healing, re-epithelialization.	Negative Pressure Wound Therapy (NPWT) has emerged as a promising modality for enhancing burn wound healing. Burn injuries pose significant global health challenges, often leading to complications such as infection and prolonged healing times. Conventional dressings, while widely used, have limitations in addressing these issues. This systematic review evaluates the efficacy of NPWT compared to traditional dressings in improving burn wound outcomes. The study analyzed data from eight randomized controlled trials involving 471 patients, sourced from databases like PubMed, Google Scholar, and ScienceDirect, following PRISMA guidelines. Results indicated that NPWT significantly enhanced re-epithelialization, reduced bacterial infections, and improved graft take rates, although the latter showed variability across studies. The therapy's benefits are attributed to mechanisms such as angiogenesis, reduced oxidative stress, and better exudate management. However, the review highlights the need for further research with larger populations to validate these findings and explore NPWT's integration with standard skin grafting techniques. The implications of this study support the adoption of NPWT in burn care protocols, offering potential reductions in healing time and complication rates.

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INTRODUCTION

Negative pressure wound therapy (NPWT), also known as vacuum-assisted closure (VAC), is an advanced wound care modality that involves local pressure reduction at a wound site (Huang et al., 2014). This modality provides sub-atmospheric pressure in a closed dressing, inducing microdeformation and macro deformation, angiogenesis, granulation, enhanced microvascular perfusion, reduced oedema, exudate control, and a lower risk of bacterial infection in wounds (Lalezari et al., 2017). NPWT requires a vacuum source, dressing, and drainage tubing—typically changed every 2 to 3 days (4). It is best applied directly to the open wound bed (standard NPWT) or closed incisional wound (iNPWT). Given its benefits, NPWT enhances burn wound healing progression compared to standard conventional dressings alone (Krug et al., 2011).

Burn injuries represent a significant global health concern. The World Health Organization estimates that over 11 million individuals experience burn injuries annually, with approximately 180,000 fatalities, predominantly in developing countries (Lestari et al., 2023). These injuries inflict considerable damage to skin and internal organs, potentially causing death, disability, psychological complications, and substantial financial burdens. Heightened mortality risk among burn patients is predominantly associated with immunosuppression, advanced age, catabolic states, and sepsis; these factors are recognized as primary mortality contributors. Additionally, extensive skin damage involving a large total body surface area significantly exacerbates morbidity and mortality risks (Zhang et al., 2024). Burn treatment remains complex, necessitating attention not only to the acute phase but also to subsequent reconstruction, rehabilitation, and long-term anti-scarring interventions. Consequently, a critical 48–72 hour post-burn period exists during which necrosis may occur. Mitigating ongoing tissue loss, reducing tissue oedema, and maintaining microcirculation require paramount skin dressing management (Douglas & Wood, 2017; Singh et al., 2021).

Skin dressing in burn wounds adheres to principles outlined in Jackson's burn wound model, which identifies three distinct zones: a) zone of coagulation, b) zone of stasis, and c) zone of hyperemia. The zone of stasis is the primary focus of effective burn care, encompassing timely first aid and appropriate dressing techniques. Burn wound management aims to facilitate recovery in this middle zone, achievable through skin dressing within 48 hours post-injury. Conventional dressings include silver dressings, wet-dry gauze, hydrocolloids, foams, alginates, and hydrogels. However, these fail to adequately reduce infection risk and scar formation—factors associated with prolonged re-epithelialization periods of 14–17 days (Cubison et al., 2006; Douglas & Wood, 2017; Holbert et al., 2024). To address these deficiencies, studies demonstrate compelling benefits of NPWT in acute burn wound management. NPWT application within 48 hours post-burn mitigates wound progression and deeper injury development by enhancing microcirculation in the reversible zone of stasis (Chen et al., 2010; Kantak et al., 2017). Therefore, this review aims to evaluate NPWT's impact on burn wound healing.

METHOD

1. Data Sources and Search Strategies

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Data were systematically gathered from three online databases—*i.e.*, Google Scholar, PubMed, and ScienceDirect—from their inception until April 2025. Boolean operators were used with primary keywords such as "Negative-Pressure Wound Therapy" and "burn wound." Filters were applied to refine database search results.

2. Eligibility Criteria

Included studies were required to be Randomized Controlled Trials (RCTs) adhering to the following criteria:

1. Study populations consisted of patients with burn wounds, without limitations on burn etiology;
2. The intervention applied was NPWT;
3. NPWT was compared to other conventional wound dressings;
4. Outcomes of burn wound healing (qualitative or quantitative) were reported. Studies were excluded if they were not in English, employed animal models, lacked NPWT comparisons, or were case reports, case series, retrospective studies, or observational designs.

3. Study Selection

Retrieved articles underwent title/abstract screening after duplicate removal. Articles passing this stage underwent full-text review to assess eligibility, with no exclusion criteria violations identified. Discrepancies were resolved through author consensus, establishing the final included studies. The selection process was documented in a PRISMA flow diagram.

4. Quality Assessment and Data Extraction

Included studies were evaluated using the Joanna Briggs Institute critical appraisal tool for RCT risk of bias, independently assessed by authors. An independent extractor performed data extraction, summarizing findings in Microsoft Excel 2019. Recorded data included: study identification, country, design, NPWT parameters, control group, sample size, participant distribution, burn type, wound size, NPWT duration, assessment period, wound epithelialization, graft take rate, bacterial infection, adverse events, and complications.

RESULT AND DISCUSSION

1. Search Results

Our search yielded 487 articles, of which 100 were from Google Scholar, 67 from PubMed, 315 from ScienceDirect, and five articles from citation searching. Thirty-six duplicates were removed. Following the removal, we retrieved 47 articles to be assessed for the eligibility criteria thoroughly and deemed articles that were non-RCT, not available for full-text, pilot and protocol study, did not use burn wound patients as its population, and conducted in animal model experimental. Finally, we included eight articles with four new included studies than the previous systematic review study for further systematic qualitative review. Our selection process was presented in the PRISMA diagram in Fig. 1.

2. Risk of Bias Assessment

The assessment of the bias risk was conducted using the JBI appraisal tool. Most studies exhibited a moderate risk of bias with no or unclear data for several questions. Additionally, some studies did not investigate the factors following pre-, during, and post-surgery, which might affect the result. Nevertheless, we proceeded to analyze all studies, as the risk of bias is unlikely to affect the results significantly and provides the necessary data for our analysis.

3. Characteristics and Results of Individual Studies

The summary of each individual study was displayed in Table 2. The subject of these studies was burn wound patient undergoing split-skin graft with NPWT and compared to other conventional dressing. We focused on examining the NPWT vs control conventional dressing group outcome in wound epithelialization, graft take post intervention, bacterial infection, adverse event, and common complication who occurred after intervention. Out of eight studies, three studies did not mention wound epithelialization, two studies did not mentioned graft take rate, and only four studies explained the bacterial infection related outcome. Most of the studies also did not mention exact adverse event and complication finding. Otherwise, we still able to point out the conclusion from the data summary.

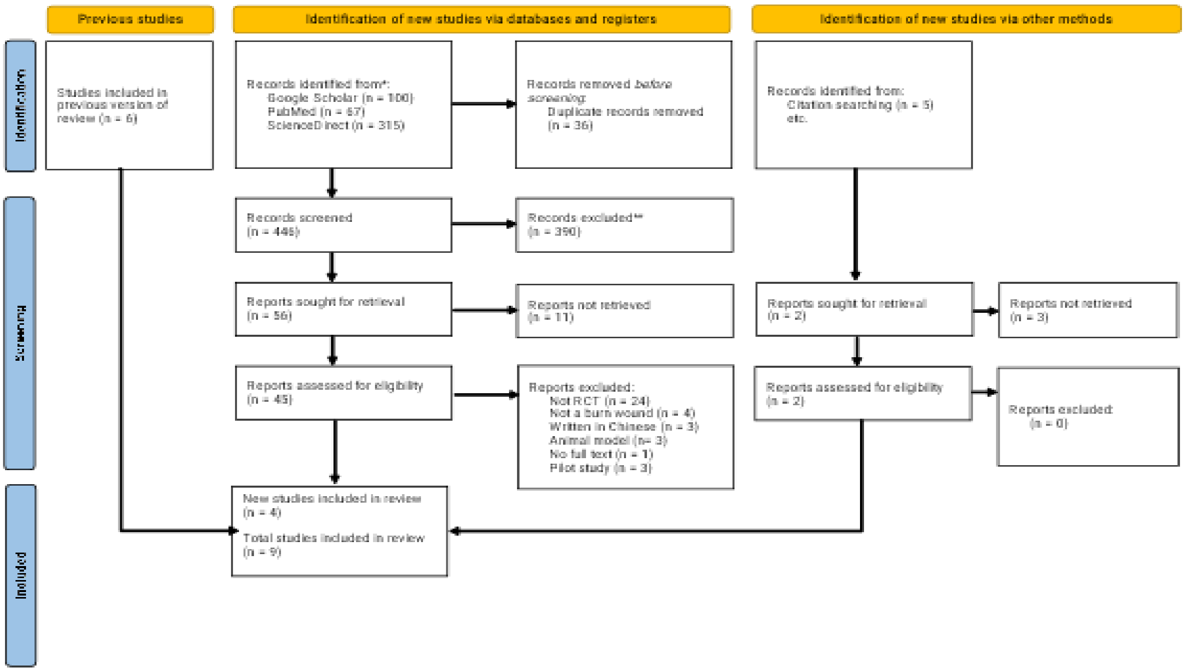

Figure 1. PRISMA flow diagram

Question:	Petkar et al, 2011	Bloemen et al, 2012	Honnegowda et al, 2016	Hsiao et al, 2016	Honnegowda et al, 2018	Ibrahim et al, 2019	Frear et al, 2020	Tapking et al, 2024
1. Was true randomization used for assignment of participants to treatment groups?	Y	Y	Y	N	Y	Y	Y	Y
2. Was allocation to treatment groups concealed?	U	Y	U	Y	U	U	Y	Y
3. Were treatment groups similar at the baseline?	Y	N	Y	Y	U	Y	Y	Y
4. Were participants blind to treatment assignment?	Y	Y	Y	U	U	Y	Y	Y
5. Were those delivering treatment blind to treatment assignment?	N	U	U	U	U	U	U	U
6. Were outcomes assessors blind to treatment assignment?	U	U	U	U	U	U	U	U
7. Were treatment groups treated identically other than the intervention of interest?	Y	Y	Y	Y	Y	U	U	Y
8. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	Y	Y	Y	Y	Y	Y	Y	Y
9. Were participants analyzed in the groups to which they were randomized?	U	U	Y	U	Y	Y	U	Y
10. Were outcomes measured in the same way for treatment groups?	Y	Y	Y	Y	Y	Y	Y	Y
11. Were outcomes measured in a reliable way?	Y	Y	Y	Y	Y	Y	Y	Y

12. Was appropriate statistical analysis used?	Y	Y	Y	Y	Y	Y	Y	Y
13. Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?	N	Y	U	Y	Y	Y	Y	Y

Table 2. Qualitative Summary of Individual Study Characteristic

Study ID	Petkar et al, 2011(16)	Bloemen et al, 2012(17)	Honnegowda et al, 2016(18)	Hsiao et al, 2016(19)
Country	India	Netherlands	India	Taiwan
Study Design	Prospective RCT	Multicenter RCT	Prospective RCT	Prospective RCT
NPWT	NPWT 80 mmHg	NPWT 125 mmHg	intermittent NPWT + cycle of 30 minutes suction and 3,5 hours rest	NPWT
Control Group	Vaseline gauze, cotton pads	Dermal substitute (Matriderm), SSG	squeezed 5% povidone-iodine gauze	Saline moisten gauze, petroleum gauze
Sample Size (mean age, SD)	Mn = 32 (range: 7-68) Mc = 28.5 (range: 7-60)	Mds-npwt = 44, 17.0 Mds = 48, 19.4 Mnpwt = 49, 13.3 Mst = 53, 18.3	Mn = 32.3, 9.50 Mc = 34.5, 13.0	Mn = 51.9 Mc = 52.0
N (each group)	NPWT group (n=21) Control group (n=19)	DS-NPWT (n=21) DS (n=23) NPWT (n=22) SSG (n=20)	NPWT group (n=25) Control group (n=25)	NPWT group (n=14) Control group (n=14)
Type of Burn Wound	acute or old burn with split-skin grafting	Deep dermal or full-thickness burn wounds requiring skin transplantation	burn-injury	partial or full-thickness dermal defect undergoing skin graft
Wound Size (mean, SD)	NPWT: 244 cm^2 (range: 16–1200) Control: 183 cm^2 (range: 16–1000)	TBSA (%): DS-NPWT = 8, 5.8 DS = 9.6, 8.1 NPWT = 10, 13.3 SSG = 7.7, 7.4	NPWT: 19 cm^2 (range: 9-36) Control: 18 cm^2 (range: 10-39)	NPWT: $\leq$120 cm^2 = 78.57% $\geq$120 cm^2 = 21.43% Control: $\leq$120 cm^2 = 64.28% $\geq$120 cm^2 = 35.72%
NPWT Duration	4 days	3-5 days	NR	7 days
Assessment Period	4th day-3 weeks post-op	4-7 days post-op; 3rd and 12th months post-op	0-10th day	7, 21 day, and 3 months post-op
Wound Epithelialization (mean%, SD)	NR	DS-NPWT = 8, 5.8 DS = 9.6, 8.1 NPWT = 10, 13.3 SSG = 7.7, 7.4 *p-value* = 0.433	Median (Q_1, Q_3) NPWT: 3 (2, 4.25) Control: 2 (1.75, 4) *p-value* = 0.008	NR
Graft Take (mean%, SD)	9th day: NPWT: 96.7%, 3.55 Control: 87.5%, 8.73	mean (95%, CI) DS-NPWT = 94 (88.3-101.2) DS = 92.4 (88.3-99.5) NPWT = 94.2 (88.5-100.0) SSG = 96.1 (94.2-97.9)	NR	7th day: NPWT: 71.4% Control: 85.7% *p-value* = 0.6451

		p-value = 0.552		
Bacterial Infection (mean%, SD)	NR	Post-op contamination* DS-NPWT (n=71%) DS (n=76%) NPWT (n=35%) SSG (n=78%) *p-value* = 0.042	NR	NPWT: 0% Control: 0% *p-value* = 1.00
Adverse Event	NR	NR	NR	None
Complication	NR	DS-NPWT (n=33%) DS (n=30%) NPWT (n=23%) SSG (n=10%) *p-value* = 0.303	NR	None

NPWT, negative pressure wound therapy; TBSA, total body surface area; RCT, randomized controlled trial; Mn, mean age in NPWT group; Mc, mean age in control group; NR, not reported; SSG, split-skin graft; DS, dermal substitute; *pathogens: *Staphylococcus aureus, Pseudomonas aeruginosa*, *group G Streptococcus, Escherichia coli;* SE, standard error;

(cont.)

Study ID	Honnegowda et al, 2018	Ibrahim et al, 2019(20)	Frear et al, 2020(21)	Tapking et al, 2024(22)
Country	India	Egypt	Australia	Germany
Study Design	Prospective RCT	RCT	RCT	Prospective RCT
NPWT	intermittent NPWT + cycle of 30 minutes suction and 3,5 hours rest	NPWT -125 mmHg	NPWT 40-80 mmHg	NPWT 80 mmHg
Control Group	5% povidone iodine solution-soaked gauze	MES,	anocrystalline silver-impregnated fibre mesh + silicone interface	gel containing polyhexanide, fatty gauze and cotton wool
Sample Size (mean age, SD)	38.5 (range: 12-65)	Mn = 27.2, 3.6 Mmes = 26.5, 4.2 Mc = 26.2, 3.8	median Mn = 4 (range: 1-8) Mc = 4 (range: 1-9)	Mn = 39.8, 13.7 Mc = 44.8, 16.2
N (each group)	NPWT group (n=32) Control group (n=28)	MES group (n=15) NPWT group (n=15) Control group (n=15)	NPWT group (n=47) Control group (n=54)	NPWT group (n=33) Control group (n=28)
Type of Burn Wound	burn-injury	partial-thickness thermal burns	acute thermal burn covering less than 5% of their total body surface area (TBSA)	second degree burns of least at one extremity
Wound Size (mean, SD)	14 cm^2	TBSA (%) MES: 30.6, 3.8 NPWT: 31.3, 3.3 Control: 31.9, 4.3	TBSA (%) NPWT: 1.5 (range: 1-2) Control: 1 (range:1-2)	TBSA (%) NPWT: 3.1, 13.7 Control: 3.4, 2.8
NPWT Duration	NR	5 minutes on-2 minutes off for 24 hours, 3x a week for 3 weeks	2-3 days	4 days
Assessment Period	0-10th day	72 hours, 10 days, 21 days post-op	3-5 days, 3 and 6 months	8 weeks
Wound Epithelialization (mean%, SD)	Mean, SE NPWT: 3.5, 0.36 Control: 2.3, 0.29 *p-value* = 0.015	NR	Days (median, (95% CI) NPWT <48h: 7.5(5.25-8) NPWT ≥48h: 9(7-11) *p-value* = 0.025	Days 1st phase: NPWT: 11.0, 4.9 Control: 8.6, 3.8 *p-value* = 0.074

			Control <48h: 9(8-13.75) Control ≥48h: 10.5(9-14) *p-value* = 0.121	2nd phase[#]: NPWT: 7.8, 2.6 Control: 9.8, 5.2 *p-value* = 0.580
Graft Take (mean%, SD)	NR	Wound surface area MES[1]: 47.2, 7.2 MES[2]: 85.4, 10.6 (*p-value* = <0.001) NPWT[1]: 27.8, 6.6 NPWT[2]: 74.7, 16.4 (*p-value* = <0.001) Control[1]: 15.7, 5.7 Control[2]: 37.2, 10.4 (*p-value* = <0.001	NPWT: 2% Control: 7%	Days NPWT: 10 (range: 8-11) Control: 9 (range: 7-11)
Bacterial Infection (mean%, SD)	NR	Colony count: MES[1]: 92.0, 22.3 MES[2]: -0.4, 0.1 (*p-value* = <0.001) NPWT[1]: 84.1, 17.0 NPWT[2]: -6.3, 2.2 (*p-value* = <0.001) Control[1]: 97.2, 18.3 Control[2]: 85.6, 19.6 (*p-value* = <0.001)	NR	at 1st dressing change NPWT: 15.2% Control: 14.3% *p-value* = 0.794
Adverse Event	NR	NR	Yes NPWT: Wound maceration (n=1) Peri-wound blistering (n=1) Exacerbation of pre-existing viral illness (n=2) Control: Exacerbation of pre-existing viral illness (n=1)	NR
Complication	NR	NR	Scar NPWT: 11% Control: 28% *p-value* = 0.031	Secondary surgery NPWT: 15.2% Control: 21.4% Scar assessment NPWT: 52.0, 17.4 Control: 57.9, 13.5

NPWT, negative pressure wound therapy; TBSA, total body surface area; RCT, randomized controlled trial; Mn, mean age in NPWT group; Mc, mean age in control group; NR, not reported; SE, standard error; MES: microcurrent electrical stimulation; [1], Pre-treatment until Day 10 post-op; [2], Pre-treatment until Day 21 post-op; [#], after surgical necrosectomy & split-thickness skin grafting;

This systematic review encompasses a total of eight articles involving four hundred seventy-one patients with various types of burn wounds. The results from these eight articles indicate that the application of Negative Pressure Wound Therapy (NPWT) in conjunction with split-skin grafts can yield superior outcomes regarding re-epithelialization, graft take rate, bacterial infection prevention, and reduced scar formation in burn wounds. Among the four studies that referenced wound epithelialization, data demonstrates that NPWT exhibits a more favorable outcome compared to the control group dressing. Although only the study conducted by Honnegowda et al. in 2016 (median, Q1-Q3: 3, 2-4.25), Honnegowda et al. in 2018 (mean, SE: 3.5, 0.36), and Frear et al. in 2020 (days median (95% CI): 7.5 (5.25-8) and 9 (7-11) with p-values of 0.008, 0.015, and 0.025, respectively, provides significant data (Frear et al., 2020; Muguregowda et al., 2018). The findings reported by Honnegowda et al. in 2016 further indicate that wound healing was significantly improved in the NPWT group after ten days of treatment when contrasted with the conventional dressing group (mean, SD: 8.70, 0.21 vs 6.24, 0.40) (Muguregowda et al., 2018). Such results suggest that the majority of studies present a significant improvement in burn wound healing associated with the application of NPWT. These beneficial effects are highly considered to be correlated with a significant increase in ground substance and antioxidants, while concurrently reducing oxidative stress, matrix metalloproteinase-2 (MMP-2), wound surface pH, and nitric oxide levels, thereby facilitating epithelialization, granulation, angiogenesis, and minimizing inflammation of the skin graft with the NPWT system (Muguregowda Honnegowda et al., 2016; Sinha et al., 2013).

However, a contrasting result was observed in the graft take rate. Unlike the wound healing results, which showed a significant outcome, most studies indicated a good rate but not significant. Of the six studies examining graft take outcomes, Petkar et al. (2011) reported a higher graft take rate compared to the conventional dressing (96.7%, 3.55 vs 87.5%, 8.73) (Petkar et al., 2011). The study by Ibrahim et al. (2019) also revealed statistically significant lower mean values of burn wound surface area at the 10 and 21 days follow-up periods for MES and NPWT. However, there was no statistically significant difference between the NPWT and MES groups in the mean values of reduction in wound surface area, although there was a greater percentage reduction in wound surface area in the MES group (85.4, 10.6) (Ibrahim et al., 2019). This finding aligns with previous meta-analyses that indicated NPWT is not superior to standard split-thickness skin grafts. Nonetheless, the meta-analysis results showed a 95% Confidence Interval of Standard Mean Difference as 2.62 (1.01, 4.22), $p = 0.001$, and I^2 94%, demonstrating high heterogeneity among the results (Lin et al., 2021). While not highly significant, several cases of patients undergoing NPWT were discharged successfully without requiring re-grafting, with no reports of leakage in the dressing and drape. The use of NPWT in burn patients may also reduce the time needed and the frequency of dressing changes. Negative pressure dressing can improve graft take, accelerate the process, and shorten the duration of graft dressings compared to conventional dressings covered with Vaseline gauze alone (Rosadi Seswandhana et al., 2020; Teng, 2016)

Reducing the frequency of dressing changes in Negative Pressure Wound Therapy (NPWT) significantly influences the potential for bacterial contamination of the wound. Two of the studies included in this analysis concerning NPWT yielded favorable results in reducing bacterial contamination, with statistically significant p-values of 0.042 and <0.001 (17,20). In contrast, the other two studies presented non-significant results, with p-values recorded at 1.00 and 0.794 (Hsiao et al., 2017; Tapking et al., 2024). The positive outcomes associated with NPWT are further corroborated by previous research concerning dressing changes. Additionally, reducing the frequency of dressing changes minimizes the duration that burn wounds are exposed to open air, potentially decreasing the rates of postoperative infections resulting from external contaminants. It is important to note, however, that this condition is heavily dependent on the correct application of dressings, irrespective of the type utilized (Teng, 2016). Hsiao et al. illustrated in their investigation that both the NPWT and conventional groups achieved a zero percent infection rate (Hsiao et al., 2017).

Although the majority of the study results are statistically significant, it does not definitively conclude that Negative Pressure Wound Therapy (NPWT) consistently yields superior outcomes. The existing guidelines continue to recommend skin grafting for full-thickness burns during the healing phase subsequent to wound excision. Consequently, the adverse events and complications, along with the factors that may have induced the varying outcomes, have yet to be thoroughly discussed due to the limited available data. Furthermore, the total population in this systematic review is not sufficiently large to warrant a definitive conclusion. This is particularly crucial as the factors influencing the significance of NPWT in burn wound healing may be substantial.

CONCLUSION

This systematic review indicates that NPWT offers improved outcomes in wound healing and in reducing bacterial infections. However, further studies involving larger populations are necessary to obtain precise data regarding the graft take rate. This finding relates to the efficacy of NPWT when combined with standard split-thickness skin grafting compared to other dressing modalities. Thus, this systematic review presents valuable evidence supporting the adoption of NPWT in the management of burn wound healing.

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