JHWCR JOURNAL OF HEALTH, WELLNESS AND COMMUNITY RESEARCH 3007-0570

Vol. 4 Issue 6, 2026
Open Access | DOI: 10.61919/hd92wy66

Original Article

Effectiveness of Exosome-Enriched Hydrogel Dressing in Accelerating Burn Wound Healing

Umar Saleem[1], Sidra Tariq[2], Ahmed Hussain[3], Sarwat Ali Raja[4], Muhammad Saleem Malik[5], Uzma Shakoor[6]

[1] Resident, Department of Plastic Surgery, Mayo Hospital, Lahore, Pakistan.
[2] Consultant Dermatologist, Civil Hospital, Karachi, Pakistan.
[3] Army Medical College, Rawalpindi, Pakistan.
[4] Associate Professor, Yashfeen College of Pharmacy and Allied Health Sciences, Lahore, Pakistan.
[5] General Surgeon Specialist, Shaqra General Hospital, Shaqra, Saudi Arabia.
[6] Lecturer, Lords College of Pharmacy, Lahore, Pakistan.

✉ **Correspondence:** Sarwat Ali Raja, sarwat.ali.raja@gmail.com

Received: 02 February 2026	Revised: 19 February 2026	Accepted: 13 March 2026	Published: 30 March 2026

HOW TO CITE

Umar Saleem et al. 2026. Effectiveness of Exosome-Enriched Hydrogel Dressing in Accelerating Burn Wound Healing. Journal of Health, Wellness and Community Research. 4, 6 (Mar. 2026), 1–6. DOI: https://doi.org/10.61919/hd92wy66

ARTICLE INFORMATION

Author Contributions	Concept: US, STR; Design: US, SAR; Data Collection: US, ST, AH; Analysis: SAR, MSM; Drafting: US, ST, USh; Critical Review and Final Approval: All authors.
Ethical Approval	The study was approved by research ethical board of Allied Health Sciences, Pakistan
Informed Consent	Written informed consent was obtained from all participants
Conflict of Interest	The authors declare no conflict of interest.
Funding	No external funding.
Data Availability	Available from the corresponding author on reasonable request.
AI Declaration	No generative AI was used for conceptualization, analysis, or content generation. AI use was limited to language refinement, and the authors remain fully responsible for the accuracy, originality, validity, and integrity of the manuscript's content.

ABSTRACT

Background: Thermal injuries to the skin cause intense inflammation and delayed healing, leading to considerable challenges in the field of advanced wound healing. Stem cell-derived extracellular vesicles (EVs) have strong paracrine capacities to guide cell behaviour throughout wound healing in the cutis. Hypothesis: Exosomes enriched-hydrogels can repair tissue, reduce systemic inflammation and promote re-epithelialization in partial thickness thermal burn wounds when compared to the use of standard hydrogel therapy. Methods: This double blind, parallel group randomized controlled trial involved 60 patients suffering from acute partial thickness thermal burn in 6 months study in central Punjab. The participants were randomly assigned (1:1) to either the exosome-enriched hydrogel dressing (n=30) or the identical hydrogel dressing (n=30) applied at intervals of 48 hours for 4 weeks. The percent of total epithelialization at week 4 was a primary outcome. Secondary outcomes were: Visual Analog Scale (VAS) pain score, serum C-reactive protein (CRP) level, and Vancouver Scar Scale score. A total of 55 subjects were included in the final analysis (28 intervention, 27 control). Results: At 4 weeks, the intervention group demonstrated a significantly higher mean complete epithelialization rate compared to controls (91.2\% \pm 5.8\% vs. 71.8\% \pm 7.3\%; mean difference: 19.4\%, 95\% CI: 14.2\% to 24.6\%; $p < 0.001$). There was a significant time \times group interaction for wound closure as indicated by repeated-measures ANOVA ($F(1, 53) = 112.45$, $p < 0.001$). Patients treated with exosome hydrogels experienced significantly greater reductions in VAS pain scores (1.8 \pm 0.7 vs. 3.9 \pm 0.9; $p < 0.001$), lower serum CRP levels (6.2 \pm 1.8\text{ mg/L} vs. 14.5 \pm 3.1\text{ mg/L}; $p < 0.001$), and lower scar scale ratings (2.4 \pm 0.8 vs. 4.8 \pm 1.1; $p < 0.001$). In conclusion, exosome-enriched hydrogel dressings can efficiently promote re-epithelialization and minimize early inflammation and tissue scarring in PTBI, and this cell-free regenerative strategy is very promising. Keywords: Administration, Cutaneous; Biomaterials; Burns; Cicatrix; Exosomes; Hydrogels; Wound Healing.

INTRODUCTION

Despite significant progress in both basic and clinical research, burn injuries remain one of the most challenging problems in Regenerative medicine and are a major cause of severe morbidity, prolonged hospital stay and

© 2026 The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY 4.0) License | jhwcr.com

substantial financial burden in the world(1). Deep partial thickness and full thickness thermal injury initiate a series of events which leads to tissue necrosis, lasting oxidative stress, and a strong inflammatory cell infiltration(2). The traditional methods for wound management aim at preventing microbial colonization and maintaining a moist wound bed, from non-stick materials to conventional topical antimicrobials and autologous skin grafting. But, standard approaches may not be sufficient to actively teach or speed up the processes going on in the cell required for best tissue repair. Delayed healing is associated with the development of secondary infections and sepsis as well as excess myofibroblastic activity, which can result in hypertrophic scarring, contractures and functional disability. Therefore, new advanced therapeutic platforms that can actively manipulate the physiological microenvironment to obtain rapid epithelial renewal and functional regeneration of the skin are needed(4).

Stem cell-derived extracellular vesicles (ECs), or exosomes, are recently identified as strong paracrine factors in tissue repair processes in recent years. These membrane-bound nanovessicles contain a copious amount of bioactive molecules such as micro RNAs, growth factors, and regulatory proteins that directly regulate intercellular communication(5). Exosomes derived from mesenchymal stem cells (MSCs) possess a highly pro-angiogenic, immunomodulatory, and anti-apoptotic effects. While whole-cell therapies have their drawbacks, exosomal therapies have clear merits like reduced immunogenicity, enhanced biochemical stability, and a lack of the concerns of ectopic tissue development or cellular transformation. However, these promising biological properties are not realized in the clinical setting, as free exosome suspensions are rapidly degraded by enzymes, are poorly retained at the site, and are quickly removed from fluid-exudative burn wound sites. These nanovesicles are extremely delicate and require an innovative delivery vehicle to maintain their integrity and enable their controlled and long-term release(6).

The three-dimensional polymeric network that is a feature of biocompatible hydrogels gives them the special place as advanced wound care scaffolds in mimicking the native extracellular matrix. Hydrogels ensure an optimal moisture condition when placed at the wound interface, absorb excess exudate, provide autolytic debridement and protect newly formed tissue from mechanical stress. A synergistic approach is obtained by incorporating exosomes in dynamic, bio-responsive hydrogel matrices: exosomes are encapsulated, maintaining bioactivity and bio-retention at the wound site, which promotes tissue matrix healing and released nanovesicles regulate cell behavior at the site by interacting with the local cells. Preliminary studies in animal models have confirmed the efficacy of the use of exosome functionalised hydrogels, which have led to an increase in re-epithelialisation, accelerated collagen deposition and decreased inflammation in animal models, although clinical data in humans is less robust. There is still a solid need for extensive clinical data regarding the therapeutic efficacy, safety profile and physiological mechanisms of action of exosome-enriched hydrogels in human thermal injuries(7).

To meet this gap between preclinical potential and clinical use, systematic clinical trials are necessary to assess the clinical worth of exosome-enriched matrices for burns patients(8). The capacity to propionate parameters such as the complete healing of wounds, vascular regeneration, cytokine changes in the microenvironment, and the quality of the scar will be convenient to make the limits of the therapeutic application of this new biomaterial platform. Therefore, it was decided to systematically evaluate the effectiveness of exosome-loaded hydrogel dressings vs standard hydrogel dressings on re-epithelialization, excess inflammatory response and structural tissue regeneration in partial thickness burn wounds in a randomized controlled study(9). The purpose of this trial is to establish an evidence base for the use of exosome-hydrogel therapy as a new generation of standard in treatment of advanced burns in controlled clinical conditions(10).

MATERIAL AND METHODS

This was a single center, prospective, double blind, parallel group, randomized controlled trial (RCT) directed at a tertiary care burn center in Central Punjab, which was designated due to its centralized burden of the disease, uniform hospital protocols for burns in the region and similar baseline dietary profile of its patients, thereby minimizing the environmental confounding reasons in the treatment and wound healing of burns. The study took place in a six-month period, from May 2025 to October 2025, including the recruitment of participants, active interventions, and follow-up needs. A sample size calculation was used in conjunction with effect sizes reported in previous clinical trials that evaluated bioactive hydrogels for dermal repair to determine that 60 patients (30 patients in each arm) would be sufficient for this study, with a recruitment target of 51 patients, based on the 10% drop-out rate. Adults aged 18-50 years with acute partial thickness burns on 5-15% of their total body surface area (TBSA) within 24 hours of burn who met the eligibility criteria were included.Participants were adults (18-50 years) who had experienced acute partial thickness thermal burn wounds to 5-15% of their total body surface area (TBSA) within 24 hours of the burn. To minimize systematic bias, exclusion criteria were used, including chronic metabolic

diseases (e.g. diabetes mellitus), systemic infections in the past, suspected autoimmune diseases, and topical therapy in the past before presentation.

Participants were allocated to groups by randomisation, through a computer-generated block sequence with variable block sizes, in a 1:1 ratio. Allocation concealment was independently obtained by sequentially numbered, opaque, sealed envelopes that were handled by an independent research coordinator separate from clinical care and assessment. Group assignments were kept double-blinded by both the participants and the outcome assessors, dressings were packaged in identical but unlabeled sterile containers, and the applications were made by nursing staff with special skills, who were not involved in data collection. The intervention group was treated with a standardised exosome enriched hydrogel dressing directly onto the wound bed every 48 hours for 4 weeks of active intervention. Control group was treated with the same inert hydrogel dressing with the same application regimen and the same hygiene routine as the experimental group but was not enriched. The degree of adherence was checked on a daily basis by hospital admission records and daily clinical charts and analyzed with the intention to treat principle, so as to consider the possible non-compliance or loss to follow-up.

Outcome measures were assessed at the start of the intervention (baseline) and at the end of the 4-week intervention. Complete epithelialization was the primary outcome with the percentage of wound closure determined by planimetric digital photography and analysed with ImageJ software. Secondary outcomes were subjective wound pain (VAS), local inflammation (serum C-reactive protein) and scar quality (Vancouver Scar Scale). The Shapiro–Wilk test was used to test the normality of the data. Paired t-tests were used to assess for within group changes from baseline to post-intervention with continuous variables, and independent t-tests were used for between group comparisons. A repeated-measures analysis of variance (ANOVA) was used to assess group-by-time interaction effects for all time points. To assess correlations between reduction in inflammatory markers with the rate of wound closure, Pearson correlation analysis was used. The level of statistical significance was defined as p value < 0.05.

RESULTS

A quantity 78 patients with acute partial thickness thermal burn injuries screened for inclusion in the study over a 6-month period (May 2025 – October 2025). Of these, 18 (12 not suitable and 6 refused particular patient) were removed leaving a baseline randomized sample of N=60 participants. The participants were randomly divided into an intervention group (exosome-enriched hydrogel dressing, n=30) and a control group (plain hydrogel dressing, n=30). Of the 5 participants who were lost to follow-up during the 4-week intervention period, 2 were from the intervention group (1 who withdrew voluntary and 1 who was transferred to facility) and 3 were from the control group (2 not adherent to protocol and 1 lost to contact). Thus, the final ITT (intention to treat) analysis population consisted of 55 study subjects (28 in the intervention group and 27 in the control group).

Baseline demographic and clinical features assessed in the entire randomized sample (N=60) showed good comparability between the two arms. Overall, the mean age was 33.4 ± 8.2 years and 38 (63.3%) were males. The mean % of the total body surface area was 9.8% ± 2.8%. There were no statistically significant differences between the intervention and control groups in terms of age, sex distribution, burn severity or baseline clinical parameters (all p>0.05).

Table 1. Baseline demographic and clinical characteristics of the randomized participants

Characteristic	Total (N=60)	Exosome-enriched hydrogel (n=30)	Plain hydrogel (n=30)	Between-group difference (95% CI)	p-value
Age, years	33.4 ± 8.2	33.1 ± 7.9	33.7 ± 8.6	-0.6 (-4.9 to 3.7)	0.779
Male sex, n (%)	38 (63.3)	19 (63.3)	19 (63.3)	—	1.000
Burn TBSA, %	9.8 ± 2.8	9.6 ± 2.7	10.0 ± 2.9	-0.4 (-1.8 to 1.0)	0.582
VAS pain score, 0–10	7.8 ± 1.1	7.9 ± 1.0	7.7 ± 1.2	0.2 (-0.4 to 0.8)	0.486
Serum CRP, mg/L	42.5 ± 8.4	43.1 ± 8.1	41.9 ± 8.8	1.2 (-3.2 to 5.6)	0.585

The mean percentage of wound closure at the primary endpoint after 4 weeks of intervention was significantly higher in the intervention group (n=55) than in the control group. Independent t-test showed a mean difference of 19.4% (95% CI, 14.2% to 24.6%) was statistically significant from the exosome-enriched hydrogel, p < 0.001.

Table 2. Primary and secondary clinical outcomes for 4 weeks

Outcome	Exosome-enriched hydrogel (n=28)	Plain hydrogel (n=27)	Between-group difference (95% CI)	Hedges g	p-value
Wound closure, %	91.2 ± 5.8	71.8 ± 7.3	19.4 (15.8 to 23.0)	2.91	<0.001
VAS pain score, 0–10	1.8 ± 0.7	3.9 ± 0.9	-2.1 (-2.5 to -1.7)	-2.57	<0.001
Serum CRP, mg/L	6.2 ± 1.8	14.5 ± 3.1	-8.3 (-9.7 to -6.9)	-3.24	<0.001
Vancouver Scar Scale score	2.4 ± 0.8	4.8 ± 1.1	-2.4 (-2.9 to -1.9)	-2.47	<0.001

We got the Values, which are mean ± SD. Between-group differences are intervention minus control and were calculated from the reported means, SDs, and group sizes using independent-samples comparisons. Hedges g represents the standardized between-group difference; its sign follows the direction of the reported mean difference. CI, confidence interval; CRP, C-reactive protein; VAS, Visual Analog Scale.

Table 3. Within-group changes from baseline to week 4

Outcome	Group	Baseline, mean ± SD	Week 4, mean ± SD	Mean change
Wound closure, %	Exosome-enriched hydrogel	0.0 ± 0.0	91.2 ± 5.8	91.2
Wound closure, %	Plain hydrogel	0.0 ± 0.0	71.8 ± 7.3	71.8
VAS pain score, 0–10	Exosome-enriched hydrogel	7.9 ± 1.0	1.8 ± 0.7	-6.1
VAS pain score, 0–10	Plain hydrogel	7.7 ± 1.2	3.9 ± 0.9	-3.8
Serum CRP, mg/L	Exosome-enriched hydrogel	43.1 ± 8.1	6.2 ± 1.8	-36.9
Serum CRP, mg/L	Plain hydrogel	41.9 ± 8.8	14.5 ± 3.1	-27.4

CRP, C-reactive protein; SD, standard deviation; VAS, Visual Analog Scale. Mean change was calculated as week 4 minus baseline. Confidence intervals for within-group change are not presented because SDs of paired changes or participant-level data were not reported.

Table 4. Group-by-time interaction and correlation analyses

Analysis	Estimate	df	Effect size	95% CI	p-value
Wound closure: group × time interaction, F	112.45	1, 53	0.680	—	<0.001
VAS pain: group × time interaction, F	84.12	1, 53	0.613	—	<0.001
Serum CRP: group × time interaction, F	96.38	1, 53	0.645	—	<0.001
Week-4 CRP vs wound closure, Pearson r	-0.74	53	—	-0.84 to -0.59	<0.001

Those effect sizes in repeated-measures analyses are partial η^2 values, based on the F statistic and degrees of freedom reported. Fisher's z-transformation was used to obtain the 95% CI for the Pearson r. CRP: C-reactive protein, df: degrees of freedom, VAS: Visual Analog Scale.

Wound closure on the exosome-enriched hydrogel group and plain hydrogel group was 91.2 ± 5.8% and 71.8 ± 7.3%, respectively, at week 4. This difference between groups was 19.4 percentage points (95% CI, 15.8 to 23.0; p<0.001) with a standardized effect size of Hedges g=2.91. Mean VAS pain scores were also lower in the intervention group by 2.1 points (95% CI, -2.5 to -1.7; p<0.001; g=-2.57). Serum CRP concentrations differed by -8.3 mg/L (95% CI, -9.7 to -6.9; p<0.001; g=-3.24), while Vancouver Scar Scale scores differed by -2.4 points (95% CI, -2.9 to -1.9; p<0.001; g=-2.47) at week 4.

The mean wound closure increased by 91.2 percentage points in the intervention group and 71.8 in the control group from baseline to week 4. Means of VAS decreased by -6.1 and -3.8 points, respectively, and mean of serum CRP decreased by -36.9 mg/L and -27.4 mg/L. Uncertainty intervals of paired change scores could not be computed using the reported aggregate data because SDs of the change scores within groups were not reported.

The reported repeated-measures analyses proven group-by-time interactions for wound closure (F[1,53]=112.45, p<0.001), pain scores (F[1,53]=84.12, p<0.001), and serum CRP (F[1,53]=96.38, p<0.001). These statistics yielded partial η^2 values of 0.680, 0.613, and 0.645, respectively, telling us a high levels of parting in change of forms between groups across the two assessment times. At week 4, serum CRP was inversely correlated with % of wound closure (r=-0.74, 95% CI -0.84 to -0.59; p<0.001).

DISCUSSION

We saw in this randomized controlled trial that exosome-enriched hydrogel dressing significantly fast-tracked the re-epithelialization, condensed systemic inflammation, and improved basic scar outcomes, compared to the control hydrogel dressing, in acute partial-thickness thermal burn wounds(11). The exosome-enriched group had a mean thorough epithelialization rate of 91.2% over the 4-week periodic duration of the active intervention, as

compared with 71.8% for the control group, it was seen statistically significant(12). meaningful secondary clinical improvement was seen in this trajectory of enhanced tissue closure, including a more swift decline in patient-reported pain scores and a large drop in serum C-reactive protein levels(13). The negative relationship between inflammatory resolution and wound closure rates suggests that the incorporation of exosomes is able to effectively resolve the inflammatory cascade in the wound microenvironment and shift it from an inflammatory condition to an active one involving matrix remodeling(14).

Extracellular vesicles are known to exhibit regenerative properties during dermis wound healing as reported in previous preclinical and emerging clinical studies, which are in line with the findings of this study. The findings of this study were in good correlation to the previous preclinical and emerging clinical literature that have focused on the regenerative properties of EVs on dermal wound healing process. The role of stem cell-derived exosomal signaling and targeted regulation of endothelial cell proliferation, migration and angiogenesis through microRNA and protein cargo in these nanovesicles had been investigated previously(15). The speedy tissue closure detected in the present trial is in vision with the theoretical notion that hydrogels are an ideal bio-interactive matrix that keeps good the fragile integrity of exosomes and local holding throughout the fluid-exudative burn bed(16). In addition, the parallel cut in scores on the Vancouver Scar Scale in the intervention group confirms previous biological models that exosomal modulation inhibits aberrant myofibroblast differentiation, heavy collagen cross-linking and thus leads to a more planned dermal structure(17).

The translation of this would have big clinical implications for burn care algorithms. Secondary wound infection, prolonged hospitalization, and hypertrophic scarring are direct consequences of the critical clinical window for treatment of many thermal injuries in which epithelialization is directly related to the risk of the injury. A non-invasive, cell-free, bioactive scaffold for exosome delivery is a biological intervention that could facilitate physiological wound closure with minimal logistics, immunologic and tumorigenicity concerns of live stem cell transplantation(18). The obvious decrease in pain intensity at the early time frame also indicates that local inflammatory cytokines can be suppressed, providing local analgesia, without the need for dependence on systemic analgesics for normal dressing changes(19).

The results are encouraging, but the study has a number of methodological weaknesses which caution the interpretation of the results. First, the number of participants analyzed (n = 55) was adequate to determine differences at the primary endpoints, but is still relatively small and from a single tertiary care center. Second, the study included only acute, partial-thickness thermal burns, whereas it did not include full thickness burns or burns in older age groups or those in the diabetic population. Third, the evaluation of the outcomes was restricted to 4 weeks after the intervention, which prevents firm conclusions to be drawn on long-term improvements in tensile scar strength, normalization of pigmentation and delayed scar contracture over multi-year periods. In addition, since systemic C-reactive protein was monitored as a surrogate inflammatory marker of systemic inflammation, local wound tissue cytokine profiling was not done because of protocol limitations(20).

The treatment outcomes need to be investigated further in multi-center clinical trials with larger patient sample sizes in order to confirm the therapeutic effects in more heterogeneous patient populations such as high risk diabetic patients and geriatric patients. Dose-responses for exosome concentrations in hydrogels will further be investigated as a way to optimize clinical protocol guidelines. Further long-term follow-up studies up to 6 and 12 months after injury are needed to fully understand the maturation process of scars and the functional range of motion results. Future designs incorporating localized tissue RNA sequencing and histological sampling would reveal detailed molecular signaling networks responsible for the exosome-induced dermal regeneration of human skin.

CONCLUSION

In partial-thickness thermal burn wounds, exosome-enriched hydrogel dressings can be shown to make a significant difference in re-epithelialization, systemic inflammation, and scar quality when compared to the same dressings used to treat thermal burns with only hydrogel. This bioactive scaffold delivers a long-term supply of bioactive nanovesicles, ensuring early repair of tissues and minimizing post-burn issues. Exosome-loaded hydrogel therapy provides a safe, cell-free advanced wound care platform with optimized healing velocity and aesthetic results, laying the groundwork for advanced burn management in the future.

REFERENCES

1. Jeschke MG, van Baar ME, Choudhry MA, Chung KK, Gibran NS, Logsetty S. Burn injury. Nat Rev Dis Primers. 2020;6(1):11.
2. Liang Y, He J, Guo B. Functional hydrogels as wound dressings to enhance wound healing. ACS Nano. 2021;15(8):12687-12722.
3. An Y, Lin S, Tan X, Zhu S, Li F, Wang Y. Exosomes derived from stem cells as novel cell-free therapeutics in skin wound healing. Int J Mol Sci. 2021;22(11):5780.
4. Xian P, Hei Y, Wang R, Wang H, Yang J, Zhang J. Mesenchymal stem cell-derived exosomes accelerate skin wound healing by promoting angiogenesis and collagen synthesis. Int J Biochem Cell Biol. 2020;125:105786.
5. Liu J, Chen Z, Wang J, Ruan R, Xu X, Yang X. Encapsulation of exosomes in hydrogels for controlled release and enhanced tissue repair. Bioact Mater. 2022;14:385-397.
6. Yang J, Chen Z, Pan D, Li H, Shen J. Umbilical cord mesenchymal stem cell-derived exosomes wrapped in hydrogel accelerate burn wound healing. Tissue Eng Part A. 2020;26(11-12):641-651.
7. Shi Q, Qian Z, Liu D, Sun J, Wang X, Liu H. Sustained release of exosomes from bioactive hydrogels enhances re-epithelialization and reduces scarring in full-thickness cutaneous wounds. Biomaterials. 2021;269:120638.
8. Chen L, Xu Y, Zhao J, Zhang Z, Wang R. Biomaterial-assisted exosome delivery for skin tissue engineering: mechanics, modulation, and tissue repair. Adv Healthc Mater. 2022;11(4):2101895.
9. Zhou X, Zhang W, Jiang Y, Wang S, Liu X. Clinical perspectives of extracellular vesicle-loaded biomaterials in regenerative medicine. Bioact Mater. 2023;22:512-528.
10. Zhao D, Yu Z, Li Y, Wang Y, Li Q, Han D. Mesenchymal stem cell-derived exosomes accelerate burn wound healing through paracrine signaling and promoting angiogenesis. Stem Cell Res Ther. 2020;11(1):269.
11. Wu P, Zhang B, Shi H, Qian H, Xu W. MSC-derived exosomes in skin wound repair: molecular mechanisms and therapeutic potential. Front Cell Dev Biol. 2021;9:661270.
12. Hu L, Wang J, Zhou X, Xiong Z, Zhao J, Yu R. Exosomes derived from human adipose-derived stem cells accelerate cutaneous wound healing via optimizing fibroblast functions. Theranostics. 2021;11(1):188-203.
13. Li M, Hou Q, Zhong L, Zhao Y, Fu X. Enhanced wound healing and scar inhibition through controlled release of exosomes using bioresponsive hydrogels. J Control Release. 2022;348:421-435.
14. Huang C, Liu L, Wang Y, Zhang Y, Tan J. Mechanisms of scar prevention using exosomal therapy in deep burn wounds. Wound Repair Regen. 2023;31(2):142-153.