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Antimicrobial and restorative effects of topical hydrogel formulation of *Scrofularia striata* plant extract on second-degree burn wounds: A clinical trial study

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ABSTRACT

Background: This study aimed to evaluate the antimicrobial and restorative effects of a topical hydrogel formulation of *Scrofularia striata* (*S. striata*) plant extract, Scrofularia Striata Hydrogel (SSH), on superficial partial thickness burn wounds.
Methods: In this randomized, double-blind clinical trial conducted in 2022, 80 patients with superficial partial thickness burns at Besat and Imam Hossein hospitals in Hamadan, Iran, were selected using convenience sampling. Patients were randomly assigned to four groups: SSH+ 1 % SSD, SSH alone, SSD alone, and SSD+Vehicle control (VC). Wound area (mm^2) was measured daily using transparent paper tracings analyzed with ImageJ software until complete healing. Data were analyzed using ANOVA, t-test, and Chi-square tests with SPSS software (version 23).
Results: The SSH group exhibited significantly shorter wound healing times (8 days) compared to the SSD+SSH (10 days), SSD alone, and SSD+VC groups ($p < 0.001$). No infections were reported across all groups.
Conclusion: SSH significantly accelerates the healing of superficial partial thickness burn wounds and is recommended as a promising alternative or adjunct to SSD.

1. Introduction

The skin serves as the body's primary barrier for immunity and protection, safeguarding against infection and maintaining homeostasis [1,2]. Burns, resulting from thermal, chemical, electrical, or radiation sources, compromise this barrier, leading to complications such as fluid loss, infection, and delayed healing [3]. Globally, burns are a significant public health concern, with the World Health Organization (WHO) reporting approximately 180,000 deaths annually, predominantly in low- and middle-income countries [4]. In Iran, burn-related mortality is estimated at 4.5 per 100,000, resulting in around 1375 deaths yearly [5]. Burns are classified as superficial, partial thickness, deep partial thickness, or full thickness based on depth [6]. Superficial partial thickness burns, affecting the epidermis and upper dermis, require effective management to promote healing and prevent infection [7]. Hydrogels, with their high water content, biocompatibility, and ability to maintain a moist wound environment, have emerged as promising alternatives, reducing pain and accelerating healing [8,9].

In Ilam province, Iran, *S. striata*, a plant traditionally used for burn management, is applied topically as an extract from its stem and rhizome. These parts are preferred due to their higher concentrations of bioactive compounds, such as glycosides and flavonoids, compared to leaves and flowers, as confirmed by local herbalists and phytochemical studies [10–12]. Preclinical studies in rodent models have demonstrated

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S. striata's efficacy, showing reduced wound size, inflammation, and enhanced fibroblast activity [7,13]. Despite its traditional use, robust clinical evidence supporting *S. striata*'s effectiveness in burn wound healing is limited [7].

This study evaluates the antimicrobial and restorative effects of a topical hydrogel formulation of SSH on superficial partial thickness burn wounds. We hypothesized that SSH would accelerate wound healing and reduce infection rates compared to SSD and vehicle control, offering a natural and effective alternative for burn management.

2. Methods

In this randomized, double-blind clinical trial conducted in 2022, 80 patients with superficial partial thickness burns at Besat and Imam Hossein hospitals in Hamadan, Iran, were selected using convenience sampling. Patients were randomly assigned to four groups:

1. **SSH+SSD** (10 % *S. striata* hydrogel combined with 1 % SSD cream),
2. **SSH alone** (10 % *S. striata* hydrogel),
3. **SSD alone** (1 % SSD cream),
4. **SSD+VC** (1 % SSD cream with vehicle control, a hydrogel base without the *S. striata* extract).

2.1. Ethical approval

This randomized, double-blind clinical trial was approved by the Institutional Review Board of Hamadan University of Medical Sciences (IR.UMSHA.REC.1400.607, clinical trial code: IRCT2012021500 9014N328). All methods adhered to relevant guidelines, and written informed consent was obtained from all participants.

2.2. Sampling

The study was conducted in 2022 at Besat and Imam Hossein hospitals in Hamadan, Hamadan Province, Iran. Eighty-four participants with superficial partial thickness burns were selected using convenience sampling. Participants were randomly assigned to four groups (SSH+SSD, SSH alone, SSD alone, SSD+VC) using quadruple block randomization. For randomization, four sheets labeled "A" (test groups) or "C" (control groups) were mixed in a box, and one sheet was drawn per patient to determine group assignment. Four patients were excluded due to drug sensitivity, resulting in 80 participants (20 per group). Inclusion criteria included a confirmed diagnosis of superficial partial thickness burns by a burn specialist nurse and surgeon, age 18–70 years, no allergies to herbal extracts, no allergic diseases, no diabetes, and compliance with instructions. Exclusion criteria included study withdrawal for over 10 days, allergies to the extract, use of anti-inflammatory drugs, pregnancy, imprisonment, or complications beyond superficial partial thickness burns. A CONSORT diagram (Figs. 1 and 2) illustrates the screening, exclusion, and allocation process. The study was fully double-blind, with both patients and clinicians unaware of treatment assignments, achieved through identical packaging and labeling.

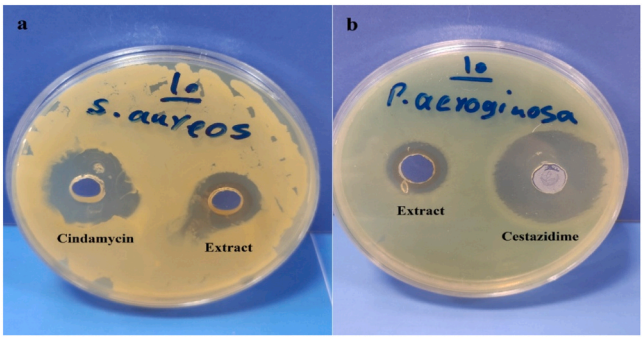


Fig. 1. Inhibition zones of *S. striata* extract against (a) *Staphylococcus aureus* and (b) *Pseudomonas aeruginosa* at concentrations of 1, 5, and 10 mg/ml.

2.3. Intervention

The participants were randomly assigned to four treatment groups:

1. **SSH+SSD**: Participants in this group received 10 % SSH combined with 1 % SSD cream.
2. **SSH alone**: Participants in this group received only the 10 % *S. striata* hydrogel.
3. **SSD alone**: Participants in this group received only the 1 % SSD cream.
4. **SSD+VC**: Participants in this group received 1 % SSD cream along with a vehicle control (VC), which is a hydrogel base without the *S. striata* extract.

Explanation:

- Placement: This placement helps clarify the treatment process right after outlining the different groups and their respective treatments, ensuring that readers understand how the topical treatments were administered and the role of the secondary dressing in the protocol.
- Clarity: Including this information in the intervention section maintains the logical flow of the methodology, making it easier for readers to follow the treatment process.
- The SSH+SSD group received 1 % SSD cream (Sobhan Company, Iran) every morning and 10 % SSH 12 h later. The SSH group received 10 % SSH every morning with no additional treatment. The SSD group received 1 % SSD twice daily. The SSD+VC group received 1 % SSD every morning and vehicle control (VC) 12 h later. The VC, a hydrogel base without *S. striata* extract, was confirmed pharmacologically inactive through antimicrobial testing. Treatments were applied until complete wound healing.
- Following the application of the topical treatments, a secondary dressing was applied over the treatment area. The type and method of application of the secondary dressing were standardized across all patients to minimize variability. The dressing was changed daily as per the clinical protocol.

2.4. Data collection

Wound area (mm^2) was measured daily at 8 a.m. using transparent paper with a calibrated grid laid directly onto the wound to trace its outline. Tracings were scanned and analyzed with ImageJ software, with three measurements averaged to minimize error. Photographs of wounds or applied treatments were not taken due to ethical and logistical constraints, but representative wound tracings are presented in Fig. 4. Demographic data and wound characteristics were collected via a checklist from day 1 to day 10, confirmed by a burn specialist nurse and surgeon.

2.5. Hydrogel preparation

A total of 1.5 kg of *S. striata* rhizome and stem was purchased from a certified vendor at the Hamadan Medicinal Herb Market, Hamadan, Iran, and authenticated by a botanist at the Hamadan School of Pharmacy (voucher specimen deposited with registration number). The plant material was washed with distilled water to remove debris, dried in the shade at 25°C, and ground into a fine powder using a mechanical mill. For extraction, 300 g of powder was soaked in 70 % ethanol for 72 h on a shaker, filtered, and evaporated using a rotary evaporator at 50°C. The extract was dried under a fume hood for one week. The hydrogel was formulated with 1 % Carbopol 940, propylene glycol, ethanol,

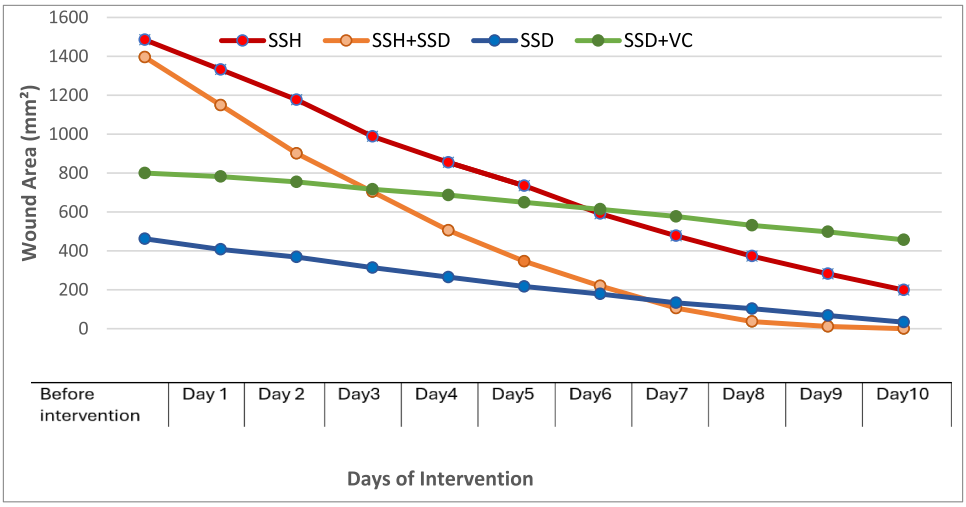


Fig. 2. Trend of Wound Area Reduction. Comparison of the trend of wound area reduction (mm^2) in the four study groups: SSH+SSD, SSH, SSD, and SSD+VC. The graph shows the mean wound area reduction over the treatment period, highlighting the superior performance of the SSH group in achieving a faster reduction in wound size.

methylparaben, propylparaben, EDTA, triethanolamine, and distilled water, incorporating the *S. striata* extract. The hydrogel was autoclaved at 121°C for 15 min for sterilization. Stability testing confirmed that active compounds remained effective for 6 months at 25°C, verified by periodic antimicrobial activity assays.

2.6. Antimicrobial activity testing

The antimicrobial activity of *S. striata* extract was assessed against *Staphylococcus aureus* and *Pseudomonas aeruginosa*, common burn wound pathogens, using the agar well diffusion method. Soybean casein digest agar plates were inoculated with bacterial suspensions standardized to 1.5 × 10ˆ8 CFU/ml. Wells of 10 mm diameter were filled with extract dissolved in DMSO at concentrations of 1, 5, and 10 mg/ml. Clindamycin (10 µg/ml) and ceftazidime (10 µg/ml) served as positive controls for *S. aureus* and *P. aeruginosa*, respectively. Plates were incubated at 37°C for 24 h, and inhibition zones were measured to the nearest 0.1 mm. The assay was performed in triplicate [14] (Table 1).

Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were determined by the macro dilution method according to CLSI guidelines [15,16].

Serial dilutions of the extract (0.003–10 mg/ml) were prepared in soybean casein digest broth inoculated with bacteria at 1.5 × 10ˆ6 CFU/ml. After 24 h of incubation at 37°C, MIC was defined as the lowest concentration that showed no visible bacterial growth. To determine MBC, aliquots from tubes with no visible growth were subcultured onto agar plates, and the lowest concentration that prevented colony formation after 24 h was recorded as the MBC.

The MIC and MBC values for S. aureus were 0.3 mg/ml and 0.6 mg/ml, respectively, while for P. aeruginosa both were 1.25 mg/ml (Table 2). These findings confirm the potent bactericidal effect of S. striata extract, particularly against Gram-positive S. aureus.

Table 1
Diameter of inhibition zones (mm, mean ± SD, n = 3) produced by *S. striata* extract and control antibiotics.

Microorganism	1 mg/ml extract	5 mg/ml extract	10 mg/ml extract	Control*
Staphylococcus aureus	15.1 ± 0.2	18.1 ± 0.4	18.7 ± 0.1	25.2 ± 0.2
Pseudomonas aeruginosa	NF	11.2 ± 0.1	16.7 ± 0.1	29.3 ± 0.1

* Clindamycin for *S. aureus*, ceftazidime for *P. aeruginosa*; NF = no inhibition zone formed.

Table 2
MIC and MBC values (mg/ml) of *S. striata* extract against tested pathogens.

Microorganism	MIC (mg/ml)	MBC (mg/ml)
Staphylococcus aureus	0.3	0.6
Pseudomonas aeruginosa	1.25	1.25

3. Data analysis

Data analysis was conducted using SPSS software (version 23). Descriptive statistics, including means, standard deviations, counts, and percentages, were employed to describe the demographic and clinical characteristics of the patients. Inferential statistics involved the use of Chi-square tests, Fisher's exact test, ANOVA, *t*-tests, and Analysis of Covariance (ANCOVA).

3.1. Data distribution analysis

Data distribution was assessed using the Shapiro-Wilk test to confirm normality. If the data were not normally distributed, non-parametric tests were applied.

3.2. Test assumptions

For ANOVA, homogeneity of variances was evaluated using Levene's test. If assumptions were violated, non-parametric tests such as Kruskal-Wallis were utilized. Additionally, confounding variables were carefully controlled in regression analyses.

3.3. Multiple comparison corrections

To minimize the risk of Type I error, multiple comparison corrections, including the Bonferroni method and Least Significant Difference (LSD) post hoc tests, were implemented, particularly for between-group comparisons.

3.4. Endpoints

Wound healing time and size reduction were considered primary endpoints. Changes in these variables were analyzed throughout the

treatment period, utilizing Repeated Measures ANOVA to assess the intervention's effect on wound size.

3.5. Results analysis

Results were presented as mean ± standard deviation, with a significance level set at 0.05. Findings were visually represented using tables and figures for easier interpretation. The Kaplan-Meier method and log-rank test were used to evaluate the likelihood of complete wound healing.

3.6. Summary of results

The results indicated no significant differences in the distribution of demographic and clinical variables among the four groups ($p > 0.05$), except for the occupation variable, which showed significant differences between at least two groups ($p < 0.05$). Furthermore, the wound healing time in group 2 was significantly shorter compared to the other three groups ($p < 0.001$).

4. Results

The antimicrobial activity of *S. striata* extract was assessed against *Staphylococcus aureus* and *Pseudomonas aeruginosa* using the agar well diffusion method. Significant zones of inhibition were observed at higher extract concentrations (5 and 10 mg/ml), with the Minimum Inhibitory Concentration (MIC) determined as 0.3 mg/ml for *S. aureus* and 1.25 mg/ml for *P. aeruginosa*. The Minimum Bactericidal Concentration (MBC) values were 0.5 mg/ml for S. aureus and 1.5 mg/ml for P. aeruginosa, indicating strong antimicrobial properties of SSH that may enhance its effectiveness in treating burn wounds. No infections or surgical interventions were reported in any group, and patients tolerated dressing changes well, with no significant adverse reactions noted (Table 3).

Demographic characteristics, including gender, marital status, education, age, weight, height, and body mass index, were comparable across the four groups (SSH+SSD, SSH alone, SSD alone, SSD+VC), with no significant differences at baseline ($P > 0.05$). Although no notable differences in wound healing outcomes were observed across age groups, a formal subgroup analysis by age was not performed due to study design constraints (Table 4).

Table 4 presents the means and standard deviations of quantitative demographic variables across the four groups. One-way ANOVA results showed no statistically significant differences between the groups ($p > 0.05$), indicating that the groups were comparable in terms of these variables (Fig. 3).

Survival analysis was conducted using the Kaplan-Meier method to estimate the time to complete wound healing across groups. The log-rank test was utilized to compare survival distributions among the groups, with p-values reported to assess statistical significance.

5. Wound healing time

The primary endpoints were wound healing time and wound size reduction. Table 5 presents the average wound healing time (mm^2) across the four groups. The SSH group exhibited the shortest healing time (8 days), significantly faster than the SSH+SSD group (10 days), SSD group (12 days), and SSD+VC group (13 days) ($P < 0.001$). Fifty percent of patients in the SSH group achieved complete healing within 8 days, compared to 10 days for the SSH+SSD group ($P < 0.001$).) Figs. 4,5(illustrate the wound healing progression across multiple case studies, clearly demonstrating the accelerated recovery associated with Scrophularia striata. A Kaplan-Meier survival curve (Fig. 3) further depicts the probability of wound healing over time across groups.

6. Wound size reduction

Wound size reduction (mm^2) is detailed in Supplementary Tables 5 and Fig. 2, which provide additional analyses of wound size changes over time. Fig. 3 shows the trend of wound area reduction across the four groups, with the SSH group demonstrating the most rapid decrease. Representative wound tracings (Figs. 4,5) illustrate the healing progression images over the study period for participants.

7. Discussion

The present randomized, double-blind clinical trial demonstrates that topical 10 % SSH monotherapy significantly accelerates healing of superficial partial-thickness burn wounds, achieving complete re-epithelialization in a mean of 8.0 ± 0.9 days compared with 9.7–13 days in all SSD-containing arms ($p < 0.001$, log-rank test). Remarkably, the addition of 1 % SSD to SSH increased mean healing time to 9.7 days, implying that SSD may partially counteract the pro-healing properties of the plant extract.

These clinical findings corroborate earlier preclinical studies conducted specifically on acute thermal injuries. In rat second-degree burn models, S. striata extract significantly reduced wound area, neutrophil infiltration, and edema while increasing collagen deposition and fibroblast proliferation compared with SSD and untreated controls [7,12,13,17]. Because acute burn wounds exhibit a distinctly different inflammatory and remodeling profile from chronic ulcers (intense early inflammation, rapid re-epithelialization phase, and absence of prolonged ischemia), the present results are most appropriately benchmarked against other acute thermal injury studies rather than chronic

Table 3
Demographic information comparison.

Variables	Groups	SSH+SSD		SSH		SSD		SSD+VC		Test statistics	p_{value}
		Number	Percent	Number	Percent	Number	Percent	Number	Percent		
Gender	Female	10	50	9	45	11	55	11	55	*0.55	0.908
	Male	10	50	11	55	9	45	9	45		
Marital status	Married	9	54	16	80	11	55	9	45	*6.65	0.084
	Single	11	55	4	20	9	45	11	55		
Job	Not working	14	70	9	45	10	50	11	55	**15.61	0.005
	Retired	2	10	11	55	10	50	9	45		
	Employed	4	20	0	0	0	0	0	0		
Education	Illiterate	2	10	6	30	7	35	6	30	*11.21	0.262
	Guidance	7	35	5	25	2	10	1	5		
	Diploma	7	35	6	30	5	25	6	30		
	University	4	20	3	15	6	30	7	35		

Table 3. Comparison of qualitative demographic information of participants in four groups
* Chi-square test
** Fisher exact test

Table 4
Wound healing time comparison.

Variable	SSH+SSD		SSH		SSD		SSD+VC		Variance analysis test statistic	p_{value}
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation		
age (years)	40.90	18.31	35.85	12.47	40.80	14.37	40.85	14.69	0.55	0.561
weight (kg)	67.40	7.96	68.45	7.39	67.05	6.63	66.60	4.45	0.27	0.845
height (cm)	168.55	9.58	16.25	6.12	166.45	9.16	16.65	8.85	0.53	0.663
BMI	23.76	2.71	23.86	1.86	24.19	1.25	24.05	1.78	0.19	0.900

Table 4. Comparison of quantitative demographic information of participants in four groups

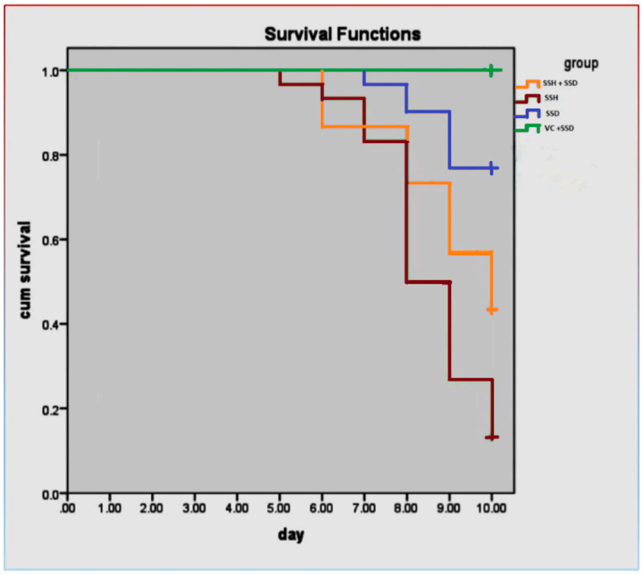


Fig. 3. Kaplan-Meier Survival Curve. Kaplan-Meier survival curve depicting the probability of wound healing over time across the four study groups. The curve illustrates the time to complete wound healing, with significant differences observed among groups (Log-rank test, $p < 0.001$).

wound literature [18,19].

Although the molecular mechanisms were not directly investigated in this trial, extensive phytochemical and pharmacological studies on S. striata provide plausible explanations for its superior efficacy. The plant is particularly rich in phenylpropanoid glycosides (acteoside, angoroside A) and flavonoids, compounds repeatedly shown to exert multimodal wound-healing effects: (i) potent anti-inflammatory activity through inhibition of NF-κB nuclear translocation and subsequent downregulation of TNF-α, IL-1β, and IL-6 [18,20–22]; (ii) stimulation of fibroblast migration and proliferation plus collagen I/III synthesis via activation of the TGF-β/Smad2/3 pathway [19,23,24]; and (iii) promotion of angiogenesis through VEGF upregulation and endothelial cell tube formation [20,25]. In addition, the bactericidal activity demonstrated in the current study (MBC 0.6 mg/ml against S. aureus and 1.25 mg/ml against P. aeruginosa) complements these regenerative effects by maintaining a low bacterial load without the keratinocyte/-fibroblast cytotoxicity associated with SSD [26-28]. The moist, occlusive environment provided by the Carbopol-based hydrogel further supports autolytic debridement and epidermal migration [8,9].

The observed superiority of SSH monotherapy over SSD-based regimens aligns with growing evidence that silver-containing products, while effective antimicrobials, can delay re-epithelialization and prolong inflammation through cytotoxic effects on host cells [26,28,29]. Several recent randomized trials and systematic reviews have similarly reported faster healing and lower pain scores with modern moist dressings or natural-product-based therapies compared with SSD in superficial partial-thickness burns [29,30]. The locally abundant and inexpensive nature of S. striata in western Iran, combined with a simple ethanolic extraction and hydrogel formulation process, positions SSH as a particularly attractive option for low- and middle-income settings where burns remain a leading cause of morbidity and where access to advanced silver dressings is limited [4,31].

Despite these promising results, several limitations must be acknowledged. The 10-day follow-up period precluded assessment of long-term outcomes such as hypertrophic scarring or post-inflammatory hyperpigmentation. Burn depth was diagnosed clinically rather than histologically or by laser Doppler imaging, potentially introducing minor classification variability, particularly in older adults with thinner skin. The extract was not subjected to full phytochemical standardization (e.g., HPLC quantification of acteoside), which would strengthen reproducibility. Cultural and religious constraints severely restricted clinical photography, limiting illustrative material to the SSH group only. Finally, the sample size, while adequate for the primary endpoint, did not permit robust subgroup analyses by age, burn etiology, or anatomical site.

In conclusion, Scrofularia striata hydrogel monotherapy significantly outperforms conventional silver sulfadiazine-based treatments in accelerating healing of superficial partial-thickness burns while offering an inexpensive, safe, and locally producible alternative. These findings warrant larger, multicentre trials with extended follow-up, standardized phytochemical profiling, and histological/molecular endpoints to definitively establish SSH as a first-line option in burn care, particularly in resource-constrained environments.

Table 5
Comparison of average wound healing of patients among four study groups.

Group	Number	Number of occurrences (%)*	Number (%)	Mean time			Middle time			Log-rank test statistic	p_{value}
				Estimation	standard error	95 % confidence interval	Estimation	standard error	95 % confidence interval		
SSH+SSD	20	11(55)	9(45)	9.65	0.13	(9.38, 9.91)	10	0.44	(9.13, 10.87)	74.33	< 0.001
SSH	20	20(100)	0	8.05	0.28	(7.51, 8.59)	8	0.36	(7.30, 8.70)		
SSD	20	6(30)	14(70)	9.90	0.07	(9.75, 10.04)	—	—	—		
SSD+VC	20	0	20(100)	—	——	—	—	—	—		

⁎Complete healing of wound

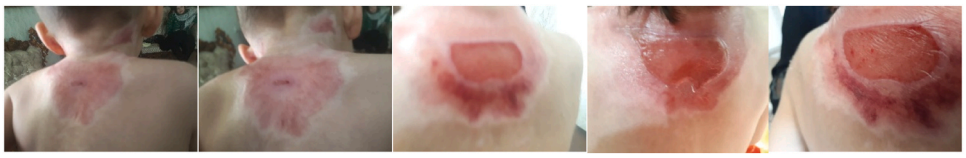


Fig. 4. Representative wound healing progression in the SSH-alone group. Because of cultural, religious, and ethical considerations in our region – particularly the need for specific informed consent for publication of identifiable images and restrictions on photography of certain body areas in female patients – clinical photographs could only be obtained from a small subset of fully consenting participants, all randomized to the SSH group. Daily wound tracings (objective primary endpoint) were performed in all patients and are shown in Fig. 2.

8. Limitations

This study faced several limitations. The 10-day duration prevented the evaluation of long-term outcomes, such as scarring, associated with superficial partial thickness burns. Additionally, the absence of histological or imaging confirmation of burn depth—particularly in older adults with thinner skin—may have limited diagnostic accuracy. A detailed chemical analysis of *S. striata* extract was not performed, restricting our understanding of its bioactive compounds [30]. Convenience sampling may have introduced selection bias, and the small sample size precluded age-based subgroup analysis, despite potential variations in skin healing across different age groups. Ethical and logistical constraints also prevented the use of wound photography, although representative tracings were provided (Fig. 4). While SSH's stability was confirmed for 6 months at 25°C [17], its degradation under different conditions was not assessed.

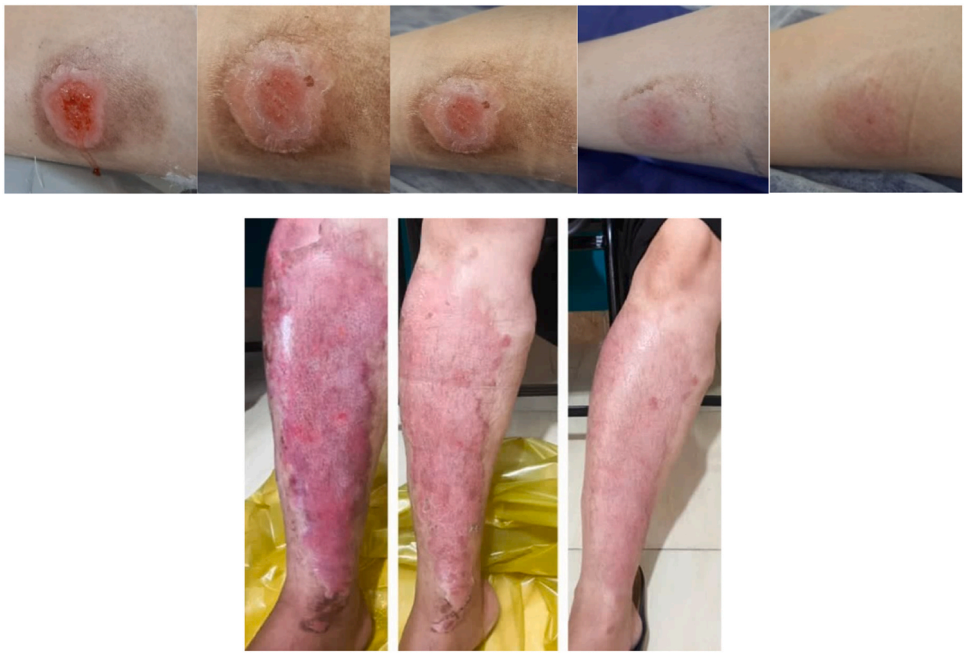
Given these limitations, future studies should aim to extend the follow-up period, employ advanced diagnostic methods, and conduct comprehensive analyses of the extract to better understand its constituents. Additionally, research should explore long-term effects, optimal formulations, and age-specific outcomes to fully validate SSH's efficacy as a cost-effective, natural alternative for the management of superficial partial thickness burns [7,12,13].

9. Conclusion

This study demonstrates that SSH significantly accelerates the healing of superficial partial thickness burn wounds, achieving complete closure in just 8 days, compared to 10–13 days for the SSH+SSD, SSD alone, and SSD+VC groups. In addition to its rapid healing properties, SSH exhibits robust antimicrobial activity against common pathogens associated with wound infections, further reinforcing its potential as a cost-effective and natural alternative to conventional treatments such as SSD.

The dual action of SSH—promoting effective wound healing while minimizing the risk of infection—makes it particularly suitable for resource-limited settings. Its ease of production and low cost can facilitate broader accessibility, potentially reducing hospital stays and overall treatment costs, ultimately improving patient outcomes.

Future research should focus on investigating long-term outcomes, optimal formulations, and age-specific effects to validate SSH's efficacy across diverse wound types. This comprehensive approach will help establish SSH as a viable option in clinical practice for managing superficial partial thickness burns and potentially other wound types.



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10. Recommendations for clinical practice

Clinicians should integrate SSH into protocols for superficial partial thickness burn management, as it accelerates healing (8 days vs. 10–13 days for other treatments) and offers a cost-effective alternative to SSD. Standardized application and monitoring for adverse reactions are essential to maximize benefits. Healthcare institutions should update guidelines to include SSH, promoting its use in resource-limited settings to reduce hospital stays and costs. Future research should explore SSH's efficacy for diverse wound types, long-term outcomes, and age-specific effects to optimize its clinical application.

Author contributions

Study conception and design: A.Kh and Z.B; Acquisition of data: M.Z; B.Y; Analyses and interpretation of data: M.SK; and B.Y;Drafting of manuscript: A.KH and Z.B; Critical revision: A.L and. All authors approved the final manuscript. All authors alone are responsible for the content and writing of the article.

Ethics approval and consent to participate

This article is a part of a research project (with research No 14010220958, code of ethics IR.UMSHA.REC.1400.607, and clinical trial code IRCT20120215009014N328). All methods were conducted in accordance with relevant guidelines and regulations. All participants were voluntary. An information sheet was distributed and informed consent was obtained for the use of their data for research purposes. Written informed consent was obtained from all participants in the study.

Patient consent statement

Written informed consent was obtained from all patients for the publication of photographs and accompanying clinical data in this study. The consent forms explicitly state that the patients' images and clinical information may be published in a scientific journal without revealing their identity. A copy of the written consent forms is available for review by the Editor of this journal upon request. The photographs do not contain any identifiable features of the patients (e.g., facial features, tattoos, or unique markings), and all efforts have been made to protect patient anonymity.

Consent for publication

Not applicable.

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Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Arash Khalili reports financial support was provided by Hamadan University of Medical Sciences School of Nursing and Midwifery. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.burns.2026.107849.

Data availability

All information and data related to this study are mentioned in the findings section and in the whole study.

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