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Enhancing Wound Healing in Aesthetic Surgery: The Role of Chitosan–*Moringa oleifera* Gel

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Abstract

Background & Objectives: This study aimed to evaluate the efficacy of chitosan gel infused with the hydroalcoholic extract of *Moringa oleifera* leaf powder in promoting wound healing and reducing scar formation following cosmetic breast surgery.

Materials & Methods: A total of 42 patients undergoing cosmetic breast surgery were enrolled in this randomized controlled study. Each patient's breast was divided into two lateral hemispheres: one side received *Moringa oleifera* gel, while the other served as a control with a placebo gel. The gels were applied for two weeks postoperatively. Scar appearance was assessed at two weeks and three months post-surgery using the Vancouver Scar Scale (VSS), which evaluates vascularity, pigmentation, elasticity, and height. Data were analyzed to compare outcomes between the treated and control sites.

Results: Of the initial 42 patients, 36 completed the study. Twenty-five and thirty-one patients were evaluated at the two-week and three-month follow-ups, respectively. Wounds treated with the *Moringa*-infused gel demonstrated an 84% improvement in healing compared to those treated with the placebo. Statistically significant improvements were observed in all evaluated parameters—including vascularity, pigmentation, height, and elasticity—in favor of the *Moringa oleifera* gel.

Conclusions: Chitosan gel infused with the hydroalcoholic extract of *Moringa oleifera* leaf powder significantly enhances wound healing and improves scar appearance following cosmetic breast surgery. These findings highlight its potential as a valuable adjunct in postoperative wound care for reducing scarring and promoting tissue regeneration.

Keywords: Wound, Scar, Chitosan, Herbal, Cosmetic Surgery

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Introduction

Breast cosmetic surgeries, including procedures such as augmentation, reduction, lifts, and reconstructions, rank among the most commonly performed aesthetic surgeries worldwide (1, 2). Despite advances in surgical techniques and postoperative care, wound

healing continues to pose a significant challenge in these procedures (3, 4). Complications such as infections, scarring, delayed healing, tissue necrosis, and wound dehiscence can negatively impact both physical outcomes and patient well-being. Postoperative infections, occurring in approximately 5–30% of cases, often extend healing times and necessitate additional medical interventions (5, 6). Furthermore, issues such as hypertrophic scars and keloids frequently result in unsatisfactory aesthetic and psychological outcomes (7, 8). Factors such as inadequate blood supply, high wound tension, and comorbidities including diabetes and smoking contribute to delayed wound healing, further complicating recovery and diminishing patients' overall quality of life (9, 10). Effective wound healing is crucial in breast cosmetic surgeries, as it directly influences aesthetic results, patient satisfaction, and healthcare costs (11, 12). Optimal wound care minimizes the risk of infection, reduces severe scarring, accelerates recovery, and enhances breast symmetry and contour. Improved outcomes not only boost patients' self-esteem and psychological well-being but also make the surgical process more cost-effective, benefiting both patients and healthcare systems through enhanced resource allocation (13–15).

Given these challenges, there is growing interest in innovative, natural treatments to enhance wound healing and prevent scar formation. *Moringa oleifera*, also known as the "miracle tree," has emerged as a promising candidate due to its exceptional medicinal properties (16–18). Rich in vitamins, minerals, and amino acids essential for skin repair, *Moringa* also possesses potent anti-inflammatory, antioxidant, antimicrobial, and anti-tumor properties, making it ideal for wound healing. Studies have demonstrated its ability to accelerate healing, reduce inflammation, and lower infection risk—all of which are critical in surgical care (19–23).

Chitosan gel, a biopolymer derived from chitin, complements *Moringa oleifera*'s healing properties. Renowned for its biocompatibility, biodegradability, and non-toxicity, chitosan is widely used in wound care (24). It supports cell proliferation, tissue regeneration, and microbial barrier formation while maintaining a moist environment conducive to optimal healing (25, 26).

This study investigates the impact of chitosan gel infused with the hydroalcoholic extract of *Moringa oleifera* leaf powder on wound healing in breast cosmetic surgery. We hypothesize that this innovative treatment will significantly enhance healing, reduce scarring, and improve patient satisfaction. Additionally, the treatment may reduce healthcare costs by decreasing complication rates and promoting faster recovery. By combining chitosan's biocompatibility with *Moringa*'s anti-inflammatory and antimicrobial benefits, this research pioneers a novel approach to addressing challenges in postoperative wound care.

Materials and Methods

Ethics and Data Privacy

The study was approved by Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.MSP.REC.1398.1004). The study protocol was also registered with the Iranian Registry of Clinical Trials (IRCTID: IRCT20211206053294N1). In accordance with established ethical standards, access to data was restricted to authorized personnel only, ensuring confidentiality and data integrity throughout the study. To protect patient privacy and comply with ethical guidelines, all identifiers—such as names, dates of birth, and medical record numbers—were removed from the dataset prior to analysis. Only authorized researchers had access to the de-identified data.

Gel Preparation

A hydroalcoholic (water–alcohol) extract was prepared from the dried powder of the *Moringa oleifera*, which was provided by Persian Gulf University, Bushehr. The extraction process

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was conducted under controlled conditions in the laboratory of the Department of Persian Medicine, Tehran University of Medical Sciences. This extract was then incorporated into a base gel made from chitosan polymer powder (Sigma-Aldrich, CAS Number: 9012-76-4, molecular weight: 100–300 kDa, and degree of deacetylation (DDA) ≥85%), resulting in six concentrations of gel formulations: 0%, 0.1%, 0.5%, 1%, 3%, and 5%. Based on the MTT assay results, the 3% hydroalcoholic extract gel was selected as the optimal formulation, labeled for clinical trial use, and then handed over to a clinician for further evaluation.

MTT Assay

The MTT assay was performed to assess the cytotoxicity of the chitosan-based gel containing hydroalcoholic extract of *Moringa oleifera* leaf powder. Human foreskin fibroblast cells (HFFs) were seeded in a 96-well plate (4×10^4 cells/well) and incubated at 37 °C with 5% CO_2 for 24 hours. The medium was then replaced with fresh medium containing the gel at different concentrations (0%, 0.1%, 0.5%, 1%, 3%, and 5%), and the cells were incubated for 24, 48, and 72 hours. After treatment, 100 µL of MTT solution (0.5 mg/mL) was added to each well, followed by incubation at 37 °C for 4 hours to allow for formazan crystal formation. The MTT solution was then removed, and 100 µL of DMSO was added to dissolve the crystals. Absorbance was measured at 570 nm using a microplate reader, and cell viability was calculated relative to the untreated control group. A viability of ≥80% was considered non-toxic, whereas a viability below 70% indicated potential cytotoxicity (27).

Study Design

The study involved patients referred for breast cosmetic surgery at Panzdeh Khordad Hospital. Participants aged 18 to 70 years were included after providing informed consent and being screened to exclude individuals with conditions such as recent chemotherapy, substance abuse, systemic diseases, corticosteroid use, cancer, hormonal drug use, and smoking. Ultimately, 42 patients met the inclusion criteria (Figure 1).

On the day of surgery, each patient received two gels in identical white containers: one containing *Moringa oleifera* hydroalcoholic extract and the other a placebo. The gels were labeled with two different colors according to a randomized allocation sequence enclosed in sealed envelopes. Patients were randomly instructed to apply one gel to the right lateral breast and the other to the left lateral breast, thereby ensuring that each patient served as their own control. This random allocation (i.e., *Moringa oleifera* on the right breast and placebo on the left, or vice versa) was maintained in a double-blind manner so that neither the researchers nor the participants knew which breast received which gel.

The results were compared between the lateral regions of the scars where the gel was applied (*Moringa* and placebo groups) and the corresponding medial regions of the same scars where no gel was applied (*Moringa* control and placebo control groups). Participants were blinded to the gel contents but were informed that comparisons would be made between treated and untreated areas.

Beginning 24 hours after surgery, patients were instructed to apply the gels twice daily for 14 days. They were advised not to apply any product to the medial part of the wound and to avoid rubbing other substances on the surgical area throughout the study. No dressings were required following gel application.

Data Collection

At the end of the second week, two clinical assistants assessed the patients' wound healing progress using a combination of patient-completed questionnaires and clinical examination. To ensure accurate examination, photographs of the wounds were taken under consistent distance and lighting conditions using a Canon D79 camera in a studio, with each photograph including a centimeter scale for reference.

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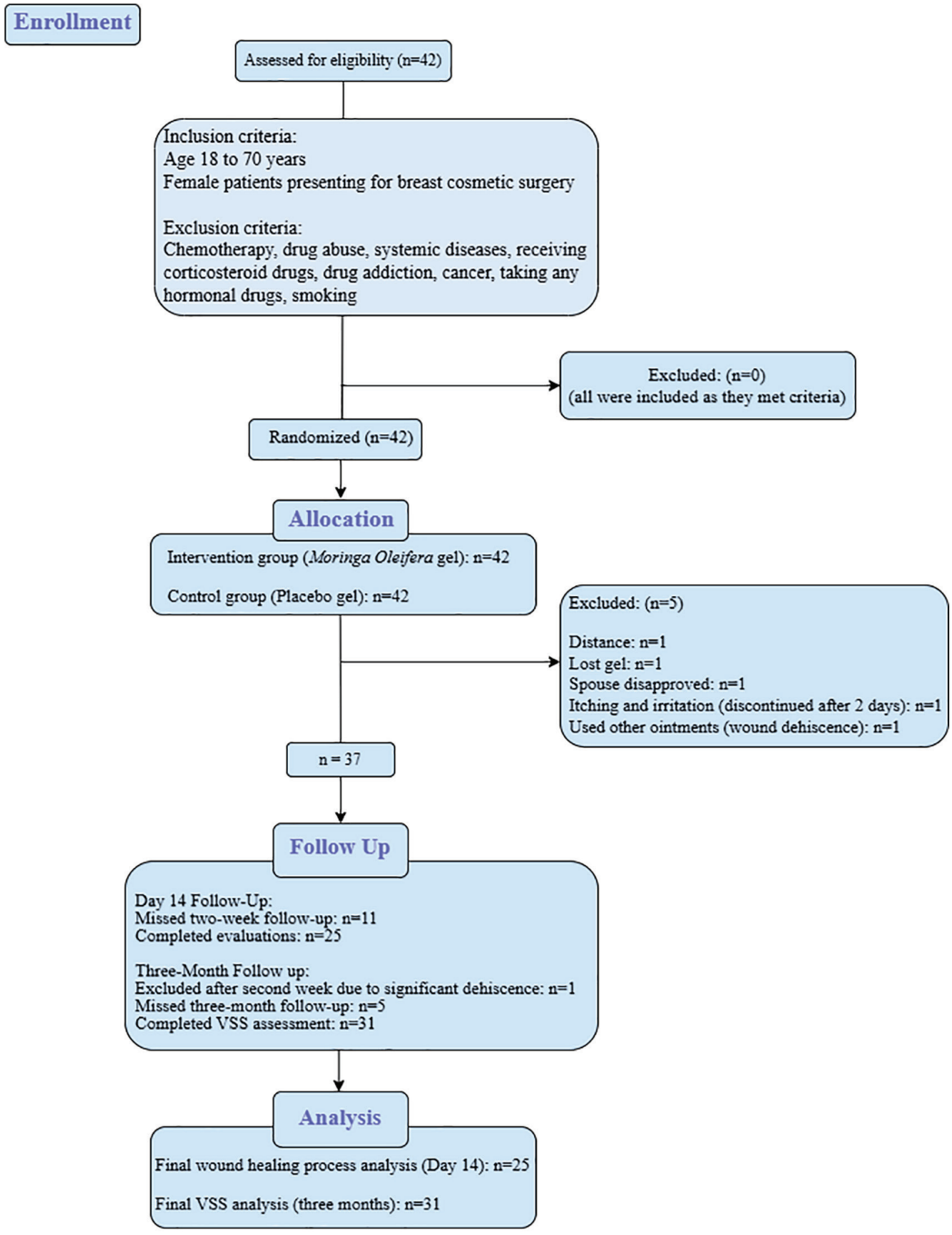

Figure 1. Consort Flowchart

Furthermore, to assess the scars using the Vancouver Scar Scale (VSS), data were collected at the three-month mark, entered into Excel, and scored according to the following VSS criteria: Vascularity: 0 (normal), 1 (pink), 2 (red), 3 (purple) Pigmentation: 0 (normal), 1 (hypopigmentation), 2 (hyperpigmentation) Pliability: 0 (normal), 1 (supple), 2 (yielding), 3 (firm), 4 (banding), 5 (contracture) Height: 0 (normal-flat), 1 (<2 mm), 2 (2-5 mm), 3 (>5 mm) The scores for these four variables were determined based on the degree of variance from natural skin. This scale provides a useful tool for assessing prognosis and treatment.

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Statistical Analysis

The collected data were analyzed using SPSS (special package for social sciences) version 24 software. The chi-square test (or Fisher's exact test) was employed to examine the relationships among the VSS variables. Comparisons of measurements were conducted using ANOVA (analysis of variance) or the Friedman test. A significance level of 0.05 was used to evaluate the research hypotheses.

Result

MTT Assay

The results of the MTT assay demonstrated that the chitosan-based ointment containing hydroalcoholic extract of *Moringa oleifera* leaf powder exhibited both concentration- and time-dependent effects on HFF cells. At lower concentrations (0.1%–3%), cell viability remained above 95% at all time points (24, 48, and 72 hours), indicating no significant cytotoxic effects. Even at 1% and 3% concentrations, viability remained above 94% after 72 hours. However, at the highest concentration (5%), a progressive decline in cell viability was observed over time. While viability was 92% at 24 hours, it decreased to 85% at 48 hours and further declined to 70.1% at 72 hours. These results suggest a potential for cytotoxicity with prolonged exposure to the highest concentration. Collectively, the findings indicate that the 3% chitosan-based ointment formulation is non-cytotoxic and may be suitable for further clinical evaluation (Figure 2-A).

Study Population

The study included 42 women with a mean age of 41 years (range: 19 to 53 years) and an average body mass index (BMI) of 26.78. Of these participants, 38 underwent reduction mammoplasty, while 4 received breast prosthesis implants.

Three patients discontinued use of the gel before the 14th day for various reasons: one due to geographic inaccessibility, another because she lost the gel, and the third as a result of her spouse's disapproval. These patients were excluded from the study. Additionally, one patient discontinued treatment after 2 days due to itching and irritation at the wound sites and was also excluded. One patient concurrently used other healing ointments alongside the study treatment, resulting in wound dehiscence on day 18.

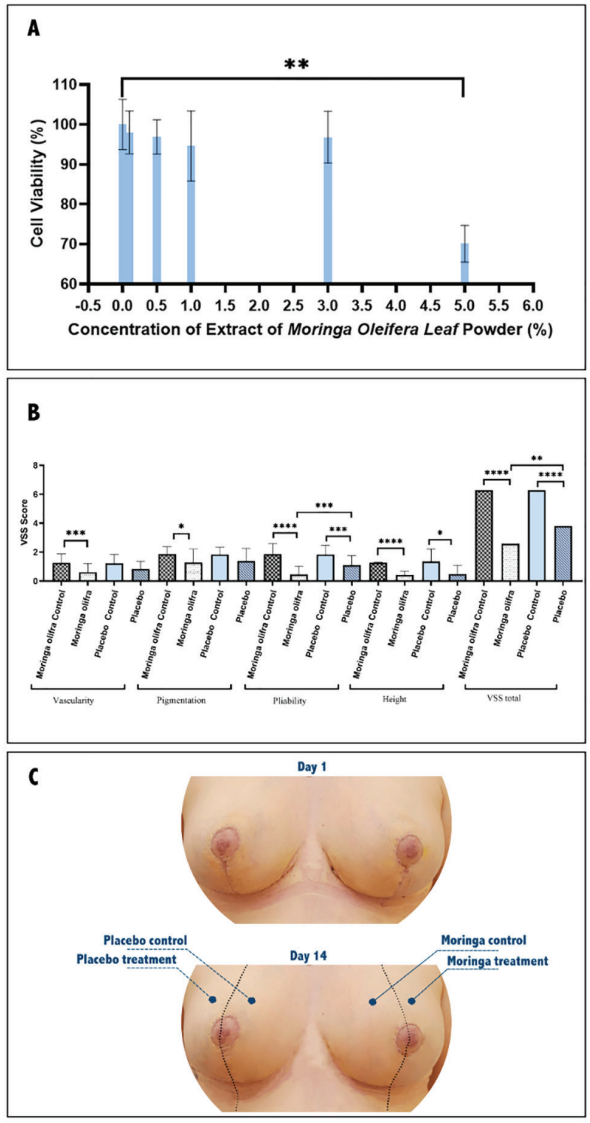

Figure 2. A) MTT Assay of Chitosan- *Moringa oleifera* Gel contaning different concentration of the hydro-alcoholic extract of *Moringa oleifera* leaf. **B)** Comparison of VSS scores across the Moringa treatment group, placebo group, and their respective controls. **C)** Photographs of a patient showcasing satisfaction with wound healing progress following treatment with moringa gel.

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This patient was excluded due to non-compliance with wound assessment protocols. Another patient developed bilateral breast dehiscence on day 16, necessitating grafting and was excluded as the dehiscence was attributed to the surgical technique. In one instance, a wound measuring 1×1×3 cm^3 appeared above the original incision site, which worsened upon contact between the 3% *Moringa oleifera* gel and the adhesive. Despite experiencing severe itching, another patient continued using the gel for 14 days, with symptoms subsiding one month later. Two additional patients reported mild itching while using the *Moringa* gel but expressed greater satisfaction with wound healing and scar quality compared to previous treatments. Brief wound dehiscence in the T-shaped area was observed in four patients and was attributed to surgical technique. Overall, 10% (4 out of 42) of patients reported itching and irritation with the *Moringa* gel, with one of these patients being excluded from the study after 2 days of use. The treatment was generally well tolerated, with no cases of wound infection or allergic reactions reported.

Of the 42 patients initially enrolled, five were excluded prior to day 14. Eleven missed their two-week follow-up, and one was excluded after the second week due to significant wound dehiscence. Day 14 evaluations were completed for 25 of the remaining 37 patients. At the three-month follow-up, five additional patients did not attend, leaving 31 patients who successfully underwent VSS assessment, which was conducted using a blinded evaluation method.

Survey Questionnaire

On day 14, based on patient responses to the questionnaire, 84% reported greater satisfaction with *Moringa* compared to placebo and control treatments. Eight percent preferred placebo over *Moringa* and control, while another 8% rated *Moringa* and placebo as equally effective, both outperforming the control. No patients indicated greater satisfaction with the control treatment over *Moringa* or placebo. These findings suggest that a substantial majority of patients were more satisfied with *Moringa* than with either placebo or control.

Furthermore, patients using *Moringa oleifera* reported faster wound healing and drying compared to those receiving placebo or control gels. The amount of blood secretion was also markedly higher in areas treated with the control gel and, to a lesser extent, with placebo, compared to wounds treated with *Moringa oleifera*.

VSS Score

Thirty-one patients were included in the final analysis for scar assessment. Each patient received both the *Moringa oleifera* gel and a placebo gel in a blinded fashion, serving as their own control. The four scar parameters assessed using the VSS—vascularity, pigmentation, pliability, and height—were analyzed using SPSS software (Table 1). A lower VSS score reflects a more favorable impact on scar formation following cosmetic breast surgery.

As shown in Figure 2-B, while no significant differences were observed between the VSS scores of the *Moringa* and placebo control groups, significant improvements were noted when comparing the treatment and placebo groups to their respective controls. Specifically, the *Moringa* treatment group exhibited significantly lower VSS scores in vascularity, pigmentation, pliability, and height, indicating a positive effect on scar formation. The *Moringa* group also showed higher proportions of 'Pink' and 'Normal' vascularity, 'Normal' pigmentation, and 'Flat' scars, with no cases of 'Purple' vascularity or scars greater than 5 cm.

Overall, the results demonstrated that the *Moringa* treatment group achieved the most favorable outcomes, followed by the placebo group, with the control group showing the least improvement. The reduction in VSS scores in the *Moringa* group was primarily attributable to significant improvements in pliability and height, highlighting the potential effectiveness

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Table 1. Descriptive statistics of collected VSS parameters (vascularity, pigmentation, pliability, and height).

Variable	Parameter	Placebo Control	Placebo	Moringa Control	Moringa
Vascularity	Normal	14	2	7	2
	Pink	15	20	22	21
	Red	2	8	2	7
	Purpr	0	1	0	1
Pigmentation	Normal	10	2	8	2
	Hypopigmentation	2	0	3	1
	Hypopigmentation	19	29	20	28
Pliability	Normal	18	0	5	0
	Supple	12	10	18	9
	Yielding	1	15	8	18
	Firm	0	6	0	4
Height	Flat	24	5	18	5
	<2	7	15	11	13
	2~5	0	8	2	10
	>5	0	3	0	3

of *Moringa oleifera* in enhancing scar healing and improving cosmetic outcomes. Figure 2-C presents two photographs of a patient satisfied with the results of using the *Moringa* gel, comparing day 1 and day 14.

Discussion

Previous studies have investigated various interventions for scar management, including pressure therapy, massage, silicone gels, corticosteroid injection, laser therapy, radiotherapy, 5-fluorouracil, onion extract, imiquimod, COX-2 inhibitors, and TGF-β3. However, these treatments have demonstrated limited efficacy and considerable side effects, emphasizing the need for novel, effective, and safe scar management options. The present study contributes to this body of literature by demonstrating the potential therapeutic benefits of *Moringa oleifera* (28–32).

This study aimed to evaluate scar characteristics following cosmetic breast surgery in thirty-one patients who received both a gel containing *Moringa oleifera* and a placebo gel in a blinded, within-subject design. The use of the VSS to assess four parameters—vascularity, pigmentation, pliability, and height—enabled a comprehensive evaluation of scar outcomes. The findings offer valuable insights into the potential application of *Moringa oleifera* in scar management and postoperative cosmetic recovery.

The results were particularly promising. A substantial 84% of patients reported greater satisfaction with *Moringa oleifera* compared to placebo and control treatments. Only 8% preferred the placebo, while another 8% rated *Moringa* and placebo as equally effective, both outperforming the control. Notably, no patients expressed higher satisfaction with the control treatment over *Moringa oleifera* or placebo. These findings suggest that *Moringa oleifera* is not only effective in enhancing scar characteristics but also highly acceptable to patients—consistent with the growing popularity of herbal medicines due to their efficacy, safety, and cost-effectiveness (33).

Patients treated with *Moringa oleifera* experienced more rapid wound healing and drying than those treated with control or placebo gels. The volume of blood secretion was significantly greater in areas treated with the control gel and, to a lesser extent, the placebo, compared to those treated with *Moringa oleifera*.

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The *Moringa* treatment group also demonstrated significantly lower VSS scores for vascularity, pigmentation, pliability, and height, suggesting a beneficial impact on scar quality. Furthermore, this group exhibited higher frequencies of 'Pink' and 'Normal' vascularity, 'Normal' pigmentation, and 'Flat' scars, with no instances of 'Purple' vascularity or scars exceeding 5 cm in height. These findings indicate that *Moringa oleifera* not only promotes scar resolution but also improves overall cosmetic outcomes.

The multifaceted benefits of *Moringa oleifera* are attributed to its rich composition of bioactive compounds, including flavonoids and tannins such as vicenin-2, quercetin, kaempferol, and phytosterols (34, 35). These constituents exhibit anti-inflammatory and antioxidant properties that collectively facilitate accelerated healing and reduced scar formation (36). This is supported by multiple in vivo and in vitro studies highlighting the wound-healing potential of *Moringa oleifera* (37–40). In addition, *Moringa oleifera* exhibits notable antibacterial activity, particularly against *Staphylococcus aureus*. Its antibacterial properties may contribute to wound healing by preventing infections, which can exacerbate inflammation and increase blood secretion (41, 42).

Research has shown that *Moringa oleifera* extracts promote wound healing through several mechanisms, including enhanced wound contraction and modulation of growth factors such as vascular endothelial growth factor (VEGF) and matrix metalloproteinases (MMPs) (38). In vivo studies have demonstrated substantial healing effects, with formulations such as zein nanoparticles loaded with *Moringa oleifera* extract exhibiting superior efficacy compared to standard treatments (43). Moreover, *Moringa oleifera*-coated sutures have been developed to prevent infection and promote healing, further indicating its versatile applications in wound care (40). The dermatoprotective effects of *Moringa* have also been documented in various studies, reinforcing its potential to improve skin health and scar quality (44, 45).

Overall, our findings are consistent with prior research on the therapeutic potential of herbal medicines in enhancing scar outcomes and support the established wound-healing properties of *Moringa oleifera*, suggesting its promise as a clinical therapeutic agent (37, 38).

Limitations and Future Directions

Potential Mechanisms of Action: This study raises questions regarding the mechanisms by which *Moringa oleifera* may exert its effects on scar healing. Further research is necessary to elucidate the biochemical pathways and specific constituents of *Moringa* that contribute to scar improvement.

• **Comparison with Standard Treatments:** Future studies should compare the efficacy of *Moringa oleifera* with that of standard scar treatment modalities to determine its relative effectiveness and potential integration into clinical practice.

• **Long-Term Effects:** Longitudinal studies are needed to evaluate the long-term effects of *Moringa oleifera* on scar characteristics and to ensure its sustained safety and efficacy.

• **Other Wound Types:** Investigations into the effects of *Moringa oleifera* on various wound types—such as diabetic ulcers, burn injuries, and pressure sores—are warranted. These wounds pose significant clinical challenges and demand effective therapeutic options.

• **Larger Sample Sizes:** Future studies with larger sample sizes will yield more robust evidence regarding the efficacy of *Moringa oleifera* in scar management. This will enhance the generalizability of findings and support its broader application in clinical settings.

Conclusion

The findings of this study suggest that *Moringa oleifera* may offer substantial benefits in improving scar characteristics following cosmetic breast surgery. The observed improvements in vascularity, pigmentation, pliability, and height indicate that *Moringa oleifera* has the potential

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to enhance scar healing and contribute to better cosmetic outcomes. Its natural origin, favorable safety profile, and cost-effectiveness render *Moringa oleifera* an appealing candidate for scar management. Nevertheless, additional research is required to fully elucidate its mechanisms of action, compare its efficacy with conventional treatments, and assess its long-term impact across various wound types. This study lays a foundation for the development of effective scar management strategies based on rigorously conducted randomized clinical trials.

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Conflict of Interest

The authors declare no conflicts of interest.

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Ethical Considerations

The study was approved by Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.MSP.REC.1398.1004).

Code of Ethics

The study protocol was also registered in the Iranian Registry of Clinical Trials (IRCTID: IRCT20211206053294N1).

Authorship Contribution

SH, SM, and NM: data collection. SH and NB: manuscript drafting. SM, KH, and HS: conceptualization and study design. KH and NB: critical revision and proofreading. All authors approved the final version of the manuscript.

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