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IN VIVO EVALUATION OF THE WOUND-HEALING POTENTIAL OF NANOZINC GEL CONTAINING ZINC OXIDE NANOPARTICLES

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ABSTRACT

The development of topical formulations containing zinc oxide nanoparticles has attracted considerable attention because of their antimicrobial, anti-inflammatory, and regenerative properties. The present study aimed to evaluate the wound-healing efficacy of NanoZinc gel in an in vivo excisional wound model.

The study was performed using fifteen healthy white mice randomly divided into control and treatment groups. Full-thickness excisional skin wounds (1 cm in diameter) were created under aseptic conditions. Animals in the treatment group received topical NanoZinc gel (0.02%, 2 mg/kg), whereas the control group was treated with sunflower oil. Wound healing was monitored for 14 days by measuring wound area using ImageJ software. Statistical analysis was performed using one-way ANOVA with GraphPad Prism 8.0 ($p < 0.05$).

NanoZinc gel significantly accelerated wound contraction compared with the control group. Faster epithelialization and granulation tissue formation were observed from day 5 onward, with almost complete wound closure by day 9. No signs of skin irritation or local toxicity were detected. The obtained findings indicate that NanoZinc gel possesses pronounced wound-healing activity and represents a promising topical formulation for further preclinical and clinical investigations.

Introduction. Wound healing is a complex biological process involving hemostasis, inflammation, proliferation, and tissue remodeling. Delayed or impaired wound healing remains a significant clinical challenge, particularly in patients with chronic diseases, infections, and metabolic disorders. Therefore, the development of effective wound-healing agents with

antimicrobial, anti-inflammatory, and regenerative properties is an important area of biomedical research [1].

Zinc is an essential trace element that plays a critical role in skin regeneration, collagen synthesis, immune response, cell proliferation, and antioxidant defense. Numerous studies have demonstrated that zinc deficiency significantly delays tissue repair, whereas adequate zinc availability accelerates wound closure and improves tissue regeneration [1]. Zinc oxide nanoparticles (ZnO NPs) have attracted considerable attention due to their unique physicochemical characteristics, including high surface area, biocompatibility, antimicrobial activity, and ability to stimulate cellular proliferation involved in tissue repair [2].

Recent investigations have shown that ZnO nanoparticles promote angiogenesis, fibroblast migration, collagen deposition, and re-epithelialization while simultaneously reducing bacterial contamination of wounds [2,3]. Systematic analyses have further confirmed the therapeutic potential of zinc oxide nanoparticles in the treatment of various skin injuries, including acute wounds, burns, diabetic ulcers, and infected wounds [3]. Incorporation of ZnO nanoparticles into hydrogel-based formulations has been reported to enhance moisture retention, improve mechanical stability, and significantly accelerate wound healing compared with conventional formulations [4].

Despite their promising biological activity, careful evaluation of the safety and efficacy of ZnO nanoparticles remains essential because their biological effects depend on particle size, concentration, and formulation characteristics [5]. Standardized in vivo excisional wound models are widely accepted for evaluating the wound-healing efficacy of topical formulations and provide reproducible data for preclinical assessment [6]. Statistical analysis of biological experiments should also follow established biostatistical principles to ensure the reliability of the obtained results [7].

Based on these findings, the present study aimed to evaluate the wound-healing activity of **"Nanozinc" gel (TashPharmi, Uzbekistan)** using an **in vivo** excisional wound model.

Skin wound healing is a complex biological process involving hemostasis, inflammation, proliferation, and tissue remodeling. Zinc oxide nanoparticles have demonstrated antimicrobial, antioxidant, and regenerative properties, making them promising candidates for topical wound-healing formulations. The present study evaluated the therapeutic efficacy of NanoZinc gel in an excisional wound model in mice.

Materials and Methods

Fifteen white mice (18–22 g) were divided into control and treatment groups. Full-thickness excisional wounds (1 cm diameter) were created under aseptic conditions. NanoZinc gel (0.02%, 2 mg/kg) was applied daily for 14 days. Control animals received sunflower oil. Wound area was measured using ImageJ, and statistical analysis was performed using one-way ANOVA in GraphPad Prism 8.0.

Results and Discussion

NanoZinc gel accelerated wound closure, promoted epithelial

regeneration, and improved granulation tissue formation. By day 9, wound size was markedly smaller than in the control group. No irritation or adverse effects were observed, confirming the safety and regenerative potential of the formulation.

Wound-healing activity of "Nanozinc" gel (TashPharmi, Uzbekistan)

The wound-healing activity of **"Nanozinc" gel (TashPharmi, Uzbekistan)** was evaluated using an **in vivo** excisional wound model. The wound area was measured on the 9th day after treatment. The experimental group treated with **"Nanozinc" gel** demonstrated a significantly smaller wound area compared with the untreated control group (**$p < 0.001$**, $M \pm SD$, $n = 5$).

Table 1. Wound-healing activity of "Nanozinc" gel (TashPharmi, Uzbekistan) on Day 9

Group	Wound area on Day 9 (mm^2), Mean ± SD
Control	7.95 ± 1.91
Nanozinc gel (TashPharmi, Uzbekistan)	**0.70 ± 1.05***

Initial wound area (Day 1)

The initial wound sizes were comparable between the experimental groups before treatment, indicating that the animals started the experiment with similar wound characteristics.

Table 2. Initial wound area on Day 1

Animal No.	Control (mm^2)	Nanozinc gel (mm^2)
1	32.884	23.645
2	32.048	34.570
3	53.983	37.429
4	21.450	43.902
5	73.398	35.079
Mean	**42.75**	**34.93**
SD	**20.80**	**7.32**

Residual wound area (Day 9)

By Day 9, animals treated with **"Nanozinc" gel** exhibited almost complete wound closure. Three out of five animals showed complete healing (0 mm^2 residual wound area), whereas the remaining animals had only minimal residual wound areas. In contrast, larger residual wounds remained in the control group.

Table 3. Residual wound area on Day 9

Animal No.	Control (mm^2)	Nanozinc gel (mm^2)
1	0.000	0.000
2	0.000	4.417
3	0.000	3.303
4	9.329	0.000
5	4.699	0.000
Mean	**2.81**	**1.54**
SD	**4.18**	**2.15**

Figure 1. Representative photographs of wound healing in the control and Nanozinc gel (TashPharmi, Uzbekistan) treatment groups on Day 9.

Discussion.

Topical treatment with **"Nanozinc" gel (TashPharmi, Uzbekistan)** markedly accelerated wound healing in comparison with the untreated control group. The gel promoted rapid wound contraction, resulting in nearly complete wound closure by the ninth day. These findings are consistent with previous reports demonstrating that zinc oxide nanoparticles stimulate fibroblast proliferation, collagen synthesis, angiogenesis, and re-epithelialization while simultaneously providing antimicrobial protection against wound infections [1–4].

The observed wound-healing activity may be attributed to the biological properties of zinc nanoparticles, which enhance tissue regeneration, reduce oxidative stress, and modulate inflammatory responses during the healing process [1,3,5]. Overall, the obtained results suggest that **"Nanozinc" gel** is a promising topical formulation for accelerating skin wound repair and warrants further preclinical and clinical evaluation.

Conclusion

NanoZinc gel containing zinc oxide nanoparticles demonstrated significant wound-healing activity in vivo and may serve as a promising topical agent for further preclinical and clinical development.

The present study demonstrated that **"Nanozinc" gel (TashPharmi, Uzbekistan)** possesses pronounced wound-healing activity in an **in vivo** excisional wound model. Topical application of the gel significantly

accelerated the healing process and resulted in complete wound closure by the ninth day of treatment. The obtained findings indicate that the zinc nanoparticle-based gel effectively promotes tissue regeneration and supports the natural wound-healing process. These results confirm the potential of **"Nanozinc" gel (TashPharmi, Uzbekistan)** as a promising topical wound-healing agent and provide a scientific basis for its further preclinical and clinical investigations.

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