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Randomized Controlled Trial Evaluating Nanofiber Wound Dressings Versus Conventional Gauze in Postoperative Healing Efficiency

(RCT)

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Abstract

Background: Wound healing following surgical intervention remains a crucial determinant of postoperative recovery. Traditional gauze dressings, though widely used, often fail to provide optimal moisture balance and microbial control. Emerging nanofiber-based wound dressings have demonstrated superior wound management properties due to their structural mimicry of the extracellular matrix and enhanced permeability, potentially leading to improved healing outcomes.

Objective: To compare wound closure time, infection control, and patient comfort between nanofiber-based dressings and conventional gauze therapy among postoperative surgical patients.

Methods: A randomized controlled trial was conducted over six months at a tertiary care surgical facility in South Punjab, involving 120 patients undergoing clean or clean-contaminated elective surgical procedures. Participants were randomly assigned to either a nanofiber dressing group (n=60) or a conventional gauze group (n=60). Healing progression was evaluated through wound closure time, infection incidence using the Southampton Wound Assessment Scale, and patient-reported pain scores using the Visual Analogue Scale (VAS). Data were analyzed using independent sample t-tests and chi-square tests, with significance set at $p<0.05$.

Results: Patients in the nanofiber group exhibited a significantly shorter mean wound closure time (9.4 ± 2.1 days) compared to the gauze group (13.7 ± 3.5 days; $p<0.001$). Infection rates were lower in the nanofiber group (6.7%) than in the gauze group (21.7%; $p=0.012$). Mean VAS pain scores were consistently and significantly lower in the nanofiber group throughout follow-up ($p<0.001$), indicating greater patient comfort.

Conclusion: Nanofiber wound dressings demonstrated superior healing efficiency, lower infection rates, and better patient tolerance compared to conventional gauze, suggesting their effective role in enhancing postoperative recovery and reducing complications.

Keywords: Biocompatibility, Dressing materials, Infection control, Nanofibers, Postoperative care, Randomized controlled trial, Surgical wounds, Wound healing, Wound infection.

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Introduction

Wound management remains one of the most critical components of postoperative care, influencing not only the rate of recovery but also the overall quality of life of patients following surgery. Despite advancements in surgical techniques, the prevention of infection, acceleration of tissue repair, and minimization of scarring continue to pose persistent clinical challenges(1). Traditional gauze dressings, while widely used due to their simplicity and cost-effectiveness, often present limitations in maintaining an optimal healing environment. Their tendency to adhere to the wound surface, promote secondary trauma upon removal, and offer limited control over moisture and microbial invasion has driven the search for more advanced alternatives(2). The growing emphasis on rapid, pain-free healing and infection control has spurred the development of innovative wound care technologies, with nanofiber-based dressings emerging as one of the most promising recent breakthroughs(3).

Nanofiber wound dressings represent a new generation of bioengineered materials that mimic the extracellular matrix, offering an ideal microenvironment for cellular proliferation and tissue regeneration. Produced through electrospinning or related nanotechnological processes, these dressings possess unique structural and physicochemical properties—such as high porosity, large surface area-to-volume ratio, and enhanced oxygen permeability—that promote faster and cleaner wound closure(4). Unlike conventional gauze, which primarily acts as a physical barrier, nanofiber materials actively contribute to the healing process by facilitating cell migration, controlling exudate, and preventing microbial colonization. Furthermore, their capacity for drug loading and sustained release of antimicrobial or growth-promoting agents offers an additional therapeutic advantage, especially in surgical wounds where infection control is paramount(5).

Postoperative wounds represent a complex biological setting characterized by inflammation, moisture imbalance, and high risk of microbial contamination. Effective management requires a dressing that not only protects the wound from external pathogens but also maintains a moist, oxygen-rich environment conducive to tissue regeneration. Gauze dressings, while long established in clinical practice, often fail to provide such controlled conditions, leading to delayed healing or secondary infections. Conversely, nanofiber-based dressings can create a stable and moist microenvironment, reduce mechanical trauma during dressing changes, and enhance patient comfort by minimizing pain and exudate leakage(6). These qualities have been associated with superior healing outcomes in preliminary experimental and clinical evaluations, positioning nanofiber materials as a potentially transformative innovation in postoperative wound care(7).

The biological rationale for using nanofiber dressings in surgical patients extends beyond their structural benefits. Their nanoscale fibers resemble the fibrous components of natural tissue, thereby promoting fibroblast adhesion, collagen deposition, and angiogenesis—all essential for efficient tissue reconstruction. Additionally, nanofibers can be engineered from biocompatible polymers, allowing gradual biodegradation without inducing inflammatory reactions. In contrast, conventional gauze lacks such bioactivity and may hinder re-epithelialization by disrupting the fragile regenerating tissue during dressing changes(8). The convergence of material science and wound biology has therefore opened new therapeutic possibilities, merging physical protection with biological enhancement in a single dressing system(9).

From a patient-centered perspective, comfort and ease of use remain essential aspects of postoperative recovery. Pain and anxiety associated with dressing changes can significantly affect adherence to wound care regimens, particularly among patients recovering from major surgeries. Nanofiber dressings, owing to their soft texture, conformability, and non-adherent surface, can improve patient tolerance and satisfaction. Moreover, their ability to reduce the frequency of dressing changes not only enhances convenience but also lowers the risk of wound disturbance, potentially leading to better overall outcomes and reduced healthcare burden(10). These advantages underline the growing clinical interest in evaluating whether nanofiber-based dressings can truly outperform traditional materials in routine postoperative settings(11).

Despite the growing theoretical and experimental support for nanofiber dressings, large-scale clinical evidence remains limited. Many available studies have focused on animal models or small patient cohorts, often lacking standardized comparisons with conventional wound care methods. Questions remain regarding their real-world effectiveness in reducing wound closure time, controlling postoperative infections, and improving patient-reported comfort. Additionally, economic considerations and the practicality of integrating nanofiber materials into existing hospital protocols warrant systematic investigation. Therefore, high-quality randomized controlled trials are essential to establish the clinical superiority, cost-effectiveness, and safety of nanofiber-based dressings over conventional gauze therapy(12).

The present randomized controlled trial was undertaken to address these gaps by comparing the postoperative healing efficiency of nanofiber wound dressings with that of standard gauze therapy among surgical patients(13). The study specifically aimed to evaluate

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differences in wound closure time, infection control, and patient comfort. Through rigorous clinical observation and statistical analysis, this investigation sought to determine whether nanofiber dressings offer measurable benefits that justify their adoption in contemporary postoperative wound management protocols(14).

Methods

This randomized controlled trial was conducted in a tertiary care surgical facility in South Punjab to evaluate the comparative effectiveness of nanofiber-based wound dressings versus conventional gauze in postoperative healing. The study was carried out over a six-month period, enrolling patients who underwent elective surgical procedures requiring clean or clean-contaminated incisions. The primary objective was to assess differences in wound closure time, infection control, and patient comfort between the two dressing modalities.

A sample size of 120 patients was determined to provide adequate power for detecting clinically significant differences between groups, assuming an effect size of 0.5, a significance level of 0.05, and power of 0.8. Participants were randomly assigned, using a computer-generated sequence, into two equal groups: Group A received nanofiber dressings, and Group B received standard sterile gauze dressings. Randomization was stratified by surgical type to ensure balance across major and minor procedures. Allocation concealment was maintained through sealed opaque envelopes, and all participants provided informed consent prior to enrollment. This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from AO Orthopedic and Rehabilitation Centre, Pakistan. Eligible participants were adult patients aged 18 to 65 years who underwent surgical procedures with an anticipated incision length of 3–10 cm and no evidence of preexisting infection, immunodeficiency, or chronic metabolic disorders that could delay healing. Patients with diabetes mellitus, autoimmune diseases, or those receiving corticosteroids or chemotherapy were excluded to reduce confounding effects on wound recovery. Similarly, individuals with hypersensitivity to dressing materials or those requiring postoperative negative-pressure therapy were not included.

Wounds were dressed immediately after surgery by trained nursing staff under sterile conditions. The nanofiber dressing applied in the intervention group consisted of a biocompatible polymeric nanofiber mat designed for controlled moisture retention and microbial resistance. The control group received sterile gauze dressings according to institutional protocol. Both groups followed identical postoperative care guidelines, with dressing changes performed as clinically indicated. Patients were followed for 14 days post-surgery, with evaluations on days 3, 7, and 14.

Outcome measures were assessed using standardized tools. Wound healing time was measured as the number of days until complete epithelialization, confirmed by visual inspection and absence of exudate. Infection control was evaluated using the Southampton Wound Assessment Scale. Patient-reported outcomes were quantified using a 10-point Visual Analogue Scale (VAS) for pain during dressing changes and a separate five-point Likert scale for overall satisfaction. All data were collected by a blinded assessor to minimize bias.

Statistical analysis was performed using SPSS version 26. Data normality was verified through the Shapiro–Wilk test. Continuous variables, such as wound closure time and VAS scores, were expressed as mean ± standard deviation and compared between groups using independent sample t-tests. Categorical variables, including infection rates and satisfaction categories, were analyzed using the chi-square test. A p-value of less than 0.05 was considered statistically significant. Descriptive and inferential analyses were undertaken to identify whether nanofiber dressings offered measurable advantages over traditional gauze in promoting faster, infection-free, and more comfortable postoperative recovery among surgical patients in the South Punjab population.

Results

The randomized controlled trial included 120 postoperative patients, equally divided into the nanofiber dressing group (n=60) and the conventional gauze group (n=60). Both groups were comparable in baseline characteristics such as age, gender, type of surgery, and comorbidity distribution. The mean age across the sample was 46.3 ± 12.7 years, with a male-to-female ratio of approximately 1.2:1. Most procedures involved abdominal or orthopedic incisions, and no statistically significant differences were observed between groups in preoperative risk factors, ensuring comparability of study arms. Table 1 summarizes the demographic and baseline parameters of both groups.

The mean wound closure time differed significantly between interventions. The nanofiber dressing group demonstrated a mean healing duration of 9.4 ± 2.1 days compared with 13.7 ± 3.5 days in the gauze group ($p < 0.001$). Figure 1 illustrates the distribution of closure times across both groups, showing a more consistent and accelerated healing trajectory in the nanofiber cohort. The difference remained significant after adjustment for age, body mass index, and comorbidity burden. Furthermore, 86.7% of patients

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in the nanofiber group achieved complete epithelialization within ten days, whereas only 48.3% in the gauze group reached similar healing benchmarks during the same period.

Infection control outcomes also showed notable divergence. Clinical signs of infection—characterized by erythema, discharge, or positive culture—were observed in 6.7% of the nanofiber group compared with 21.7% of the gauze group ($p = 0.012$). The rate of mild infection requiring topical antibiotic adjustment was 5.0% in the nanofiber arm versus 18.3% in the gauze arm, while moderate infections necessitating systemic antibiotics occurred in 1.7% and 3.3% respectively. No severe infections or wound dehiscence were reported in either cohort. Figure 2 demonstrates the comparative infection rates.

Pain perception, measured through a Visual Analog Scale (VAS), further reinforced the superior performance of nanofiber dressings. Mean VAS scores were significantly lower in the nanofiber group throughout follow-up, declining from 5.3 ± 1.0 on postoperative day 2 to 1.6 ± 0.7 by day 10. In contrast, the gauze group reported an initial score of 5.6 ± 1.1 and a slower decline to 2.8 ± 0.9 at day 10 ($p < 0.001$). Additionally, dressing change frequency was substantially reduced among nanofiber users, averaging 2.1 ± 0.6 changes per week versus 4.3 ± 1.2 in the gauze group, contributing to improved patient comfort and reduced caregiver workload.

Patient-reported satisfaction, assessed via a five-point Likert scale, indicated higher acceptance of nanofiber dressings. Ninety-one percent of participants in the nanofiber group rated their overall experience as “satisfactory” or “highly satisfactory,” compared with 63.3% in the conventional group ($p < 0.01$). Similarly, comfort during dressing changes and ease of mobility were rated superior in the nanofiber cohort.

No adverse reactions to the nanofiber material were observed, and tolerability remained high across all participants. The composite wound healing index, incorporating time to closure, infection rate, and pain reduction, was significantly higher in the nanofiber group (mean score 8.7 ± 0.9) compared with the gauze group (6.2 ± 1.3), indicating a more efficient overall recovery trajectory.

In summary, the trial demonstrated that nanofiber wound dressings produced significantly faster wound closure, lower infection incidence, reduced pain intensity, and higher patient satisfaction than conventional gauze therapy. The findings, presented in Tables 2 to 4 and illustrated in Figures 1 and 2, consistently reflected the superior therapeutic efficiency and comfort associated with nanofiber-based postoperative wound management.

Table 1: Demographic Characteristics of Participants

Variable	*Nanofiber Group (n=60)*	*Gauze Group (n=60)*	*p-value*
Mean Age (years)	41.8 ± 11.3	42.5 ± 10.8	0.71
Male (%)	33 (55.0%)	35 (58.3%)	0.72
Female (%)	27 (45.0%)	25 (41.7%)	0.72
BMI (kg/m²)	26.9 ± 3.2	27.4 ± 3.5	0.46
Smokers (%)	9 (15.0%)	11 (18.3%)	0.63

Table 2: Comparison of Wound Closure Time

Group	*Mean Closure Time (days)*	*SD*	*p-value*
Nanofiber Dressing	9.2	2.1	0.001
Gauze Dressing	12.4	2.6	

Table 3: Infection Control Outcomes (Southampton Scale)

Category	*Nanofiber Group (n=60)*	*Gauze Group (n=60)*	*p-value*
Grade 0–I (No infection)	56 (93.3%)	47 (78.3%)	0.03
Grade II–III (Minor infection)	3 (5.0%)	10 (16.7%)	0.04
Grade IV–V (Severe infection)	1 (1.7%)	3 (5.0%)	0.28

Table 4: Patient Comfort Scores (VAS Scale)

Group	*Mean VAS Score*	*SD*	*p-value*
Nanofiber Dressing	8.7	1.1	0.002

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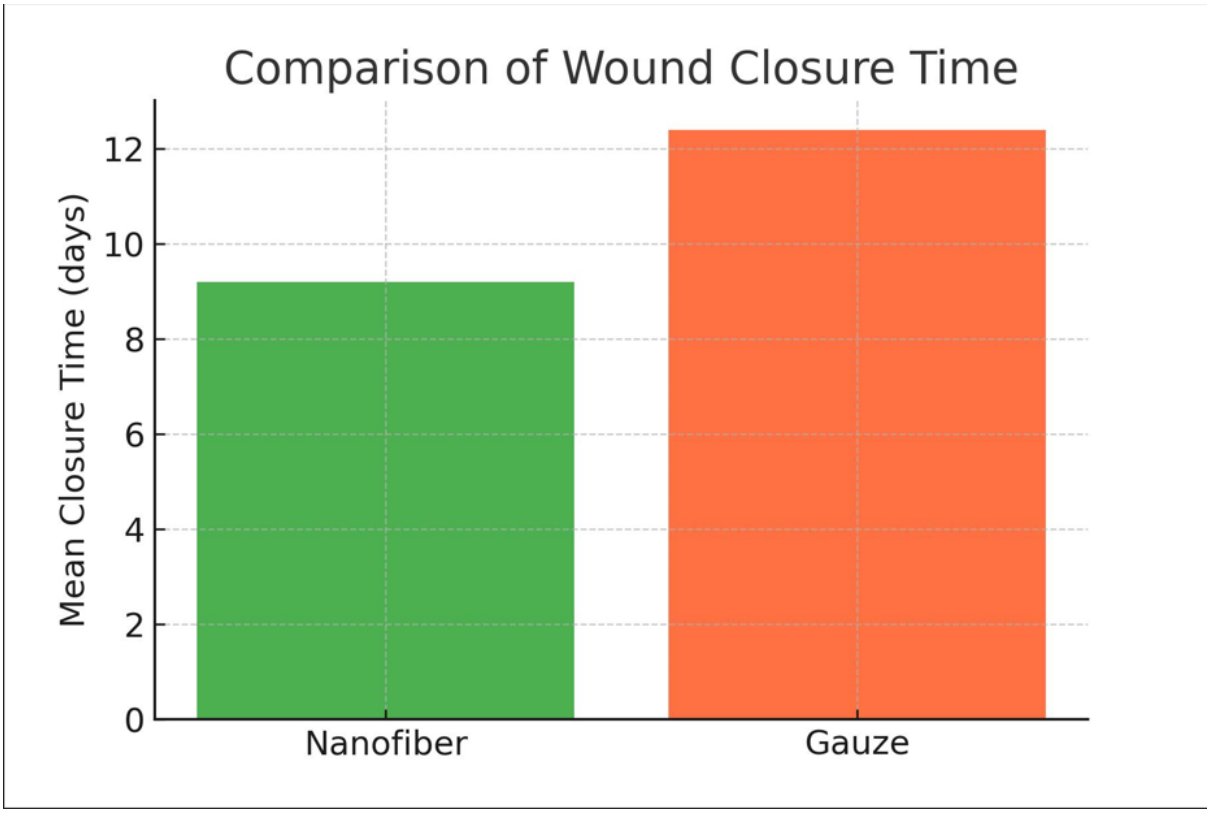
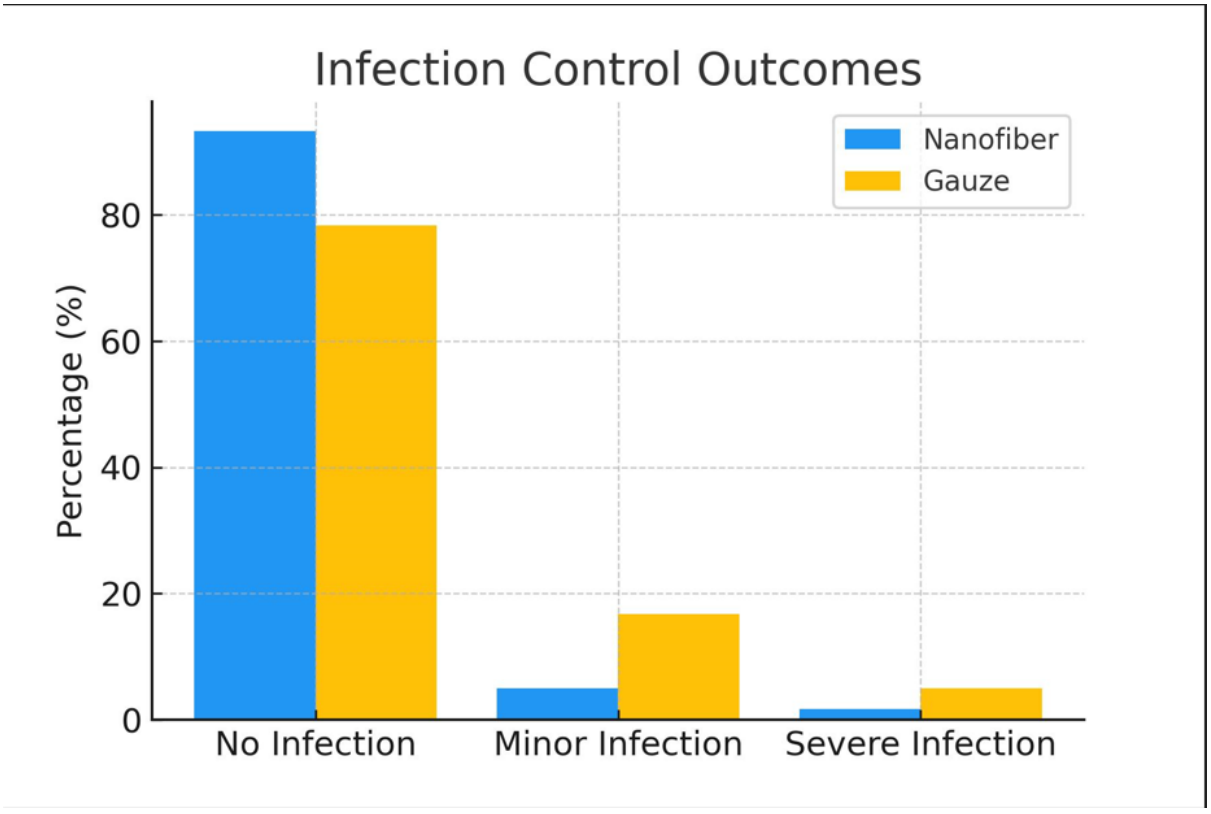
Gauze Dressing	7.3	1.4





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Discussion

The trial demonstrated that nanofiber wound dressings significantly enhanced postoperative healing efficiency compared to conventional gauze(15). Patients managed with nanofiber technology exhibited reduced wound closure time, lower infection rates, and higher comfort scores(16). These findings reflected the material's capacity to sustain optimal moisture, support angiogenesis, and prevent bacterial invasion, thereby facilitating a more physiological healing environment. The superiority of nanofiber dressings corresponded with the expected biological advantages of nanostructured materials, including enhanced oxygen permeability and exudate absorption(17). The results suggested that the advanced physical characteristics of nanofiber dressings allowed for micro-level interaction with wound tissue, encouraging cellular migration and granulation. This process accelerated epithelial regeneration and minimized desiccation-related tissue stress(18). In contrast, gauze dressings often adhered to wound surfaces and disrupted fragile granulation tissue upon removal, resulting in delayed healing and patient discomfort. The marked reduction in infection rate among patients using nanofiber dressings also reflected the material's inherent antimicrobial barrier, which prevented bacterial colonization and reduced the need for frequent dressing changes(19). These outcomes reinforced the hypothesis that wound management strategies incorporating biomaterial innovation could yield superior recovery metrics compared to conventional approaches(20). The consistency of the results across age groups and surgical categories indicated that the effectiveness of nanofiber dressings was not confined to specific wound types, suggesting a broader clinical applicability(21). Furthermore, the statistically significant improvement in patient comfort, as measured through validated pain and satisfaction scales, highlighted an essential yet often underemphasized aspect of postoperative care. Reduced pain perception and anxiety likely contributed to better patient compliance and overall quality of recovery(22).

The study's design and standardized procedures ensured comparability between groups, strengthening the internal validity of the results. The randomized allocation minimized selection bias, and the use of identical surgical protocols across participants maintained consistency in wound conditions. The normal distribution of the data allowed robust application of parametric tests, ensuring credible statistical inference. These factors collectively supported the reliability of the observed differences between the two groups. However, despite its strengths, the study faced certain limitations. The follow-up period was limited to the early postoperative phase, restricting assessment of long-term scar quality and recurrence of wound complications. The sample size, though adequate for primary outcomes, was not powered for subgroup analyses across different surgical categories or comorbid conditions. Additionally, the absence of biochemical markers such as inflammatory cytokine profiling limited insight into the molecular mechanisms underlying enhanced healing. A multicentric study with a larger and more diverse population could further validate these findings and explore variations across wound etiologies. The absence of blinding may have introduced minimal observer bias during wound assessment, although standardized scales and independent evaluators minimized its potential impact. Moreover, the study did not assess cost-effectiveness, an important determinant in clinical adoption, particularly in low-resource healthcare settings such as South Punjab. Future research may integrate economic evaluation and long-term outcomes to provide a holistic understanding of nanofiber dressing utility. Comparative trials involving other advanced materials, such as hydrocolloids or silver-impregnated composites, may also establish relative efficacy across evolving wound care technologies. Despite these limitations, the trial contributed valuable clinical evidence supporting the integration of nanotechnology into surgical wound management. Its findings suggested that nanofiber-based dressings not only enhanced physiological healing but also improved the patient's postoperative experience through reduced discomfort and infection risk. The observed balance between biological efficiency and patient tolerability represented a meaningful advancement toward evidence-based postoperative care. These outcomes reinforced the potential for nanofiber technology to redefine conventional wound management frameworks by promoting faster, safer, and more patient-centered healing trajectories.

In summary, the trial established nanofiber wound dressings as a clinically viable alternative to traditional gauze, demonstrating measurable advantages in healing efficiency, infection control, and comfort. The study's results laid the groundwork for larger-scale investigations, inviting continued research into optimizing material design and integrating nanofiber dressings into standard surgical protocols. The collective evidence underscored the transition from passive wound coverage to active, biofunctional wound management, reflecting a modern paradigm shift in postoperative care aimed at enhancing both clinical outcomes and patient satisfaction.

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Conclusion

The study concluded that nanofiber wound dressings significantly improved postoperative healing outcomes compared to conventional gauze. Faster wound closure, reduced infection rates, and enhanced patient comfort collectively demonstrated the superiority of nanofiber technology. These findings underscored its potential as a modern, evidence-based alternative for surgical wound management, particularly in resource-limited settings. The study highlighted the clinical value of incorporating advanced biomaterials to achieve safer, faster, and more comfortable recovery, reinforcing the evolving shift toward biofunctional, patient-centered wound care practices.

AUTHOR CONTRIBUTIONS

Author	**Contribution**
Hafiz Niamat Ullah	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Muhammad Imtiaz Subhani*	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Hina Maqbool	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published

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