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Research Article

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The Effect of a HealiAid ® Collagen Wound Dressing on Wound Healing in Patients: A Randomized Double-Blind Pilot Clinical Trial

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Abstract

Wound healing is a complex, multi-phase process. With rising healthcare costs, an aging population, and increasing chronic disease prevalence, the burden of wound care is escalating. Thus, finding safe and effective methods to accelerate wound healing is crucial. This study aims to explore the safety and efficacy of HealiAid® Collagen Wound Dressing in treating various types of wounds, including venous ulcers, diabetic foot ulcers, pressure ulcers, and burns. A clinical trial was conducted on 18 subjects with venous ulcers, diabetic foot wounds, pressure ulcers, and burn wounds. The study assessed the effectiveness of HealiAid in different wound types by analyzing its thermal stability, porous structure, biocompatibility, and clinical efficacy. Wound healing was strictly monitored, and the safety and tolerability of the dressing were evaluated. The results showed that HealiAid Collagen Wound Dressing has excellent thermal stability and structural integrity. Its porous microstructure enhances cell adhesion and tissue regeneration, demonstrating significant healing effects across various wound types, including venous ulcers, diabetic foot wounds, pressure ulcers, and burns. No serious adverse reactions were reported, and endotoxin levels were well below safety standards. This study confirms the safety and efficacy of HealiAid Collagen Wound Dressing in treating multiple wound types. Its outstanding thermal stability, porous structure, and biocompatibility make it a promising option for clinical wound care.

Keywords: Collagen Wound Dressing, Wound Healing, Healiaid, Clinical Efficacy

1. Introduction

Wound healing is a complex, multi-phase process involving several overlapping stages. Initially, hemostasis halts bleeding through blood clot formation. This is followed by the inflammatory phase, where immune cells remove debris and combat infection [1]. During the proliferative phase, new tissue forms as blood vessels grow, fibroblasts produce collagen to provide structural support, and epithelial cells migrate to cover the wound [2]. Finally, in the remodeling phase, collagen fibers realign and strengthen, while excess tissue is degraded, leading to scar formation [3]. This dynamic process is crucial for restoring tissue integrity and function, ensuring the body's recovery from injury. The burden of wound care is rapidly escalating due to increasing healthcare costs, an aging population, and the rising incidence of chronic diseases worldwide [4]. Consequently, identifying safe and effective methods to accelerate wound healing is both necessary and significant.

Collagen plays a pivotal role in the wound healing process. As the primary component of connective tissue, collagen provides essential structural support and facilitates various stages of wound healing [5]. In the early stages, collagen contributes to hemostasis by participating in blood clot formation and vascular constriction, aiding in the initial structural repair of the wound [6]. During the inflammatory phase, collagen, as a key component of the extracellular matrix, regulates the migration and activation of immune cells, helping to clear damaged tissue, resolve inflammation, and cleanse the wound [7]. In the proliferative phase, collagen stimulates fibroblast proliferation

and synthesis, promoting the regeneration and repair of connective tissue [1]. Collagen formation during this phase helps establish the wound's structural framework and supports fibrous tissue deposition [8]. Finally, in the remodeling phase, collagen is crucial in tissue reconstruction and reorganization [9]. The remodeling of collagen fibers enhances tissue strength and elasticity, ultimately leading to scar formation and the completion of the wound healing process [10]. Given its vital role, collagen has significant application value in wound healing treatments and is a key ingredient in many wound care products.

HealiAid® Collagen Wound Dressing, developed by Maxigen Biotech, Inc., is derived from natural collagen extracted from bovine tendon tissue. Bovine collagen hydrolyzate, a mixture of collagen peptides, has been shown to modulate collagen metabolism in human osteoarthritic articular cartilage. However, the effects of bovine collagen on wound healing are not yet fully understood, highlighting the need for further investigation. This study primarily aimed to explore the safety and efficacy of HealiAid Collagen Wound Dressing in treating various wound types, including venous ulcers, diabetic foot wounds, bedsores, and burn wounds. The study focused on evaluating the safety and effectiveness of HealiAid across these four wound types. Additionally, the study sought to comprehensively assess the thermal stability, porous microstructure, biocompatibility, and clinical efficacy of the HealiAid Collagen Wound Dressing.

2. Material and Methods

2.1 Shrink Temperature Analysis

Differential Scanning Calorimetry (DSC) was used to analyze the shrink temperature of HealiAid Collagen Wound Dressing performed by the Indusstudy Technology Research Institute (ITRI) in Chutung, Hsinchu, Taiwan, R.O.C. Briefly, place the sample and reference pans in the instrument, and the temperature increase at a constant rate of 10 ℃/minute from 25 ℃ to 130 ℃. After each running is completed, the thermal properties of the test materials such as Tonset will be calculated.

2.2 Product Preparation

HealiAid Collagen Wound Dressing is a white, porous and absorbable matrix prepared by type I fibrous collagen purified from bovine Achilles tendons. Briefly, the purified type I collagen was formulated in isopropyl alcohol and then filled into casting mold with specified dimension. After casting, the solvent was removed by lyophilization. Finally, the sterilization is executed by gamma irradiation. HealiAid Collagen Wound Dressing is supplied in a sterile, non-pyrogenic package, and is indicated for single use only.

2.3 The Porous Microstructure of the Collagen Matrix Analysis

The porous microstructure of the collagen matrix was evaluated by using Scanning Electron Microscopy (SEM), the fractured test samples were mounted on an aluminum stub and coated with 15 nm gold/palladium by using ECS-101 sputter coater (Elionix, Inc., Tokyo, Japan). The cross-sectional micrograph was examined with a JSM-5600SEM (JEOL, Japan) in secondary electron mode at 5 keV accelerating voltage.The magnifications, typically X100 to X2,000 on the micrographs.

2.4 The Periodic Structure of the Collagen Matrix Analysis

The periodic structure of triple helix of the collagen matrix was verified by using Transmitted Electron Microscopy (TEM), the test sample was embedded in epoxy resin. Ultrathin sections were cut with a diamond knife as approximately 40 nm thick, and it was counterstained with 2% uranyl acetate in 70% methanol, and viewed with a JEM-2100F/OXFORD INCA Energy TEM 250 (JEOL, Japan). The magnifications, typically X20,000 to X100,000 on the micrographs.

2.5 The Porosity of the Collagen Matrix Analysis

The porosity of the collagen matrix was measured by using Mercury Intrusion Porosimetry (MIP,Autopore IV 9500). Pore size distribution was calculated from differential pressure measurements with mercury intrusion, assuming cylindrical pores.

2.6 Pyrogen Test

Add 10 mL of LAL Reagent Water to the container and soak test sample for 30 minutes. Carefully dispense 50 µL sample solution and standard solution into appropriate wells of a microplate. Heat the microplate at 37.0±1.0 ℃ for 15 minutes. Pipette 50 µLof Limulus Amebocyte Lysate QCL-1000® reagent into each well and then incubate the microplate at 37.0±1.0 ℃ for 10 minutes. Transfer the microplate to an ELISA reader. Shake the microplate in the ELISA reader for 10 seconds. Read absorbance by the ELISA reader at the wavelength of 405 nm.

2.7 12-Week Implantation Test

This study was conducted according to the requirements of the ISO10993: Biological Evaluation of Medical Devices, Part 6, "Tests for local effects after implantation". This study aims to evaluate the absorption and local effects in rabbits after muscular implantation of HealiAid Collagen Wound Dressing at 4, 8 and 12 weeks after implantation. For each rabbit paravertebral muscles, 4 test samples were implanted in muscles along right side of the spine, 25 mm to 50 mm from the midline and parallel to the spine, and about 25 mm from each other. The sham operation was performed along the left side of the spine. Four rabbits of each group were used in this study and sacrificed one group at 4, 8 and 12 weeks after implantation to evaluate the absorption and local effects.

2.8 Clinical Investigation Study

This clinical study is single-center study was conducted at Linkou Chang Gung Memorial Hospital, involving 18 subjects randomly assigned to three groups based on wound type (ClinicalTrials.gov Identifier: NCT06280053). Ethical guidelines and informed consent procedures were followed (IRB number: 103-3024A3), with participant selection based on strict inclusion and exclusion criteria. Inclusion criteria for participants were age 18 or older with wounds, venous ulcers persisting for at least 30 days classified as grade 3, burn wounds classified as grade 2, and bedsores classified as grade 2, all with a minimum wound size of 1 cm^2. Exclusion criteria included clinical signs of infection, wounds with exposed bone, concurrent conditions affecting wound healing, known alcohol abuse, use of medications interfering with healing, multiple ulcers on the same limb, pregnancy, breastfeeding, and known allergies to the wound dressing components. Subjects were followed up at Day

7, Week 2, Week 4, Week 8, and Week 12 post-implantation. The primary efficacy measure was the percentage of wound healing at 8-week post-treatment. Secondary measures included healing percentages at various intervals, granulation tissue growth (evaluated on a scale from 0 to 5, where 0 indicated a fully healed wound or very shallow wound, 1 indicated granulation tissue covering 90% of the wound area, 2 indicated 50-89%, 3 indicated 10-49%, 4 indicated less than 10%, and 5 indicated no granulation tissue) and differences in wound exudate (measured on a scale from 0 to 3, where 0 indicated no exudate, 1 indicated a small amount not requiring daily dressing changes, 2 indicated a moderate amount requiring daily changes, and 3 indicated a large amount necessitating at least two changes per day). Safety evaluations involved recording adverse events and inflammation levels, with infection and other adverse events graded on a scale from 0 to 3 for 0 indicated no inflammation or infection, 1 indicated redness and pain, 2 indicated clear signs of infection such as swelling and pus, and 3 indicated severe systemic infection. The study included 18 subjects with an average age of 56.11±14.62 years, the majority of whom were male (61.1%). The subjects were evenly distributed across the three wound type groups: venous ulcers, burn wounds, and bedsores. The initial wound sizes were recorded as 5.1 cm^2 for venous ulcers, 29.13 cm^2 for burn wounds, and 8.64 cm^2 for bedsores. All subjects had wounds classified as grade 3 for venous ulcers, grade 2 for burn wounds, and grade 2 for bedsores, with a minimum wound size of 1 cm^2.

2.9 Statistical Analysis

All statistical tests were conducted using two-sided tests, with a p-value of less than or equal to 0.05 considered statistically significant. For group comparisons, appropriate methods were used based on the nature of the variables. Continuous data comparisons between groups were performed using t-tests for normally distributed data and Wilcoxon rank-sum tests for non-normally distributed data.

3. Results

3.1 Thermal Properties and Shrink Temperature Analysis of Healiaid Collagen Wound Dressing

The analysis of shrink temperature is employed to examine the thermal properties of collagen-based medical materials, focusing on aspects of thermal stability such as phase transitions. Understanding the stability and performance of collagen under various environmental conditions, particularly those encountered in vivo, is essential. The shrink temperatures are presented in Table 1, with the average shrink temperature of HealiAid Collagen Wound Dressing measured at 112.13±1.74°C. Intact collagen fibrils exhibit higher shrink temperatures, while denatured collagen and microfibrils display lower shrink temperatures.

Test Sample No.	Shrink temperature (°C)
1	110.13
2	113.29
3	112.98
Ave. ± SD	112.13±1.74

Table 1: Differential Scanning Calorimetry (DSC) Profiles and Shrink Temperature Analysis of HealiAid Collagen Wound Dressing

3.2 The Porous Microstructure of HealiAid Collagen Wound Dressing Has High Heterogenicity and Connectivity

The SEM micrographs reveal that HealiAid Collagen Wound Dressing features a porous microstructure characterized by high heterogeneity and connectivity (Figure 1). This attribute is crucial for assessing the structural integrity, morphological characteristics, and fiber distribution within collagen-based materials. Such pore structures are essential for cell adhesion, biodegradation, and tissue regeneration.

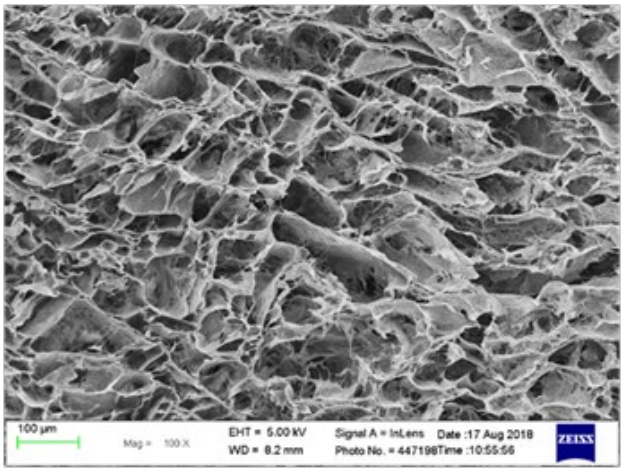


Figure 1: Porous Microstructure and Porosity Analysis of HealiAid Collagen Wound Dressing

The porous microstructure of the HealiAid Collagen Wound Dressing was analyzed using Scanning Electron Microscopy (SEM). Test samples were prepared by mounting on aluminum stubs and coating with a 15 nm layer of gold/palladium. The samples were examined in secondary electron mode at 5 keV accelerating voltage, with magnifications ranging from 100x to 2000x. The SEM micrographs revealed a highly heterogeneous and connected porous structure, essential for assessing the structural integrity, morphological traits, and fiber distribution within the collagen matrix. This porosity, measured at approximately 89.1±5.9%, is critical for cell adhesion, biodegradation, and tissue regeneration, facilitating tissue repair and growth.

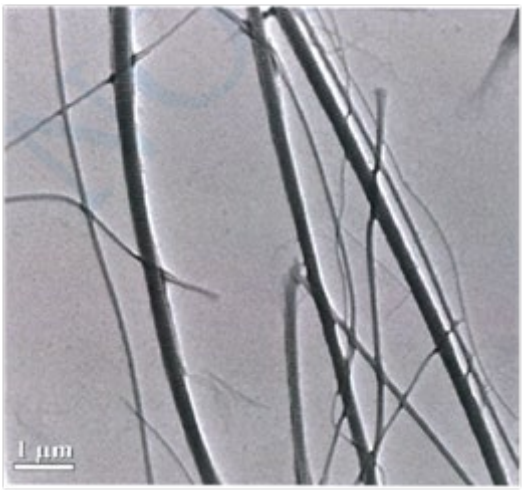
3.3 Influence of Porosity on the Microstructure and Efficacy of HealiAid Collagen Wound Dressing

HealiAid Collagen Wound Dressing exhibits a porosity of approximately 89.1±5.9%. Proper pore size distribution and porosity are crucial for maintaining the structural and microstructural integrity of collagen-based medical materials. Adequate porosity provides surface area and channels for cell attachment, facilitating cell settlement and proliferation within the material, thereby promoting tissue repair and regeneration.

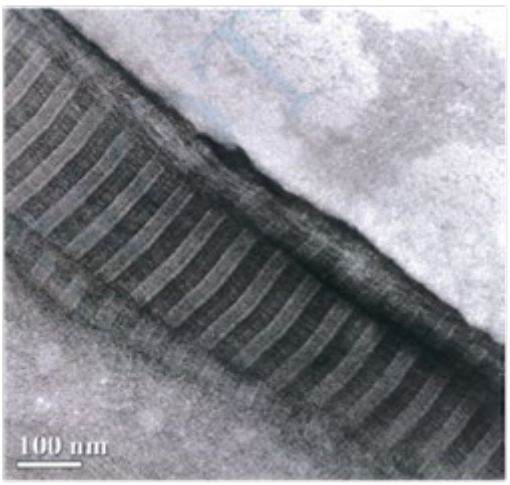
The porosity of the HealiAid Collagen Wound Dressing, measured at 89.1±5.9%, is depicted through Mercury Intrusion Porosimetry (MIP). Proper pore size distribution and porosity influence the tissue structure, providing surface area and channels for cell attachment, thus facilitating cell settlement and growth within the material to promote tissue repair and regeneration.

3.4 HealiAid Collagen Wound Dressing Retains the Triple Helix Structure of Natural Fibrillar Collagen Characteristics

Under standard negative staining conditions, dark bands indicate areas where the heavy metal staining reagent accumulates, such as the gap regions of native collagen fibrils. Light regions correspond to stain exclusion zones, such as the overlap regions of collagen fibrils. The periodic asymmetric pattern of transverse dark bands reflects the distribution of charged amino acid residues. TEM analysis demonstrates that HealiAid Collagen Wound Dressing preserves the natural fibrillar collagen characteristics, including the triple helix structure (Figure 2).



(A) TEM image with magnification ×2,000.



(B) TEM Image with Magnification ×20,000

Figure 2: Triple Helix Structure Analysis of Healiaid Collagen Wound Dressing Via Mercury Intrusion Porosimetry

Transmission Electron Microscopy (TEM) images, at magnifications of (a) ×2,000 and (b) ×100,000, verify the periodic structure of the collagen matrix's triple helix. The test sample was embedded in epoxy resin, ultrathin sections were cut approximately 40 nm thick, and counterstained with 2% uranyl acetate in 70% methanol. The periodic asymmetric pattern of transverse dark bands corresponds to the distribution of charged amino acid residues, indicating that the HealiAid Collagen Wound Dressing retains the native fibrillar collagen characteristics.

3.5 Endotoxin Limits and Pyrogen Content in Medical Devices

The endotoxin limit for a drug compound administered as a whole-body dose is typically 350 EU. In contrast to pharmaceuticals, endotoxins in medical devices must be extracted or flushed out, with the resulting extract or effluent mixed with LAL reagent for testing. FDA studies have demonstrated that recovery extraction of endotoxins from spiked device materials often falls short of complete recovery. As a result, a more stringent endotoxin limit of less than 20 EU per device has been established for medical devices to account for potential inefficiencies in the extraction process. The pyrogen content of HealiAid Collagen Wound Dressing is less than 2 EU/device, indicating that it is well below the regulated endotoxin threshold and free from pyrogen contamination.

3.6 No Observable Clinical Signs or Animal Deaths During 12 Weeks Implantation

During daily clinical observations, no observable clinical signs or animal deaths were noted throughout the study period. Gross necropsy revealed no significant signs of inflammation, encapsulation, hemorrhage, necrosis, or discoloration at the test article implantation sites. Histopathological evaluation showed a very slight reaction (rating: 1.875) at 4 weeks, a very slight reaction (rating: 1.221) at 8 weeks, and no reaction (rating: 0.501) at 12 weeks post-implantation (Table 2). The distinct structure of the test articles remained visible in all animals at 4, 8, and 12 weeks after implantation. These results indicate that HealiAid Collagen Wound Dressing was well tolerated in muscle tissue, eliciting only very slight or no inflammatory reaction.

Implantation period	Animal ID	Score (Rating)	Average (Rating)
4 weeks	A090300261001	1.791 (Very Slight)	1.875 (Very Slight)
	A090300261002	1.835 (Very Slight)	
	A090300261003	1.750 (Very Slight)	
	A090300261004	2.125 (Mild)	
8 weeks	A090300261005	1.167 (Very Slight)	1.221 (Very Slight)
	A090300261006	1.172 (Very Slight)	
	A090300261007	1.335 (Very Slight)	
	A090300261008	1.209 (Very Slight)	
12 weeks	A090300261009	0.334 (No reaction)	0.501 (No reaction)
	A090300261010	0.418 (No reaction)	
	A090300261011	0.418 (No reaction)	
	A090300261012	0.835 (No reaction)	

Table 2: Histological Pathological Evaluation in the Implantation Test

3.7 HealiAid Collagen Wound Dressing Increased Wound Healing in Clinical Trial

The study involved 18 subjects with an average age of 56.11±14.62 years, the majority of whom were male (61.1%). Subjects were evenly distributed across three wound type groups: venous ulcers, burn wounds, and bedsores. Initial wound sizes were recorded as 5.1 cm^2 for venous ulcers, 29.13 cm^2 for burn wounds, and 8.64 cm^2 for bedsores. Wounds were classified as grade 3 for venous ulcers, grade 2 for burn wounds, and grade 2 for bedsores, with a minimum wound size of 1 cm^2. The primary efficacy measure, the percentage of wound healing at 8 weeks post-treatment, showed significant improvement across all groups. In the venous ulcer group, the average wound size decreased from 5.1 cm^2 at baseline to 1.2 cm^2 at 12 weeks, reflecting a healing percentage of 76.47%. It was noted that wound expansion was observed in one subject (subject number S12) at Visit 5 (4 weeks after treatment). After undergoing angiography, it was suspected that an arterial embolism in the lower limbs was affecting wound healing. Consequently, at Visit 6 (two months after treatment), the trial was concluded for this subject, and they were referred for specialized treatment. For the remaining subjects, the healing rate was 100% at 12 weeks post-treatment, as depicted in the representative photograph of the wound site (Figure 3). The burn wound group exhibited the most remarkable results, with the average wound size decreasing from 29.13 cm^2 at baseline to 0 cm^2 at 4 weeks, indicating complete healing for all participants. The bedsore group also showed positive outcomes, with the average wound size decreasing from 8.64 cm^2 at baseline to 6.17 cm^2 at 12 weeks, corresponding to a healing percentage of 56.69%. Granulation tissue growth was assessed on a scale from 0 to 5, demonstrating significant improvement across all groups. By the conclusion of the study, the venous ulcer group achieved an average score of 0.2, indicating near-complete healing. Wound exudate levels were evaluated on a scale from 0 to 3, with the majority of subjects showing a reduction in exudate levels over time (Table 3).

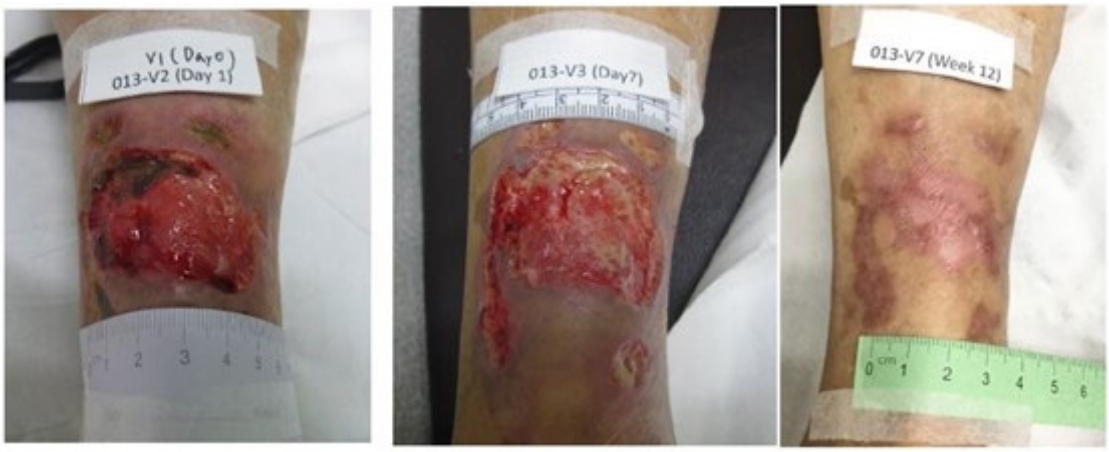


Figure 3: Wound Healing Progression of Subject S13 with Venous Ulcer

The images depict the wound's appearance at baseline (V2, Day 1), post-debridement (V3, Day 7), and at Week 12 (V7).

Wound Type	Subject Numbers	Gender	Analysis Item	Before Treatment	After Treatment				
				Baseline	7-day	2-week	4-week	8-week	12-week
Venous Ulcer	5	2 Male 3 Female	Wound Size in Average (cm^2)	5.10	5.77	5.41	3.90	1.90	1.20
			Healing Ratio (%)	0	25.78	39.24	42.00	55.33	60.00
			Granulation Assessment	1.40	0.60	0.60	0.40	0.40	0.20
			Exudate Assessment	1.20	0.80	0.60	0.60	0.40	0.20
Burn Wound	4	3 Male 1 Female	Wound Size in Average (cm^2)	29.13	6.94	2.81	0	0	0
			Healing Ratio (%)	0	52.00	76.60	100.00	100.00	100.00
			Granulation Assessment	0.75	0.25	0	0	0	0
			Exudate Assessment	1.00	0.50	0.25	0	0	0
Bedsore	4	3 Male 1 Female	Wound Size in Average (cm^2)	9.95	8.42	7.93	7.25	6.81	6.81
			Healing Ratio (%)	0	32.29	35.00	54.87	56.69	56.69
			Granulation Assessment	1.00	1.00	1.00	0.50	0.50	0.25
			Granulation Assessment	1.00	1.00	1.00	0.50	0.50	0.25
			Exudate Assessment	0.75	0.50	0.50	0.50	0.50	0.50

Table 3: Evaluation Results of Distinct Wound Type

3.8 HealiAid Collagen Wound Dressing No Serious Adverse Reactions

Safety evaluations recorded adverse events and inflammation levels, graded on a scale from 0 to 3 for infection/inflammation and from 0 to 3 for other adverse reactions. The study reported no severe adverse events (Table 4), with all participants tolerating the treatment well. Only mild to moderate adverse reactions were observed, and these were managed effectively.

Monitoring Point	Adverse Event				
	Incident Count	Mild	Moderate	Severe	Related to Device
7-day	2	1	1	0	0
2-week	1	0	1	0	0
4-week	1	1	0	0	0
8-week	0	0	0	0	0

Table 4: Adverse Event Monitoring Results

4. Discussion

This study found that HealiAid Collagen Wound Dressing has strong thermal stability and a well-structured porous microstructure, supporting effective wound healing across various wound types, including venous ulcers, burns, and bedsores. Clinical trials indicated significant improvements in wound healing with no serious adverse reactions, and low endotoxin levels confirmed its safety.

The average shrinkage temperature of HealiAid Collagen Wound Dressing is 112.13±1.74°C, demonstrating its excellent thermal stability, which is consistent with the characteristic higher shrinkage temperatures typically observed in intact collagen fibrils [11]. This result suggests that the HealiAid dressing effectively preserves the triple helix structure of collagen during the manufacturing process, thereby maintaining its structural integrity. The study indicates that cross-linked collagen materials exhibit higher thermal stability, further supporting our findings [12]. This implies that the dressing can retain its functional properties under various physiological conditions, making it suitable for clinical wound care applications [13]. The SEM analysis of HealiAid Collagen Wound Dressing reveals a highly heterogeneous and interconnected porous microstructure, with a porosity of approximately 89.1±5.9%. This structural characteristic is critical for the material's functionality in wound healing applications [14]. Studies have shown that an appropriate pore size distribution and high porosity enhance cell attachment and migration, facilitating efficient tissue integration and repair [5]. The porosity level observed in HealiAid aligns with findings that emphasize the importance of high porosity in promoting nutrient exchange and waste removal, which are vital for cell survival and tissue healing [16]. The retention of the triple helix structure in collagen within wound dressings holds significant clinical importance[10]. The triple helix is the fundamental structural unit of collagen, crucial for its mechanical strength, biological activity, and stability [17]. When collagen in a wound dressing maintains its triple helix structure, the dressing can more effectively provide the necessary support and guidance for tissue repair, promoting cell adhesion, proliferation, and differentiation [18]. Additionally, studies have shown that collagen retaining the triple helix structure is more resistant to enzymatic degradation, thereby extending the dressing's functional duration in vivo, which helps enhance its therapeutic efficacy and accelerate wound healing [19]. Therefore, the retention of the collagen triple helix structure in wound dressings is closely related to their clinical effectiveness [20]. The pyrogen content of HealiAid Collagen Wound Dressing, measured at less than 2 EU/device, significantly falls below the stringent endotoxin limit of 20 EU/device set for medical devices [21]. This low endotoxin level indicates that HealiAid effectively meets regulatory safety standards and minimizes the risk of pyrogenic reactions. Studies have shown that maintaining endotoxin levels well below regulatory thresholds is critical to preventing adverse immune responses, ensuring the safety and efficacy of medical devices used in wound care [22]. The biocompatibility of wound dressings ensures that the dressings can coexist well with surrounding tissues without triggering immune rejection or significant inflammatory responses [23]. This mechanism is achieved through low immunogenic interactions of the dressing material with cells and tissues [24]. When the dressing does not stimulate excessive activation of immune cells such as macrophages and lymphocytes, the local inflammatory response is kept to a minimum, thereby promoting tissue repair [25].

Collagen dressings have demonstrated significant clinical efficacy in the treatment of venous ulcers, burns, and pressure ulcers [26]. Firstly, in the treatment of venous ulcers, collagen dressings promote the formation of granulation tissue and provide a matrix that supports cell adhesion and migration, thereby accelerating the wound healing process [27]. Additionally, the use of collagen dressings has significantly shortened healing time and reduced wound exudate levels in venous ulcer patients [28]. In burn treatment, collagen dressings are particularly effective in promoting wound re-epithelialization, reducing scar formation, and lowering the risk of infection [29]. Studies have also shown that collagen dressings can stimulate angiogenesis in burn areas, further accelerating tissue repair [30]. For pressure ulcers, the use of collagen dressings significantly improves healing rates and reduces exudate levels [30]. Moreover, collagen dressings promote wound contraction and the formation of granulation tissue, speeding up the healing process of pressure ulcers [31]. These findings highlight the broad potential applications of collagen dressings in wound care across various types of injuries. Studies have shown that collagen wound dressings do not cause serious adverse reactions when used to treat venous ulcers, burns, and pressure ulcers [28]. Multiple clinical studies have demonstrated that collagen dressings exhibit good safety and tolerance in managing these wounds, with no reports of serious adverse events [26,32]. These findings confirm the high safety profile of collagen dressings in clinical applications, making them suitable for various wound treatments.

While the findings regarding HealiAid Collagen Wound Dressing are promising, several limitations must be considered. The studies referenced primarily focus on short- to medium-term outcomes, leaving the long-term effects of collagen dressing use less well understood. Additionally, the sample sizes in some studies were relatively small, potentially limiting the generalizability of the results to broader populations. There is also a need for more randomized controlled trials comparing

HealiAid with other wound dressings to better assess its relative efficacy and safety.

5. Conclusion

HealiAid Collagen Wound Dressing has shown strong thermal stability and a well-structured porous microstructure, supporting effective wound healing across various wound types, including venous ulcers, burns, and bedsores. Clinical trials indicated significant improvements in wound healing with no serious adverse reactions, and low endotoxin levels confirmed its safety. For future applications, HealiAid could be expanded to treat other challenging wounds such as diabetic ulcers and surgical sites. Additionally, its use could be optimized in regenerative medicine, where its collagen-based structure may support advanced tissue repair and improve outcomes in complex wound healing scenarios.

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