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Mini Review

Development of a Skin Scaffold for Wound Healing Using a Polymer Blend

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Abstract:

Native skin consists mainly of epidermal and dermal layers. Here in this work, we have constructed an artificial skin scaffold mimicking the bilayered structure of the native skin using electrospinning technique for wound healing. Polyurethane (PU) and Gelatin (Ge) were used for developing the epidermal layer and the dermal layer respectively. Ciprofloxacin HCl (Cip. HCl) a fluoroquinolone antibiotic was incorporated in both the layers for rapid wound healing. Morphology of the skin scaffold was studied using scanning electron microscopy (SEM) analysis and the chemical characterization was performed using FTIR spectroscopy. Water vapor transmission rate test and oxygen transmission rate test was conducted to evaluate the barrier properties of the scaffold. Thermal stability of the skin scaffold was evaluated using DSC and TGA while an understanding of the exudate absorbing capacity and degradation behavior of the scaffold was obtained from water absorption studies and in vitro degradation studies respectively. In vitro drug release study and drug release kinetics was explored to understand the release mechanism of Cip. HCl from the scaffold. Both the layers showed nano and micropores when analyzed using SEM. The dermal layer showed comparatively more water absorption capacity and degradation, hence providing a moist environment for the wound. The skin scaffold was permeable to water vapor and oxygen, and hence will speed up the process of wound healing. In vitro release for Cip. HCl showed a non-Fickian swelling type release with zero-order kinetics. Disk diffusion test conducted on the bilayers proved the antibacterial activity of the membrane. Hence the electrospun PU-Ge skin scaffold containing Cip. HCl is a promising candidate among modern day wound healing materials.

Key words: artificial skin scaffold; polyurethane; ciprofloxacin; gelatin; electrospinning

1.Introduction

Clinical management of deep and extensive wounds is challenging [1-3]. Any wound having a depth of more than 1 cm cannot heal by itself and requires grafts containing dermis and epidermis harvested from other parts of the body [4]. Skin tissue engineering is therefore a good option for deep wound healing as there is a limitation in getting large autografts [5-7]. For deep wounds such as second- degree burn wounds, almost all the parts of the dermis and whole of epidermis is lost. Hence the artificial skin scaffold developed for such cases should have a bilayer of dermis and epidermis mimicking the natural skin properties [8]. Bilayered collagen-based skin substitutes such as Integra and Biobrane have greatly improved the long-term function and appearance of the wound, with lower wound contraction and less pigmentation [9,10]. But these collagen-based skin substitutes are usually associated with low mechanical strength, slow angiogenesis and lacks antibacterial properties as compared to the autograft. There are different types of artificial skin scaffolds made of chitosan/ polylactic acid, chitosan/polycaprolactone PEG grafted HA and collagen/chitosan hyaluronic acid [11]. Different techniques such as electrospinning, layer by layer assembly, solvent casting and lyophilization are some of the widely used techniques for developing wound healing membranes [12-16]. In this work, we have opted for an electrospinning technique to produce an artificial skin scaffold consisting of electrospun PU and Ge. Electrospinning is one of the easiest methods used for producing membranes having nano and micron-sized pores [17]. Flow rate, voltage, time, temperature, distance from the collector, density, viscosity, conductivity, surface tension, etc. are the different variables that can be optimized to get fibers of desired

properties [18]. This technique has been widely used for almost all the types of soluble synthetic and biopolymers. Ge has been chosen as a dermal substitute because it is the partially denatured derivative of the fibrous insoluble protein collagen, and does not express any antigenicity, is cost-effective as compared to collagen, shows good hemostatic effects, is completely bioabsorbable and can be cross-linked using appropriate chemistry to improve the mechanical strength [19]. PU is an excellent medical elastomer material with good mechanical strength, oxygen permeability, barrier properties and biocompatibility and hence can be used as an epidermal substitute [20,21]. Most of these bilayered membranes do not show any antibacterial property but it is possible to add antibiotics and other growth factors so that rapid wound healing and angiogenesis can be achieved. In this case, Ciprofloxacin HCl (Cip. HCl) has been added to both the Ge and PU layers so that antibacterial property is imparted to the scaffold. The prepared bilayered membrane has been characterized and important parameters such as water vapor transmission rate, oxygen transmission rate, mechanical parameters, thermal properties, in vitro degradation, water absorption, in vitro release, drug release kinetics and antibacterial studies have been conducted so that it can be used as an effective antibacterial artificial skin scaffold.

2. Technical details

The following chemicals have been used [22]

Type B Gelatin granules conforming to USP standard has been used.

Polyurethane

HCl and analytical reagents used in the preparation of pH 7.4 buffer including Sodium chloride and Sodium dihydrogen phosphate.

Potassium chloride (KCl) and Potassium dihydrogen phosphate (KH2PO4)

2, 2, 2-trifluoroethanol (TFE)

Tetra hydro furan (THF) and N, Dimethylformamide (DMF)

The following procedures have been adopted

Preparation of skin scaffold by electrospinning

Characterization of the membranes

Scanning electron microscopy analysis

Fourier transform infrared spectroscopy

Thermogravimetric analysis

Differential scanning calorimetry

Water vapor transmission rat

Water absorption of the film

In vitro degradation of the film

Mechanical properties of films

In vitro drug release study

Mathematical modeling for controlled release of drugs Cip. HCl from the electrospun fiber

Antibacterial activity by cup-diffusion method

3. Conclusions

In this study, electrospinning technique was used to produce a bilayered PU-Ge skin scaffold wound dressing membrane composed of PU, Ge and Cip. HCl. The bi-layered structure of this wound dressing was designed, so as to mimic the skin native structure, with the PU layer representing the epidermal layer and the Ge layer representing the dermal layer. The nano porous interconnected structure of the bilayered scaffolds, as confirmed by SEM, is a desirable factor for burn wound healing since it helps in wound exudate absorption, better cell adhesion and proliferation. The thermal stability of the PU-Ge skin scaffolds is evident from the DSC and TGA studies while water absorption studies indicate the fluid absorption capacity of the bi-layered scaffold. The bi-layered PU-Ge skin scaffolds were found to be having optimal water vapor and oxygen transmission rates. An optimal WVTR enhances wound healing by improving the proliferation and function of epidermal cells and fibroblasts, while oxygen-permeable dressings help in faster wound healing. The PU-Ge scaffolds showed good mechanical strength in both wet and dry conditions as well as controlled biodegradation rates, which may be synchronized with the rate of epithelialization. The drug release kinetics follows zero-order controlled drug release, which can be considered ideal for wound dressing materials. The antibacterial property of the bilayered skin scaffold as well as individual layers were evaluated and was found to be adequate, such that any chances of infections can be ruled out. Hence the bilayered Pu-Ge skin scaffolds can act as effective antimicrobial wound dressing materials and can contribute towards enhanced wound healing.

Conflict of Interest

The author declares no competing interests.

References

1. Bhowmick, S., Thanusha, A. V., Kumar, A., Scharnweber, D., Rother, S., et al. (2018). Nanofibrous artificial skin substitute composed om PEG–PCL grafted gelatin/hyaluronan/chondroitin sulfate/sericin for 2 nd degree burn care: In vitro and in vivo study. *RSC Advances*, 8(30), 16420–16432.
2. Lazarus, G. S., Cooper, D. M., Knighton, D. R., Margolis, D. J., Pecoraro, R. E., et al. (1994). Definitions and guidelines for assessment of wounds and evaluation of healing. *Archives of Dermatology*, 130(4), 489–493.
3. Schulz, J. T., Tompkins, R. G., & Burk, J. F. (2000). Artificial skin. Annual Review of Medicine, 51, 231–244.
4. Balasubramani, M., Kumar, T. R., & Babu, M. (2001). Skin substitutes: A review. Burns, 27(5), 534–544.
5. Li, M., Zhang, L., Fan, X., Zhou, Y., Wu, M., et al. (2015). Highly selective CO2 photoreduction to CO over g-C3N4/Bi2 WO6 composites under visible light. Journal of Materials Chemistry A, 3(9), 5189–5196.
6. Pedram Rad, Z., Mokhtari, J., & Abbasi, M. (2018). Fabrication and characterization of PCL/zein/gum Arabic electrospun nanocomposite scaffold for skin tissue engineering. Materials Science & Engineering. C, *Materials for Biological Applications*, 93, 356–366.
7. Wang, F., Wang, M., She, Z., Fan, K., Xu, C., et al. (2015). Collagen/chitosan based two-compartment and bi-functional dermal scaffolds for skin regeneration. Materials Science & Engineering. C, *Materials for Biological Applications*, 52, 155–162.
8. Trinca, R. B., Westin, C. B., da Silva, J. A. F., & Moraes, A. M. (2017). Electrospun multilayer chitosan scaffolds as potential wound dressings for skin lesions. *European Polymer Journal*, 88, 161–170.
9. Ma, L., Gao, C., Mao, Z., Zhou, J., Shen, J., et al. (2003). Collagen/chitosan porous scaffolds with improved biostability for skin tissue engineering. *Biomaterials*, 24(26), 4833–4841.
10. Soller, E. C., Tzeranis, D. S., Miu, K., So, P. T., & Yannas, I. V. (2012). Common features of optimal collagen scaffolds that disrupt wound contraction and enhance regeneration both in peripheral nerves and in skin. *Biomaterials*, 33(19), 4783–4791.

11. Chen, S. H., Chang, Y., Lee, K. R., & Lai, J. Y. (2014). A three-dimensional dual-layer nano/microfibrous structure of electrospun chitosan/ poly(d,l-lactide) membrane for the improvement of cytocompatibility. *Journal of Membrane Science*, 450, 224–234.
12. Kim, W., Kim, M. J., Ki, C. S., Kim, H. J., & Park, Y. H. (2017). Fabrication of bi-layer scaffold of keratin nanofiber and gelatinmethacrylate hydrogel: Implications for skin graft. *International Journal of Biological Macromolecules*, 105(Pt 1), 541–548.
13. Kobsa, S., Kristofik, N. J., Sawyer, A. J., Bothwell, A. L. M., Kyriakides, T. R., et al. (2013). An electrospun scaffold integrating nucleic acid delivery for treatment of full-thickness wounds. *Biomaterials*, 34(15), 3891–3901.
14. Zhang, S., Wang, X.-J., Li, W.-S., Xu, X.-L., Hu, J.-B., et al. (2018). Polycaprolactone/polysialic acid hybrid, multifunctional nanofiber scaffolds for treatment of spinal cord injury. *Acta Biomaterialia*, 77, 15–27.
15. Martınez, A., Blanco, M. D., Davidenko, N., & Cameron, R. E. (2015). Tailoring chitosan/collagen scaffolds for tissue engineering: Effect of composition and different crosslinking agents on scaffold properties. *Carbohydrate Polymers*, 132, 606–619.
16. Pawar, H. V., Boateng, J. S., Ayensu, I., & Tetteh, J. (2014). Multifunctional medicated lyophilised wafer dressing for effective chronic wound healing. *Journal of Pharmaceutical Sciences*, 103(6), 1720–1733.
17. Erencia, M., Cano, F., Tornero, J. A., Fernandes, M. M., Tzanov, T., et al. (2015). Electrospinning of gelatin fibers using solutions with low acetic acid concentration: Effect of solvent composition on both diameter of electrospun fibers and cytotoxicity. *Journal of Applied Polymer Science*, 132(25), 42115.
18. Greiner, A., & Wendorff, J. H. (2007). Electrospinning: A fascinating method for the preparation of ultrathin fibers. *Angewandte Chemie* (International ed. in English), 46(30), 5670–5703.
19. Mao, J., Zhao, L., de Yao, K., Shang, Q., Yang, G., et al. (2003). Study of novel chitosan-gelatin artificial skin in vitro. *Journal of Biomedical Materials Research*. Part A, 64(2), 301–308.
20. Kim, W., Kim, M. J., Ki, C. S., Kim, H. J., & Park, Y. H. (2017). Fabrication of bi-layer scaffold of keratin nanofiber and gelatinmethacrylate hydrogel: Implications for skin graft. *International Journal of Biological Macromolecules*, 105(Pt 1), 541–548.
21. Tu, Y., Zhou, M., Guo, Z., Li, Y., Hou, Y., et al. (2015). Preparation and characterization of thermosensitive artificial skin with a Sandwich structure. *Materials Letters*, 147, 4–7.
22. S. Sneha Letha, Anjali S. Kumar, Nisha U. & M. J. Rosemary (2021): Electrospun polyurethane-gelatin artificial skin scaffold for wound healing, *The Journal of The Textile Institute*.

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