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Fabrication of Self-Healing Absorbable Polymer Based Gel for Wound Dressing †

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Abstract: Healthcare professionals must take special care of wounds to avoid serious complications such as infections, lengthy healing periods, and even amputations. This study aimed to design and manufacture a self-healing bioabsorbable polymeric based wound dressing with anti-bacterial growth and improved wound healing properties. Gel-based mixtures were successfully made-up of 5wt% chitosan with inhibition bacterial growth feature in 5–20wt% polyvinyl alcohol (PVA) called "pure mixture". It was observed that the mixture of 5wt% chitosan in 10wt% PVA resulted in the most controlled viscosity and appropriate gel-texture for wound healing. The measured viscosities of 5wt% chitosan and 10wt% PVA are 235 and 531 Pa·s, respectively. The microscopic examination confirmed that addition of chitosan into PVA has successfully inhibited the bacterial growth. Another gel-based mixture called "additive mixture" was also investigated using the optimized preparation condition of 5wt% chitosan in 10wt% PVA with incorporation of some traditional herbs in powder form named frankincense, myrrh, and alum stone. Microscopic examination proven that addition of traditional herbs into chitosan/PVA mixture has initiated some bacteria to growth. A comparison of the wound healing performance of pure mixture gel and additive mixture gel was conducted using rats. The pure mixture gel produced a faster healing rate and a lower level of inflammation than the additive mixture gel.

Keywords: composites; self-healing; polymers; absorbable; wound dressing

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1. Introduction

Skin is the largest organ with a surface area of 1.8–2 m^2 and an approximate weight of 9 kg. The skin serves as a possesses sensory, thermoregulatory, metabolic, and immunological contact between the body's internal milieu and the external environment. Skin has the potential to easily get injured by sharp objects as it is a delicate organ. Wounds are injuries that damage or result in opening in the skin or other body tissues by multiple causes such as sutures, stitches, and surgeries. Wounds initiate a complex healing process [1,2].

Wound dressing is utilized in order to aid during the healing process [3]. There are two types of wound dressing which are traditional and advanced wound dressing [4]. Wounds are a global health concern, yet Technological advancements have not fully

addressed wound management [5]. This study aims to fabricate a self-healing bioabsorbable polymeric base with anti-bacterial and improved wound healing prosperities.

2. Materials

After optimizing the morphological conditions and accurately determining the essential standards for the design, the base materials were selected to be Polyvinyl alcohol (PVA) and Chitosan. The two polymers were chosen because of the characteristics and features mentioned in Table 1. Furthermore, combining synthetic and natural polymers will enhance the dressing properties.

Table 1. The chosen polymers that are compatible with the design needs.

Polymer	Advantages	Role in Wound Healing	Reference
Chitosan	• Non-toxic • Biocompatible • Biodegradable • Safe • Antibacterial • Natural polymer • Hydrophilic	• Preventing growth of bacteria • Preventing infection of the wound • Forming a gel	[6,7]
Polyvinyl alcohol (PVA)	• Biodegradable • Harmless and non-toxic • Water soluble • Natural hydrophilic • Bio-adhesive • Biocompatible • Non-carcinogenic • Synthetic polymer	• Blending natural polymer with synthetic polymer • Taking advantage of its excellent mechanical properties	[8]

The following table shows all possible additives that could be added to the material to enhance the dressing quality. The selection from the additives will be based on their efficacy during the practical trials.

Possible Additives	Advantages	Role in Wound Healing	Reference
Frankincense	• Anti-inflammatory • Antibacterial • Antioxidant and anti-aging • Anticancer • Moisturizing • Antiseptic • Natural astringent • Safe • Absorbable	• Preventing growth of bacteria • Preventing infection of the wound • Inflammation control • Improving wound healing	[9,10]
Alum Stone	• Astringent • Hemostatic • Healing properties • Antibacterial • Anti-inflammatory • Anti-tumor • Water-soluble	• Bleeding control • Accelerating wound healing • Reducing scars • Preventing growth of bacteria	[11,12]
Rose Water	• Anti-inflammatory • Antibacterial	• Accelerating wound healing	[13]

	• Antiseptic • Analgesic • Antioxidant and anti-aging • Safe	• Reducing pain and scars • Preventing growth of bacteria • Reducing skin irritation	
Myrrh	• Antibacterial • Antimicrobial • Anti-inflammatory • Antioxidant • Healing properties	• Improving skin texture • Enhancing wound contraction • Proliferating stage maturation of the blood vessels • Accelerating wound healing	[14]

3. Method

Two mixtures were prepared for testing: a pure mixture consisting only of polymers, and an additives mixture containing additives.

The PVA mixture was prepared by heating distilled water to 90 °C, then adding 22.5 g of PVA to the water and stirring until completely dissolved. The final volume was 100 mL with a 15% PVA concentration. To prepare the Chitosan, 150 mL of distilled water was stirred with 7.5 g of Chitosan, 5% Acetic acid, and 5% Acetic acid for 24 h. The final volume was 150 mL with a 5% Chitosan concentration. The mixture was blended with heat to create a gel-based texture. The additive mixture was prepared by adding frankincense, myrrh, alum stone, and rose water to 500 mL of rose water. The solution was finalized using a double filtration method, resulting in 400 mL of the additive solution. A blend of 50% pure Chitosan and 50% PVA was combined with the additive solution, creating a gel-based texture. The gel was poured into an acrylic mold, covered with non-stick and non-woven paper, and left to solidify for two to three days. The adhesive gel was then applied to a Damas-Transparent adhesive dressing.

A bacteria growth test was conducted using a Development Buffer (DB) made of 8 mL PBS, 24 mL distilled water, 4 mL $MgCl_2$, and 4 mL $CaCl_2$. Agar powder was added to the DB to provide a stable growth surface for bacteria to form colonies. The mixture was sterilized by being holed for 15 min at 121 °C in an Autoclave. The initial investigation test involved wiping three sampled plates with a pre-sterilized DB mixture, pure mixed polymers, and composite polymers & additives, then adding 4 ml of Media Buffer (MB) under UV light for 20 min, where it enhanced the microorganism growth and fermentation environment. As a second investigation test, the MB solution was separated from sampled plates and poured into two bottles with little distilled water and 0.5 mL iodine. The solution was centrifuged for four minutes to separate the particles, creating a strong bacterial environment for the testing operation. Then, three sampled plates were wiped with pre-sterilized DB mixture, pure mixed polymers, and composite polymers & additives. 4 mL of mononuclear and iodine agent solution was added to each plate and kept at room temperature for four days.

After getting ethical approval from the deanship of the scientific research, we took three rats to evaluate their wound-healing process by making minor cuts (superficial wounds) on their body under local anesthetic. Then, we wiped the first rat's wound with the pure mixture of polymers, the second one with the mixture of polymers and additives, and the third without anything to be considered a control sample. The wounds were monitored for four days.

The viscosity of a mixture was determined through three practical steps: determining the weight of the pure polymer mix and the composite polymer mix with additives,

calculating the volume using normative beakers, calculating the density of both mixtures, and calculating the diameter and weight of a small metallic ball. These data were then applied to the mathematical formula to determine the viscosity.

4. Result

The result of the bacteria growth test has been shown in the following figure.

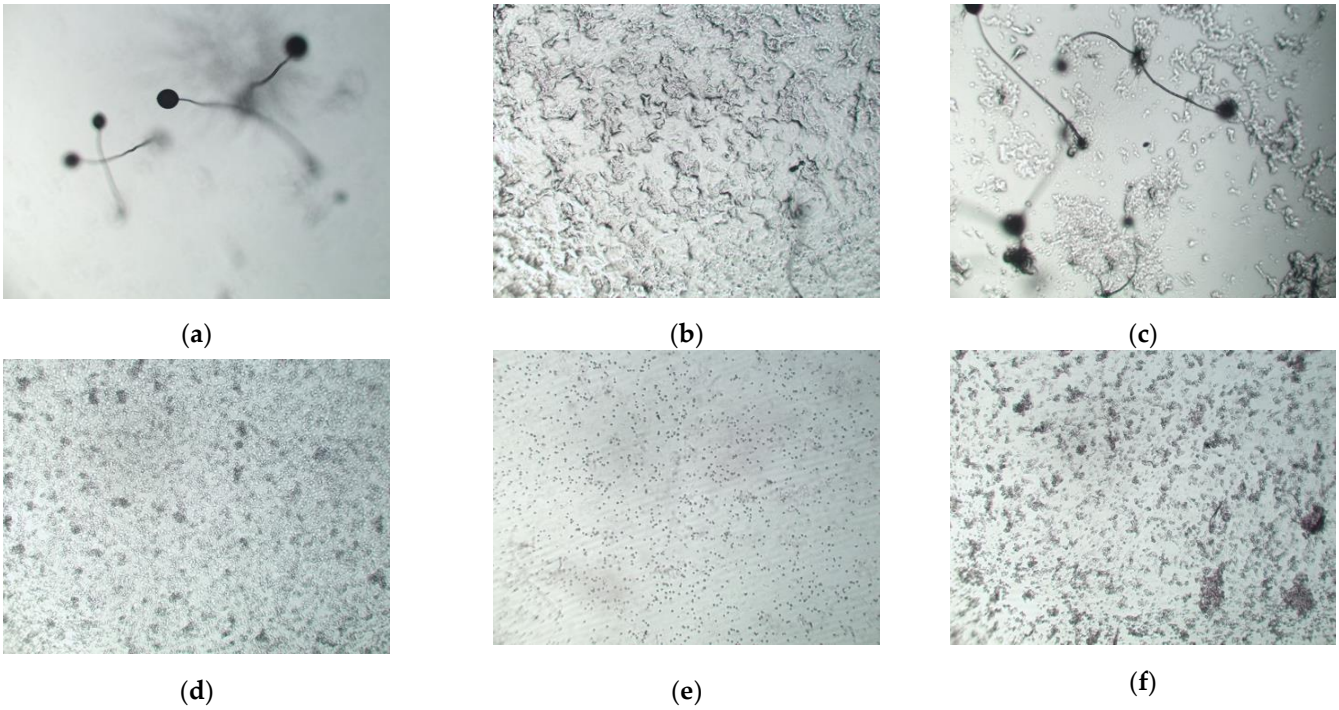

Figure 1. The results of the bacteria test under microscope. (**a**) Bacteria development of the control one; (**b**) Bacterial growth on the control plates; (**c**) Bacteria development of the pure mixture; (**d**) Bacterial growth on the plates wiped with the pure mixtue; (**e**) Bacteria development of the additive mixture; (**f**) Bacterial growth on plates wiped with the additive mixture.

The mixture's effectiveness has been assessed in lab rats and the wound healing duration has been monitored. The following figure shows the results after the lab rats have been monitored for four days after applying the gel once directly after incision.

Figure 2. The healing effectiveness of fabricated wound dressing. (**a**) The healing result of the control rat; (**b**) The healing result after applying the pure mixture on the rat; (**c**) The healing result after applying the pure mixture on the rat.

After the fabrication, the first test performed was a physical properties test that included measuring the viscosities of the mixtures. The next table and figure below illustrate the calculated viscosity results.

Table 2. The viscosity test result.

Polymers Concentration	Viscosity (Kg/m.s)
PVA 5%	2.1319
PVA 10%	531.1847
PVA 20%	4032.1501
CH 5%	235.1173

5. Discussion

The control plates showed clear and significant cell aggregation as well as a large number of fruiting bodies, indicating normal cell growth. The plates containing the pure gel mixture showed no aggregation or cell development on the growth plate and no fruiting bodies on the development plate. This indicates that the mixture had a strong inhibitory effect on microbial growth. The last two plates used with the additive mixture. The growth plate showed some aggregation and fungi, but the aggregation was not as significant as the control. The development plate showed some fruiting bodies, though most were dead. This indicates that the mixture had some inhibitory effect, but not as strong as the pure gel mixture.

The rats have been monitored for four days after applying the gel once directly after incision. For the pure mixture, the results have been promising compared to the control rat, showing a reduction in wound size. Meanwhile, the additives mixture, though it has not showed any enhancement of wound healing, made the wound look inflamed.

When the gel made from chitosan and PVA has been molded on a medical pad, it worked well for healing wounds. It helped wounds heal faster, made new skin growth, and stopped bacteria from growing. The pure gel has showed the best results. The gel is affordable, easy to get, safe, and suitable for people with allergies.

6. Conclusions and Future Work

The chitosan and PVA polymer base gel formed an effective wound dressing when applied to a medical pad. It showed promising results in accelerating wound healing, promoting new skin formation, and inhibiting bacterial growth. Testing showed the pure polymer gel mixture was most effective, while the additive-containing mixture provided little benefit. This suggests the chitosan-PVA base itself is what is effective. The polymer gel dressing's affordability, accessibility, safety, and hypoallergenic properties make it a promising option. However, further research and optimization are still needed before commercializing the product. Future work could improve the prototype through advanced manufacturing techniques to make it suitable for post-surgical wounds instead of sutures. Additionally, incorporating local natural materials from Al-Ahsa could give the product a distinctive cultural theme while contributing to the development of national industries. While the initial results are promising, substantial research and development are still needed before this polymer dressing can be routinely used as an accepted treatment. Nevertheless, with focused efforts to refine the product, with focused effort and refinement, this novel dressing has the potential to become a valuable treatment option in the near future.

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