Towards the Development of an Antibacterial Wound Dressing with Effective Management of Wound Exudate

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I. INTRODUCTION

Wound care is crucial for accelerating the wound healing process. Variety of techniques and treatments are employed in facilitating the healing and prevent further infections in wounds such as ensuring cleanliness by using mild soap, water or saline solution to carefully cleanse the wound bed to remove the debris, avoid further infections, managing the moisture level on the wound bed, and managing the wound environment. Wound dressings have been used over a time for the effective management of wounds and to increase the healing rates. Different types of materials are used in these dressings which can aid in sealing the wound, absorbing the wound exudate, and enhancing the healing process.

In the present there are several methodologies in applying antibacterial agents to enhance the healing process of wounds by preventing further infections through applying topically, giving orally and by intravenous administration (IV). According to previous literature, there are several methods used in imparting antibacterial agents to the dressing such as coating, impregnation, incorporation, immobilization, and microencapsulation [1]. Among this, microencapsulation is a good method for imparting antibacterial agents to the wound dressing because it offers several advantages such as allowing the control release of the antibacterial agent over time and protects the antibacterial agent from environmental factors like light, humidity, and temperature, which can guaranty the life of the antibacterial agent.

Apart from that, the management of the wound exudate is also important in increasing the efficiency of the healing process. Wound exudate aids to keep the moisture level around the wound, enable diffusion of immune mediators, acts as a support medium to move tissue-repairing cells throughout the wound bed, speed the separation of damaged, dead tissues and supply necessary nutrients for the cell metabolism [2]. But excessive production of wound exudate cause problems such as increasing the risk of infection, wound expansion, protein loss, frequent dressing changes, psychosocial effects difficulties in removing the wound dressings and reducing the healing rates [3]. From the literature several developments for proper management of wound exudate could be found but currently there are not any robust evidence to suggest that one type of dressing is superior to others in managing exudate or promoting wound healing.

Hence, under this study suitable antibacterial agents and auxiliary materials were identified and developed a synthesis route for an antibacterial dressing material using suitable combinations of antibacterial agents. Also, a textile based microfluidic platform for the proper management of wound exudate was developed.

II. METHODOLOGY

A. Imparting antibacterial properties to the wound dressing

Existing simple 100% cotton surgical gauze material (Suntex Industries (Pvt) Ltd, Sri Lanka) was selected (20 epi x 15 ppi, weight of 70 GSM) to improve its functionality as an effective wound dressing. Fusidic acid was taken as the antibacterial agent.

Microencapsulation was used as a technique to impart antibacterial properties to the wound dressing. Encapsulation process was tried in coacervation, in-situ polymerization and electro spraying techniques with Fusidic acid (Astron, Sri Lanka) as the active agent. Coacervation was tried with gelatin and Fusidic acid (Astron, Sri Lanka) while the in-situ polymerization and electro spraying were done with Sodium alginate and Fusidic acid (Astron, Sri Lanka).

The yield of the capsules prepared through electro spraying technique was comparatively higher than coacervation technique and smaller than the capsules prepared using in-situ polymerization technique. Prepared microcapsules were characterized by using Scanning electron microscopy (SEM) and Fourier transform infrared (FTIR).

Chitosan (Sigma-Aldrich) was used in binding the microcapsules to the simple 100% cotton surgical gauze material (20 epi x 15 ppi).

To evaluate the effectiveness of the antimicrobial agents the agar diffusion (SN 195920) test method was conducted and the investigated the performance of the test specimens against Gram positive *Staphylococcus aureus* ATCC 25923. Microcapsules were incorporated into 3 circular shaped cotton gauze (20 EPI x 15 EPI) samples having the 2 cm diameter. Samples used for the antibacterial test were,

- Sample with microcapsules
- Sample containing crushed microcapsules by applying 5N force.
- Sample added with 3 droplets of 1% NaCl on to the microcapsule bound cotton gauze sample.

Samples were kept on top of the growth bacteria cultures and the results were taken after 24 hours of application. Inhibition zones were observed in all 3 samples.

The second antibacterial test was conducted to check the release rate of the capsules with different concentrations of NaCl.

B. *Developing the Microfluidic Platform*

The vertical and horizontal wicking tests were conducted by dipping the yarns in the colored water to find the threads with the best wicking properties.

Since Permalose AQUA treated polyester thread showed the best wicking properties, further experiments were conducted using that.

Permalose AQUA treated polyester thread was used to investigate the wicking rates of wound exudate. Investigations were done using 2 solutions having viscosities closer to the viscosity of low and high viscose wound exudate as 0.9 cSt and 2.9 cSt, respectively [4].

C. *Development of the Wound Dressing*

A piece of gauze material measuring 6x6 cm^2 was selected as the base for the wound dressing. To make it hydrophobic, a hydrophobic coating is applied to the surface. A smaller piece of gauze measuring 2x1 cm^2 is designated as the antibacterial properties imparted area. Encapsulated antibacterial agent is incorporated to this area, ensuring a uniform and consistent coating. The antibacterial properties imparted gauze was then placed at the center of the hydrophobic gauze. Threads with increased hydrophilicity were strategically attached to the dressing, ensuring a proper microfluidic channel for the transfer of absorbed exudate from the hydrophilic antibacterial gauze section (center part) (Fig.1).

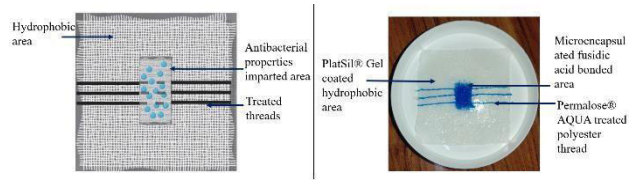

Fig 1: (a) Proposed design (b) Developed wound dressing

D. *Results and Discussion*

1) Yield of the microcapsules: Microcapsules were prepared by using both methods, but the yield of the microcapsules prepared using coacervation method was less and the size of the microcapsules prepared using in-situ polymerization was higher. Therefore, microcapsules prepared using electro spraying technique was used in development of antibacterial wound dressing.

2) SEM results: The microcapsules prepared using coacervation technique are not fully separated. It was difficult to filter the capsules. The SEM images of the capsules showed that the size range from 6 µm – 20 µm. Most of the microcapsules prepared using electro spraying technique seemed to be irregular in shape. The SEM images of the capsules showed that the size ranged from 200 µm – 800 µm.

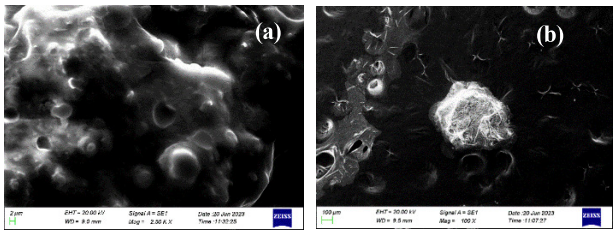

Fig 2: (a) microcapsules prepared using coacervation technique observed under magnification of 500X (b) Morphology of the microcapsules prepared using electro spraying technique observed under magnification of 100X

3) FTIR results: Based on the peak values of wavenumbers obtained from the FTIR analysis of microcapsule, it can be concluded that the sample under investigation contains bonds with specific vibrational modes. The peaks obtained in this study are consistent with the previous study conducted which prepared Fusidic acid-based calcium alginate microcapsules [5].

4) Results of the Antibacterial tests: Antibacterial test was conducted to check the effectiveness of the microencapsulated antibacterial agent and the highest inhabitance zone observed was 6.4795 cm^2 where the antibacterial agent was released through ion exchange mechanism. The second antibacterial test was conducted to check the release rate of the capsules with different concentrations of NaCl. The test revealed that an increase in concentration led to a corresponding expansion of the inhibition zone and the results indicate that the active agent within the capsules can be effectively released upon dissolution technique in the ions present in the wound exudate.

5) Assessing the effectiveness of developed microfluidic platform: The effectiveness was tested against the conventional wound dressing materials (Fig. 4). The developed wound dressing with microfluidic platform and Permalose AQUA treated threads have wicked the solution without spreading all over or spilling out. Also, this dressing has the ability to avoid the leakage of the exudate.

In relation to the developed wound dressing (Fig. 4c), a volume of 12.81 µl from 0.5 ml from each solution was wicked within 2 minutes and 6 minutes by the low viscose and high viscose solutions respectively. This indicates that the treated polyester threads could be effectively used as techniques to manage the wound exudate within the wound dressing in an effective manner.

Fig 3: Represented here are (a) Dettol plaster (Varun Medimpex Inc., India) (b) Conventional cotton gauze ((Suntex Industries (Pvt) Ltd, Sri Lanka) (c) Developed wound dressing with thread based microfluidic platform

E. Conclusions

This study aimed to create antibacterial wound dressings using microencapsulation techniques with Fusidic acid as the active core material. Electro spraying yielded higher microcapsule production than coacervation. The microcapsules' size ranged from 200 µm to 800 µm for electro spraying and 6 µm to 20 µm for coacervation. Antibacterial tests showed successful incorporation and controlled release of the antibacterial agent. An inhibitory zone of 6.4795 cm^2 was observed through ion exchange mechanism.

Additionally, Permalose AQUA treated polyester threads exhibited higher wicking rates, making them effective for managing wound exudate when combined with the antibacterial dressing material. The wicking rates were influenced by the viscosity of the wound exudate, but it could wick 12.81 µl from 0.5 ml from each solution. By using multiple threads, the dressing's effectiveness in managing wound exudate can be increased. This cost-effective wound dressing with dual functionalities of infection prevention and wound exudate management offers a platform for regular wound analysis, and future developments will focus on enhancing wicking ability and release rate studies of the antibacterial agent.

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