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An Analytical Paper on Smart Bandages

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Abstract: Chronic non-healing wounds are major health problems impacting a large number of people; they have a severe financial impact and are the leading cause of amputation of limbs. While chronic wounds are trapped in a permanent inflamed state, they are complex and proper treatment involves the detection of anomalies, proper drug administration and growth factors, and the regulation of environmental conditions. This review article, addresses technologies developed to track the wound condition in an active manner and also highlight drug delivery tools integrated with bandages to facilitate precise temporal and spatial control over drug release and review automated or semi-automated systems capable of responding to the wound environment. Smart systems, tools that have sensing, reaction, or monitoring capabilities, or a combination of these, may solve many of the challenges associated with wound healing, particularly with chronic wounds. Intelligent technologies also promote better treatment of wounds, enhance clinical outcomes, such as early diagnosis of pathogens or delivering medical warnings.

Keywords: Flexible Bandage, Quick Healing Bandage, Sensor Based Bandage.

INTRODUCTION

Chronic wounds are projected to impact millions of people worldwide and cost the economy annually. This pressure is growing as a consequence of rising healthcare costs, an aging population and an increased incidence of comorbidities such as diabetes. Wound healing takes place by concurrent and closely coordinated biochemical processes that in chronic wounds are dysregulated. Different local and systemic causes have a negative impact on effective wound healing including bacteria, chronic inflammation, low nutritional content, elevated blood pressure and inadequate perfusion. The wound bed must be vascularized for adequate oxygenation and the supply of nutrients to the healing skin to facilitate healing. It should also minimize bacterial load and the generation of exudates. Chronic wounds present a high risk of bacterial infection, because their hypoxic, protein-rich environment provides an appropriate environment for bacterial growth. Various pathogens typically exist in chronic wounds, but their existence cannot automatically be perceived as wound infection, since some reports confirm the role of low bacterial rates in facilitating wound healing.Bacteria have been shown to develop proteolytic enzymes that promote debris digestion and induce protease release from neutrophils; however, contamination occurs after essential colonization and wound healing may be compromised. Debridement is necessary because the non-viable tissue inhibits the movement of cells needed to build tissue from granulation.

Ideal wound care technology will (i) establish a damp, safe and warm environment; (ii) protect the wound bed from mechanical damage and bacterial infiltration; (iii) modulate exudate levels; (iv) enable exchange of gases; (v) facilitate thermal insulation; (vi) provide non-toxic and non-allergenic compounds; and (vii) provide therapeutic compounds necessary for optimum temporal profile healing.Numerous studies have been conducted regarding the role of biological factors involved in wound healing, such as immune cells, cytokines and chemokines. Significant progress has also been made in the drug delivery field to improve the bioavailability of administered drugs at the injury site. Wearable sensors were also developed which could accurately measure the level of important markers in the wound environment. Although there is a big gap between the wound care products used in clinical practice and the advanced platforms developed by researchers, the next generation of multifunctional' smart' dressings is expected to lead to a paradigm shift in wound care.These smart

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systems will combine various types of (bio) sensors for real-time tracking and successful wound care and address the benefits of smart dressings in this review article. Furthermore, highlights some of the sensors and active drug delivery systems built for wound care, as well as automated systems that detects both and react to specific wound parameters. Significant progress has been made in the production of smart materials capable of responding to variations in the wound environment, such as inflammatory marker upregulation, variability in ionic concentration and temperature, or ambient pH shifts.Such devices, though, cannot be actively regulated. Intelligent materials of this kind have been discussed elsewhere recently and are not included in this review article.

The Need for Smart Bandages in Wound Care:

Chronic wounds have a range of signatures and etiologies. Chronic wounds may be classified into three main categories, given their molecular and clinical heterogeneity: venous leg ulcers (VLUs) (see Glossary), diabetic foot ulcers (DFUs), or pressure ulcers (PUs). Some dressings have been established that are specified dependent on wound conditions for specific types of chronic wounds, such as dry or exuding, superficial or deep, and clean or polluted. These dressings lead to various weaknesses. As the mechanism of wound healing begins to be better understood, devices that effectively monitor opioid release spatial and temporal profile would be extremely beneficial for management of wound care.Notwithstanding advancements in wound healing technology, through interfering in faulty healing systems, there is still a need for tools that provides diagnostic information, fight infection, and successfully treat chronic wounds. These devices could revolutionize the field of wound care, and have significant therapeutic effects. Smart systems addresses many of the challenges associated with wound healing, particularly for chronic wounds, by allowing for sensing, responding, reporting, or a combination of such functions.Sensors may be paired with active drug delivery systems in order to react autonomously to potential infection or hyper inflammation. These integrated systems, which are summarized in the following sections, also have the potential to cut patients, hospitals, and insurance providers ' healthcare costs.

Dressings with Integrated Sensors:

Current wound dressings are intended mainly to keep the site covered and safe from infection. Some of them produce medications or substances capable of preventing infection and helping them recover quicker. A major drawback of these dressings is their failure to provide detail on the healing state and wound ecosystem conditions with respect to their pH, bacterial preparation, tissue oxygenation, and inflammation rates.In wound setting, sensors provides important information that would speed up wound care decision-making processes.

The decrease in healthcare costs and hospitalization duration also have significant benefits. The key range of wounds that is treated by sensor technology are persistent ulcers, lower contaminated acute wounds, and large full-thickness burns. Several markers which provide information on important physiological processes such as vascularization and inflammation have been established. Furthermore, another significant factor that hinder wound healing is infection; if infection is not handled at the early stages, it may lead to the formation of existing biofilms that are hard to treat. When biofilm is formed in a necrotic tissue it may need surgical debridement and amputation of the limbs. Infected DFUs are the dominant cause of non-traumatic amputation of the lower extremity limbs.

Sensors designed for use in wound care devices should have specific characteristics such as sufficient versatility to adapt to body contours; non-toxic and immune compatibility; and tolerance to wound exudate, which has differing pH levels and is abundant in proteins and enzymes. Scientists have established various sensors in the wound setting that quantifies essential biomarkers.

Dressing with PH sensors:

Different types of pH sensors were developed for use in wound care. For starters, many forms of electrochemical pH sensors were created which tracks the wound atmosphere continuously. Usually, electrochemical pH sensors using potentiometric calculation, polymer pH sensors, metal oxide, ion-selective electrodes and ion-selective field effect transistors. Potentiometric tests of incorporated sensors were used in engineering of many wound dressings. These sensors are manufactured on stretchable, flexible substrates. In a noteworthy test, the spraying of conductive inks and polymers on an Eco flex substratum produced a low-cost stretchable sensor. The sensor had a Nernstian reaction to pH level shifts and provided reproducible results on cyclical variations in the pH of the area. The sensor could shape and sustain conformal interaction with curved surfaces.Colorimetric sensors are another type of pH sensors which are used for bandages design. Despite embedded circuitry, these devices are reliable and simple to use. The readout of these sensors is usually based on image processing, although a naked eye view can be used to estimate the pH value or to identify the wound status if the color change is sufficiently vivid. However, the protection of the skin from the leached dye is a key challenge associated with using luminescence systems. To stop leakage during their use, pH-responsive dyes were introduced into mesoporous silica particles (MSPs) in one attempt to combat this problem.

The particles were then integrated by microfluidic spinning onto lightweight hydrogel fibers. The fibers were then applied to a clear medical tape with the intention of printing directly onto the medical tape for long-term tracking of cutaneous wounds. The pH of the wound has been calculated by analyzing collected photographs via smartphones.The pH of the wound has been calculated by analyzing collected photographs via smartphones. Image-based data analyzes are vulnerable to mistakes owing to illumination and image quality, so a hydrogel dressing was created to overcome this problem where the hydrogel was holding pH-responsive colors. The pH values were calculated using an embedded photodiode which could communicate wirelessly with smartphones.Because it is difficult to incorporate readout systems or image analysis, the proposal was sought to use dyes in which their color change becomes visible to the naked eye. For one case, a dye was created which could be loaded onto wound dressings and would glow various colors when subjected to UV light to determine the pH level of the wound.

LITERATURE REVIEW

This paper provides a comprehensive analysis of the electro pun nanofibers used to support wound healing. Furthermore, with detailed descriptions of both natural and synthetic polymeric methods, dominant polymers used in the production of these nanofibers are examined. It's also represented the function of polymeric nanofibers as drug carriers. Nano fibrous strategies to antimicrobial transmission and growth factors are discussed at length, in particular[1].A analysis discusses electrochemical testing approaches based on wound diagnostics and offers a vital summary of current work that may be important in determining the course for future devices[2].This study discusses here a new type of smart bandage for uric acid (UA) status determination, a main wound biomarker, developed by screen printing an amperometric biosensor directly onto a wound dressing. Immobilized uricase, combined with a Prussian blue designed catalytic transducer, allows the chronoamperometric identification of uric acid at low potential for research. The smart bandage biosensor integrates with a custom designed wearable potentiostat that offers on-demand wireless data transmission of UA status through radio frequency identification (RFID) or near-field communication (NFC) to a device, tablet or Smartphone[3].A smart and automatic flexible wound dressing with temperature and pH sensors mounted on flexible bandages to track wound condition in real time is proposed in this paper to resolve this unmet medical need. In addition, a stimulus-responsive drug release mechanism composed of a hydrogel lined with thermo-responsive drug carriers and a versatile heater operated electronically is also inserted into the wound dressing to activate the medications on demand[4].This research discusses the low-cost manufacture of single-use, omniphobic paper-based smart bandages (OPSBs), intended to track the condition of open chronic wounds and diagnose pressure ulcer development. OPSBs are lightweight, compact, breathable, simple to use, and burnable to disposal. A portable handheld potentiostat was developed by merely adding it to the back of the bandage to communicate with the OPSB[5].This paper shows a thread-based pH sensor that is incorporated as a smart bandage for chronic wound control with a custom CMOS read out IC. PH sensing threads are processed using a low-cost, dip-and-dry room temperature coating process for cotton threads with carbon ink and polyaniline (PANI) nanofibers. Wireless Bluetooth networking and mobile read-out allow real-time monitoring[6]. This paper explores our group's two generations of smart bandages and sensors. These devices are capable of monitoring and treating chronic wounds by measuring O2, pH and strain, and delivering drugs on demand. Next, this paper aim to close the gap between patient and caregiver by continuous monitoring of wound healing status through measures of oxygenation combined with wireless data collection and transition. First this paper demonstrate on-demand drug delivery utilizing thermos responsive particles using the same model[7].This research aims to establish immune-sensors for continuous monitoring of the wound healing phase based on changes in pH and inflammatory protein concentrations such as C-reactive protein (CRP). Sensing criteria include the use of flexible swelling hydrogels in response to environmental changes, and the use of usable surfaces that precisely identify the target protein[8].This analysis gives an overview of the developments in microfluidic testing tools focused on the thread in a variety of applications. This starts with an overall production overview accompanied by an in-depth review of the identification methods used in such systems and different implementations in terms of the initiative and results to date. A couple of thread-based microfluidics viewpoint ways are also explored in its growth[9].

SENSORS USED

Temperature Sensor:

Flexible colorimetric and electrochemical temperature monitors, close to pH sensors, is commonly used in biomedical applications. The most common type of flexible temperature sensors are the micro fabricated metallic resistive sensors. An example of this was produced from micro fabricated temperature sensor arrays for skin temperature monitoring of cutaneous wounds. The conductive lines were stretchable and built on a transparent substratum, which could create a con-formal skin contact. The interface was incorporated and could provide a diagram of the distribution of temperature in the wound field.

Oxygen Sensor:

One research produced a lightweight and wearable smart bandage to track the wound bed in real time with a personalized oxygen sensor from off - the-shelf electronic parts. The oxygen sensor was designed to a transparent parylene C substrate using an electrochemical galvanic cell. Silver and electroplated zinc electrodes functioned in this device as the cathode and anode, respectively. This device was checked on a wound condition simulator rig[10].

Moisture Sensor:

In a prominent report, electrochemical sensors underneath the dressings were used to track the moisture level at the time of bandage change. The results showed that more than 40 percent of changes in dressing occurred prior to the optimal time, indicating the need to improve current clinical protocols.

Mechanical and electrical sensors:

Sensors capable of measuring the rigidity and impedance of the skin or wound provides important data on the conditions of the tissue. Impedance spectroscopy utilizing versatile electrode arrays was used in a prominent analysis to determine the state of the skin and the initiation of skin damage in reaction to excessive pressure.

CONCLUSION

Chronic wounds are a major health-care issue. For increasing numbers of patients for diabetes, the incidence of diabetic wounds and ulcers would likely increase. It is also expected that numbers of burns, PUs, and other wounds will grow, particularly in elderly populations. Changes in living standards have affected healthcare products and their goals in developed countries. Therefore, significant efforts have been made to create more successful treatments for managing various types of wounds. These activities contributed to the discovery of growth factors, enzymes, and medications that could enhance or modulate physiological processes that influence wound healing.In fact, different drug delivery methods were established and perfected to bring the therapeutics to the wound bed more efficiently. Nonetheless, recent developments in the field of flexible and wearable electronics have allowed a new class of dressings to be developed that actively help in understanding wound condition or tissue healing intervention. Though these dressings offer important wound status details, they do not target specific markers.One area which significantly improve the sector is the creation of wearable biosensors capable of detecting proteins and antigens in the wound bed.

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Given that contamination is a critical problem in wound care and can even lead to life-threatening situations, it would be extremely valuable to have devices that directly measures the bacterial load.

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