

Smart Bandages with Real-time Wound Monitoring Capabilities

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Introduction

Wound healing is a complex biological process that requires precise monitoring to ensure effective treatment and to prevent complications such as infections or delayed healing. Traditional wound care methods, while effective, often lack the ability to provide real-time feedback on the wound's status, which can lead to suboptimal treatment and longer recovery times. Recent advancements in biomedical engineering have introduced a new class of wound care products: smart bandages. These innovative dressings are integrated with sensors and electronics that enable continuous monitoring of wound conditions, such as temperature, pH, moisture levels and infection biomarkers. Smart bandages represent a breakthrough in personalized healthcare, offering the potential to revolutionize the way wounds are treated. By providing real-time data on the wound environment, these bandages enable healthcare providers and patients to make informed decisions about treatment, thereby improving healing outcomes. With the integration of wireless communication, smart bandages can transmit real-time data to mobile devices or healthcare providers, making them especially valuable in the management of chronic wounds, such as diabetic ulcers, pressure sores and burns. As research in this field continues to progress, the development of smart bandages with advanced monitoring capabilities is poised to play a key role in improving wound care, patient comfort and clinical outcomes [1].

Description

Wound care has long been an essential component of medical treatment, but the traditional methods of managing wounds often fall short in providing real-time insight into the healing process. While conventional bandages are effective at protecting wounds from external contaminants and promoting healing, they offer limited capacity to assess the condition of the wound throughout its recovery. For patients with chronic wounds, such as diabetic ulcers, pressure sores, or burns, the slow and sometimes complicated healing process necessitates frequent check-ups and interventions. In many cases, healing is delayed due to complications like infection or improper moisture balance, which can only be detected through regular visits to healthcare providers or invasive procedures. To address these issues, a new class of wound care technology has emerged; smart bandages. These advanced dressings, equipped with sensors and electronic components, allow for continuous, real-time monitoring of the wound environment. Smart bandages represent a major breakthrough in wound care, as they enable healthcare providers and patients to track the progress of wound healing without the need for frequent dressing changes or invasive assessments. By monitoring parameters such as temperature, pH, moisture levels and the presence of infection biomarkers, these bandages offer a level of insight that was previously impossible with traditional wound care

products. Real-time monitoring enables earlier detection of complications, such as infections or inadequate moisture levels and allows for more precise, data-driven treatment adjustments [2].

Smart bandages integrate various sensors that measure physiological parameters critical to wound healing. These sensors are capable of continuously collecting data from the wound site, which is then transmitted to external devices such as smartphones, tablets, or computers. This information allows healthcare providers to remotely monitor the wound and make informed decisions about the patient's care. For instance, the temperature of the wound is an important indicator of healing progress. A rise in temperature can signal infection or increased inflammation, which may require immediate attention. Similarly, pH levels in the wound are an important diagnostic tool. A decrease in pH could indicate the presence of infection, while an alkaline pH might be a sign of poor healing or necrotic tissue. Smart bandages equipped with pH sensors can detect these changes and provide alerts to healthcare providers, enabling them to respond quickly to prevent further complications. Moisture levels are another key factor in wound healing. Both excessive moisture, which can cause skin maceration and increase the risk of infection and inadequate moisture, which can slow healing and impede cell migration, must be carefully controlled. Smart bandages that monitor moisture levels help ensure that the wound remains in an optimal healing environment. These bandages can detect when the moisture level falls outside the ideal range, allowing healthcare providers to adjust treatment protocols accordingly [3].

One of the most important features of smart bandages is their ability to detect infection early. Infection is a common complication in wound healing, particularly for patients with compromised immune systems, such as those with diabetes. Traditional methods of detecting infection, such as bacterial cultures, can take several days to yield results. By the time an infection is diagnosed, it may have already spread, complicating treatment and prolonging recovery. Smart bandages can be designed to detect biomarkers of infection, such as specific bacteria or inflammatory molecules, providing real-time feedback on the wound's status. This early detection capability allows for faster treatment, which can help prevent the spread of infection and improve healing outcomes. Smart bandages are designed to be minimally invasive and easy to use. Once applied to a wound, the bandage collects data continuously, without requiring frequent removal or manipulation. The sensors integrated into the bandage convert the collected data into electronic signals, which are then transmitted wirelessly to a mobile app or healthcare provider's monitoring system. This allows patients and medical professionals to stay informed about the wound's condition without needing to perform routine dressings or invasive testing. Wireless communication is especially useful for patients who are being cared for at home, as it allows them to be monitored remotely without the need for frequent in-person visits [4].

One of the most significant advantages of smart bandages is the improvement in patient comfort and convenience. Traditional wound care often requires frequent dressing changes, which can be painful, especially for patients with large or chronic wounds. Smart bandages reduce the need for these frequent changes, as they provide real-time data on the wound's condition. This means that healthcare providers can monitor the wound's progress and only intervene when necessary, minimizing discomfort and preventing additional damage to the healing tissue. It also reduces the need for

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in-person visits, making wound care more efficient and cost-effective. Healthcare providers can monitor patients remotely, which is especially beneficial for patients with chronic wounds who require long-term care. By receiving timely alerts about any changes in the wound's condition, providers can intervene early, preventing complications such as infections or delayed healing. The ability to monitor chronic wounds remotely is especially valuable for patients with conditions like diabetes, where chronic ulcers are a common issue. These wounds often require long-term management and early intervention is key to preventing more serious complications, such as amputations. Smart bandages help to bridge the gap between the patient's home care and clinical supervision, ensuring that healthcare providers have constant access to important wound data without the need for frequent office visits [5].

Conclusion

In conclusion, Smart bandages that can monitor wounds in real time represent a significant advancement in wound care technology. By continuously monitoring key factors like temperature, pH, moisture and infection biomarkers, these bandages provide healthcare providers with valuable insights that can improve treatment outcomes and reduce complications. While challenges remain in terms of cost, standardization and sensor reliability, the potential benefits of smart bandages are clear. As the technology continues to evolve, these bandages are poised to play a crucial role in the future of wound management, offering more efficient, comfortable and effective care for patients with a wide range of wound types.

Acknowledgment

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Conflict of Interest

None.

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