Multifunctional smart nanostructured platforms for light-triggered wound healing polytherapy

ABSTRACT FOR THE GENERAL PUBLIC

The skin is the largest organ of the body and its main function is to behave as a protective barrier to preserve body fluid homeostasis, thermoregulation, and to protect against infection from external attacks. Skin injuries must be quickly and efficiently repaired, because damage to the skin results ruptures through which pathogens can enter to cause inflammation, infection, and loss of tissue fluids.

A wound is a damage of normal anatomic structure and function, which results from epidermal layer breaching, which provokes the exposure of the underlying dermis to air. If a wound is caused on the body, the body responds to such a damage through a well-organized series of complex biological and molecular processes called the healing process and the healing mechanism can be divided into a few overlapping phases. Generally, the initial responses are similar but the subsequent actions depend on the type of tissue as well as the damage level.

In practice, wounds are daily faced by doctors and healthcare workers. One of the major challenges faced by surgeons is the improvement of wound healing. The most common therapies include adequate surgical debridement, effective antibiotic therapy, proper moist dressings, and correction of metabolic abnormalities. The entire wound healing process's complexity made it a hot point of different research disciplines, including material sciences.

Nanomaterials are promising candidates for supporting the wound restoration process. Anyway, considerable effort is required to develop nanomaterial-based treatments. It is believed that the development of the next generation of biomaterials will overcome the clinical challenges and offer a more effective approach for wound healing. The deeper understanding of the wound injuries and their recovery mechanism allowed the design of more efficient wound dressing materials.

The development of bionanomaterials is a relatively new field of research in the wound dressing area. Material scientists, immunologists, biologists, surgeons, and computer scientists are closely collaborating. Their efforts are leading in new bionanomaterials, new nanotechnologies, and related methods that are emerging daily and will lead to the rapid development of nanomedicine to the benefit of patients.

The biological activities connected with wound healing are extremely varied, complex and dependent on several factors, therefore biological processes related to every wound area and structure are changing over time. This fact highlights how the currently used biomaterials, which are divided in hermetic categories, cannot be used to cover all the activities related to the host tissue repair process. Up to now, biomaterials have been successfully used to face problems without considering the mutability of the biological tissue's activities and needs over time. Scientists have been trying to mimic the multifunctional behavior of natural biological structures during the last few years. To overcome these issues, a novel class of materials capable of treating the injury with different therapeutic strategies is needed. Moreover, the possibility of triggering a single therapeutic process on-demand at a well-defined place and precise time is a key factor in developing an ideal biomaterial for wound healing treatments.

This research aims to design, develop, and test the applicability of hydrogel-based nanocomposite materials for wound healing application, having unique optical, mechanical and chemical properties merged with biocompatibility and responsivity to external stimulation. The novel nanoplatforms fabricated during the project will have the ability to merge a few targeted therapeutic strategies (e.g. photothermal, chemo- and RNA therapy) in one single nanostructured material. Moreover, due to external stimuli' responsivity, the nanostructured hydrogel can be activated to enhance the therapeutic effect, allowing an on-demand spatial and temporal control of the treatments.

The proposed bioactive nanomaterials will be created using an innovative method capable of producing materials responsive to light. The hydrogel nanomaterials based on nanofibers and nanoparticles will be extremely soft and biocompatible. The nanostructured platform will be able to efficiently deliver different bioactive molecules (e.g. anti-inflammatory drugs and microRNA) and kill bacteria on-demand to accelerate the healing process of the wounds and avoid any source of contamination in the treated area.

The development of the proposed light-triggered multifunctional nanofibrous hydrogel platform for wound healing will bring enormous advantages to patients and will open up great opportunities for other innovative and advanced medical applications. The nanostructured platform will be studied with all the necessary methods to prove their outstanding properties and allow the needed features necessary for the emerging biomedical applications. Furthermore, it is expected that the developed nanomaterials will be applied in different fields such as smart sensors, photonic, photovoltaic, and energy storage.