"Green" Bioactive Dual-Layer Dressing for Controlled Neurotrophin and Analgesic Release to Support Nerve Regeneration in Carpal Tunnel Syndrome

Carpal Tunnel Syndrome (CTS) is one of the most common compression neuropathies, affecting even 5% of the population. Although surgical decompression of the median nerve effectively relieves symptoms, for many patients the healing process is prolonged and painful, and nerve regeneration remains incomplete. Currently, there is a lack of surgical dressings that simultaneously support nerve regeneration, relieve pain, and protect the wound from infections. The aim of this project is to develop a modern, smart, dual-layer dressing that fulfills all three functions.

The project involves creating a bioactive dressing composed of two functional layers, each playing a distinct therapeutic role:

The inner layer will be made of hydrogel—a soft, flexible polymeric material largely composed of water. Thanks to its structure, hydrogels can absorb and retain fluids while being gentle to tissues. These properties make them suitable for applications such as wound treatment, drug delivery systems, and medical materials supporting the regeneration of the body. Moreover, some polymers forming hydrogels can exhibit natural antibacterial properties. This layer will contain substances that promote nerve regeneration. Its role will include the long-term, passive release of neuroregenerative factors, creating a moist environment conducive to wound healing, and providing antibacterial protection.

The outer layer will be created from a different polymer using the electrospinning technique. This method allows for the production of long and thin fibers with diameters in the nanometer scale. These nanofibers will contain an analgesic drug and will be designed to release it in a controlled manner upon light stimulation, providing rapid, localized "on-demand" pain relief without interfering with the function or stability of the inner hydrogel layer.

The research will include the synthesis and characterization of each layer independently, followed by their integration into a single therapeutic system and *in vitro* validation (*i.e.*, in a controlled laboratory environment). The studies will assess, among others, morphology, internal structure, mechanical properties (compression or tensile strength), drug release profile, biocompatibility, neuroregenerative and antibacterial activity, and the nanofibers' response to radiation. The goal is to achieve a synergistic effect that supports nerve regeneration, reduces the need for oral pain medications, and minimizes the frequency of dressing changes for wound disinfection. This approach will help limit common postoperative complications.

The project is distinguished by its use of "green chemistry" (biocompatible and biodegradable materials and mild synthesis conditions), diverse therapeutic mechanisms of action, and responsiveness to external stimuli such as radiation. This is a pioneering approach—previous solutions have primarily focused on individual functions (*e.g.*, nerve regeneration or pain relief) rather than integrating them into one bioactive dressing.

The expected outcome of the project is the development of an innovative therapeutic platform that can be applied not only in the treatment of CTS but also in other peripheral neuropathies and hard-to-heal surgical wounds. This solution has the potential to improve patients’ quality of life, accelerate their return to professional activity, and reduce healthcare costs. The project also holds strong potential for publication in high-impact scientific journals and presentation at international conferences.