Nature-inspired conductive and bioadhesive kirigami-based nanoarchitectured cardiac patch for combined chemo- and stem cell therapy

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The cardiovascular system, also called the circulatory system, is a complex network of organs and tissues responsible for transporting blood, oxygen, nutrients, hormones, and waste products through the body. The circulatory system plays a central role in supporting the functionalities of living tissues and organs. The cardiovascular system is primarily composed of different parts, including the heart, blood vessels, and blood. The heart is the most important organ of the circulatory system, which is responsible for pumping blood, nutrients, and oxygen throughout the body.

The main cardiovascular system functions are transporting oxygen and nutrients (pumping oxygenated blood from the lungs to the body's tissues), removing waste products (pumping deoxygenated blood to the lungs for oxygenation and removal of carbon dioxide and other waste products), regulating the temperature (distributing heat using blood as a vector); and maintaining pH and electrolyte balance (by pumping blood into the target tissues). The appropriate working of the cardiovascular system is indispensable for overall health. Disorders of the cardiovascular system, such as heart disease, hypertension, and stroke, can have severe consequences and may require medical intervention.

Cardiovascular diseases (CVD) refer to a class of illnesses that encompass the heart or blood vessels. These diseases are statistically the leading cause of morbidity and mortality worldwide. Several risk factors have been determined as very influential on the triggering of CVD, such as age, gender, high blood pressure, smoking, high cholesterol levels, diabetes, obesity, lack of physical activity, and abuse of alcohol. Therefore, preventive measures, including implementing a healthy lifestyle, exercising regularly, having a healthy diet, and avoiding tobacco, play a vital role in evading the severe consequences of CVD. Early detection and management of circulatory system conditions also play a crucial role in preventing these diseases. Anyway, even if the population is completely conscious of these notions, CVD remains the first cause of mortality in high-income countries like Poland. Among the whole list of CVDs, myocardial infarction remains the most lethal as well as the most impactful from the societal and economic point of view (as it severely influences the public health system).

A myocardial infarction, also known as a heart attack, occurs when blood flow to a part of the heart muscle is blocked, usually by a blood clot. The lack of blood flow denies the affected area of oxygen, and if the blood flow is not restored promptly, that part of the heart muscle begins to die. Healing the heart after a myocardial infarction is a complicated task, which is still a challenge for material engineers working in the field of biomaterial development as well as biologists and doctors, as it is well-known that medical approaches based on a single therapy are not efficient in appropriately curing infarcted hearts.

This research aims to design, develop, and test the applicability of innovative hierarchically structured nanocomposite materials that can be used as an implantable cardiac patch for myocardial infarction treatment. The novel nanoplatforms fabricated during the project can merge a few targeted biomedical strategies (e.g., chemo- and stem cell therapies) in one single nanostructured biomaterial. The outstanding functional biomedical-oriented features of the developed cardiac patch are reached thanks to its unique electrical, morphological, structural, and chemical properties merged with biocompatibility and the ability to deliver multiple advanced drugs directly. The proposed advanced cardiac patch will be fabricated using an innovative method capable of producing nanostructured platforms based on polymeric nanofibers, hydrogels, conductive polymers, and bioactive molecules.

The fabrication of the proposed multifunctional cardiac patch will open the way to developing a brand-new biomedical approach to treating myocardial infarctions. Furthermore, our nanostructured platform can find applications in several other emerging areas, including biosensors, biointerfaces, transdermal drug delivery, photovoltaic, energy storage, and actuators.