Dually porous glass shows promise in helping damaged bone regenerate

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Victims of osteoporosis and broken bones may get a boost from a new type of biocompatible glass that shows promise in helping damaged and diseased bone to regenerate, says an international team of researchers.

The specially fabricated glass, like the spongy interior of bone, contains interconnected pores that facilitate vascularization, the production of bone cells and the flow of blood and nutrients to all areas of the diseased or damaged bone.

The glass is porous at two scales, containing nanopores that measure up to 20 nanometers in diameter and macropores measuring 100 microns or wider. One nm equals one one-billionth of a meter, while one micron equals one one-millionth of a meter.

The dual porosity and the pores' interconnectedness, say the researchers, enable the glass to mimic bone's two vital functions. The nanopores facilitate cell adhesion and crystallization of bone's structural components. The macropores allow bone cells to grow inside the glass and to vascularize, or form new blood vessels and tissue.

The international team contains researchers from Lehigh and Princeton Universities in the U.S., the University of Alexandria in Egypt, and the Instituto Superior Tecnico in Portugal, as well as from Senegal. It is headed by Himanshu Jain, director of the Lehigh-based International Materials Institute for New Functionalities in Glass (IMI-NFG), which is supported by the National Science Foundation.

Jain notes that the ideal treatment for diseased or damaged bone is to coax the body's natural bone tissue to regrow. Doctors have learned to do this by taking a bone graft from one part of a person's body and using it as a "scaffold" to stimulate bone tissue elsewhere to regrow. Likewise, biocompatible glasses have been used as bone transplants.

Until now, however, no one has succeeded in using glass as a bone scaffold.

The Lehigh-led research team says dual porosity will help its glass behave as an effective scaffold for bone regrowth.

"The aim of our project was to create nano- and macroporosity in a bioactive material while achieving mechanical properties that match those of bone," says Ana Marques, a research scientist at the Instituto Superior Tecnico who used a variation of a wet-chemistry technique to prepare the dually porous glass.

"We believe our material will stimulate bone regeneration because cells will proliferate inside the scaffolding material and form tissues, thus facilitating the delivery of nutrients to regenerating bone tissue."

Mohamed Ammar, a dentist and research scientist in the tissue-engineering lab at Alexandria's Faculty of Dentistry, says the glass will induce proliferating cells in the regenerating bone to form a "matrix" around the scaffold.

"When you attach the glass to the damaged bone, a layer forms on the surface of the glass that has the same chemical composition as the natural bone. The bone cells come to this layer and attach to it, in effect forming a bone matrix around the glass."

The new material has been successfully tested in laboratory experiments.

Ammar is now supervising in vivo tests in Alexandria.

The idea for the project originated two years ago when Jain traveled to Alexandria to meet with Mona Marei, director of the tissue-engineering lab at Alexandria's Faculty of Dentistry.

Jain and Marei discussed a medical problem that is widespread in Egypt, especially among women – the deterioration of people's teeth and jawbones. Marei told Jain that osteoporosis was causing the bone around people's teeth to weaken, making it difficult for doctors to replace loosening or diseased teeth with prosthetics or implants and, in severe cases, causing fractures that required removal of bone and teeth.

Marei said she had tried without much success to replace the damaged teeth and bone with existing biocompatible glass bone transplants.

Jain consulted with Rui Almeida, professor of materials science and engineering at the Instituto Superior Tecnico and visiting professor at the IMI-NFG. Marques began experimenting with the sol-gel process, a technique that uses relatively low temperatures to prepare glass. The process inherently promotes nanoporosity; to achieve interconnected macroporosity, Marques added a polymer to the sol-gel solution.

The polymer caused a phase separation to occur parallel to the sol-to-gel transition and also enabled Marques to overcome a simple law of thermodynamics, says Jain.

"Thermodynamically, the coexistence of nanopores and macropores is unstable in that the larger pores should absorb the smaller pores," he says. "But with Ana's help, we have developed a material that defeats that expectation."

Marques has produced glass with nanopores measuring 5 to 20 nm in diameter and macropores measuring more than 100 microns across, or roughly 10,000 times the size of the nanopores.

In a related project, other researchers at Lehigh's IMI have refined the traditional melt-quench glass-making technique to produce glass that is both nano- and macroporous. A team led by Hassan Moawad, a member of the materials science faculty at Alexandria, achieved the dual porosity by developing an effective combination of silicon, calcium, phosphorous and boron oxides in the powders that are melted to make glass. The researchers also used a chemical treatment to etch the glass and induce the desired porosity.

Jain's group at Lehigh is continuing to investigate the fabrication process, mechanical properties and bioactivity of the new materials. Another Lehigh group, led by Prof. Matthias Falk of biological sciences, is measuring the responses of cells that interact with the glass materials.

Source: Lehigh University

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