New composite nanofibers next chapter in orthopaedic biomaterials

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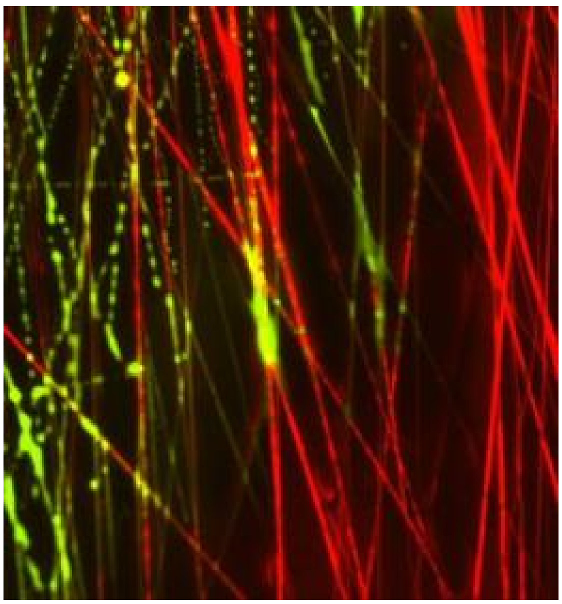

This shows the dynamic transition in a fibrous biomaterial composed of tunable fractions of structural (red) and water-soluble, sacrificial (green) electrospun polymeric nanofibers. The image was captured as fluid entered from right to left, dissolving sacrificial fibers and creating a more open fibrous network. Credit: Brendon M. Baker, Ph.D.; Perelman School of Medicine, University of Pennsylvania

Bioengineered replacements for tendons, ligaments, the meniscus of the knee, and other tissues require re-creation of the exquisite architecture of these tissues in three dimensions. These fibrous, collagen-based tissues located throughout the body have an ordered structure that gives them their robust ability to bear extreme mechanical loading.

Many labs have been designing treatments for ACL and meniscus tears of the knee, rotator cuff injuries, and Achilles tendon ruptures for patients ranging from the weekend warrior to the elite Olympian. One popular approach has involved the use of scaffolds made from nano-sized fibers, which can guide tissue to grow in an organized way. Unfortunately, the fibers' widespread application in orthopaedics has been slowed because cells do not readily colonize the scaffolds if fibers are too tightly packed.

Robert L. Mauck, PhD, professor of Orthopaedic Surgery and Bioengineering, and Brendon M. Baker, PhD, previously a graduate student in the Mauck lab at the Perelman School of Medicine, University of Pennsylvania, have developed and validated a new technology in which composite nanofibrous scaffolds provide a loose enough structure for cells to colonize without impediment, but still can instruct cells how to lay down new tissue. Their findings appear online this week in the Proceedings of the National Academy of Sciences.

"These are tiny fibers with a huge potential that can be unlocked by including a temporary, space-holding element," says Mauck. The fibers are on the order of nanometers in diameter.

Using a method that has been around since the 1930s called electrospinning, the team made composites containing two distinct fiber types: a slow-degrading polymer and a water-soluble polymer that can be selectively removed to increase or decrease the spacing between fibers. The fibers are made by electrically charging solutions of dissolved polymers, causing the solution to erupt as a fine spray of fibers which fall like snow onto a rotating drum and collect as a stretchable fabric. This textile can then be shaped for medical applications and cells can be added, or it can be implanted directly -- as a patch of sorts -- into damaged tissue for neighboring cells to colonize.

Increasing the proportion of the dissolving fibers enhanced the ability of host cells to colonize the nanofiber mesh and eventually migrate to achieve a uniform distribution and form a truly three- dimensional tissue. Despite the removal of more than 50 percent of the initial fibers, the remaining scaffold was a sufficient architecture to align cells and direct the formation of a highly organized extracellular matrix by collagen-producing cells. This, in turn, led to a biologic material with tensile properties nearly matching human meniscus tissue, in lab tests of tissue mechanics.

"This approach transforms what was once an interesting biomaterials phenomenon -- cells on the surface of nanofibrous mats -- into a method by which functional, three-dimensional tissues can be formed," says Mauck.

It is a marked step forward in the engineering of load-bearing fibrous tissues, and will eventually find widespread applications in regenerative medicine, say the authors.

Mauck and his team are currently testing these novel materials in a large animal model of meniscus repair and for other orthopaedic applications.

Provided by University of Pennsylvania School of Medicine

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