

# Researchers coat titanium with polymer to improve integration of joint replacements

July 1 2008

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Research at the Georgia Institute of Technology shows that coating a titanium implant with a new biologically inspired material enhances tissue healing, improves bone growth around the implant and strengthens the attachment and integration of the implant to the bone. Georgia Tech Photo: Gary Meek

Research at the Georgia Institute of Technology shows that coating a titanium implant with a new biologically inspired material enhances tissue healing, improves bone growth around the implant and strengthens the attachment and integration of the implant to the bone.

"We designed a coating that specifically communicates with cells and we're telling the cells to grow bone around the implant," said Andrés García, professor and Woodruff Faculty Fellow in Georgia Tech's Woodruff School of Mechanical Engineering and the Petit Institute for Bioengineering and Bioscience.

Details of the new coating appear in the July issue of the journal *Biomaterials*. The research was supported by the National Institutes of Health, the Arthritis Foundation and the Georgia Tech/Emory National Science Foundation Engineering Research Center on the Engineering of Living Tissues.

Total knee and hip replacements typically last about 15 years until the components wear down or loosen. For many younger patients, this means a second surgery to replace the first artificial joint. With approximately 40 percent of the 712,000 total hip and knee replacements in the United States in 2004 performed on younger patients 45-64 years old, improving the lifetime of the titanium joints and creating a better connection with the bone becomes extremely important.

Current clinical practice includes roughening the surface of the titanium implant or coating it with a flaky, hard-to-apply ceramic that bonds directly to bone.

In collaboration with Georgia Tech School of Chemistry and Biochemistry professor David Collard, graduate students Tim Petrie and Jenny Raynor, and research technician Kellie Burns, García coated the titanium with a thin, dense polymer.

"Our coating consists of a high density of polymer strands, akin to the bristles on a toothbrush, that we can then modify to present our bio-inspired, bioactive protein," explained García.

In this case, the polymer presented controlled amounts of an engineered protein that mimics fibronectin, a protein in the body that acts as a binding site for cell surface receptors called integrins.

It is important to control the integrins binding to the titanium implant because integrins provide signals that direct bone formation. Therefore, controlling integrin binding to the titanium will result in targeted signals that enhance bone formation around the implant.

To bind integrins to titanium, researchers previously coated titanium with a small biological signal containing the sequence arginine-glycine-aspartic acid (RGD) that binds to integrins. However, this region alone binds many different integrin receptors and with much less affinity than the full fibronectin protein.

"It has been common to mimic only very small sections of fibronectin, but when you take a small section and ignore the rest of the molecule you lose specificity and activity, and therefore signaling is impaired," said García.

For that reason, García engineered a much longer region of the same type of fibronectin that included the RGD peptide sequence as well as new sections also known to have sites that participate in integrin binding.

To evaluate the in vivo performance of the coated titanium in bone healing, chemists Raynor and Collard coated the surfaces of tiny clinical-grade titanium cylinders with the polymer brushes. Then engineers Petrie and García modified them with peptide sequences.

Two-millimeter circular defects were drilled into a rat's tibia bone and the cylinders were pressed into the holes. They tested three types of coatings: uncoated titanium, titanium coated with the RGD peptide and titanium coated with different densities of the engineered fibronectin

fragment.

To investigate the function of these novel surfaces in promoting bone growth, the researchers quantified osseointegration, or the growth of bone around the implant and strength of the attachment of the implant to the bone.

Analysis of the bone-implant interface four weeks later revealed extensive and contiguous bone matrix and a 70 percent enhancement in the amount of contact between the implant and bone with the titanium implants coated with the engineered fibronectin fragment over the uncoated or RGD-coated titanium.

García and Petrie tested the fixation of the implants by measuring the amount of force required to pull the implants out of the bone. The study showed significantly higher mechanical fixation of the implants coated with the engineered fibronectin fragment over the implants with the other coating and uncoated titanium.

In addition to total joint replacements, García is studying how to fill large gaps between bones, which sometimes occur after a traumatic injury or tumor removal.

"We are developing a strategy to present peptides that encourage the surrounding bone to grow in and fill in around the gap," said García.

By improving communication with the body's cells, García can control the integration and healing response of the body to any implanted device. Currently, most become encapsulated by a collagen sheath, which affects the performance and long-term viability of the device. García aims to use these biomaterials to help integrate devices implanted in the body.

Source: Georgia Institute of Technology

Citation: Researchers coat titanium with polymer to improve integration of joint replacements (2008, July 1) retrieved 27 April 2024 from <https://phys.org/news/2008-07-coat-titanium-polymer-joint.html>

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