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Smart implants to provide biofeedback, measure joint loads, detect infection

More research, cost reductions may be needed before these devices become commercial entities.

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While most orthopedic implant developers are focused on improving current technologies, a handful are looking to the future by developing "smart" or "intelligent" orthopedic implants that can provide real-time feedback to researchers, physicians or patients on how the implants are performing, what is happening inside a bone or joint, or if a patient has exceeded the device's optimal range of motion.

Research into smart implants is being conducted worldwide.

"All the major orthopedic manufacturers are working on one or more forms of these smart implants," Javad Parvizi, MD, FRCS, said.

Technological advances

Parvizi, member of *Orthopedics Today*'s Editorial Board, noted, "Smart implants ... go beyond the conventional ones we have right now." They may detect poor bone ingrowth, infection, subsidence or dislocation once an implant is in place.

> "Smart implants ... go beyond the conventional ones we have right now." — Javad Parvizi, MD, FRCS

This is possible through advances in the fields of nanotechnology, acoustics, computers, microchip technology and other areas, Parvizi explained. Researchers used the technology to incorporate added features into conventional implants that address some of these problems when they arise. One use may be detecting problems like vibration around prostheses, which could signal loosening. However Parvizi foresees having a microchip detect the motion and the implant "will give some sort of sign and will alert the patient or the surgeon there's a problem."

Parvizi and colleagues at the Rothman Institute in Philadelphia are developing a hip prosthesis with a smart anti-infective surface.

Image: Parvizi

"We have put smart bombs on the surface ... that will recognize the infective organisms in the vicinity and then will cleave or will deliver the antibiotic to the organisms," he said.

Javad Parvizi, MD, FRCS, said his research into smart implants for tackling periprosthetic infections was challenging from the start, from defining what normal pH is during healing to developing a novel rat periprosthetic model.

Antibiotics start working when they recognize an organism following a drop in pH of the peri-prosthetic chemical environment.

But another promising approach is a physical/chemical barrier, where researchers charge the implant surface to repel organisms that try to attach to it, a strategy they've worked on just a few months.

"Hopefully in the next year or two this will become a reality," Parvizi said. "Our animal experiments so far are encouraging."

Despite the promise of smart implant technology, researcher Georg Bergmann, PhD, of Berlin, remains critical of the field. He is doubtful any of the products he has researched, which measure forces on knee, shoulder and hip joints and the spine, will be commercially available anytime soon.

"It is expensive. You need educated personnel for making the measurements. Interpretation of the measurements may be difficult, depending on the settings and on several factors," Bergmann told *Orthopedics Today*.

He also wonders who will pay for follow-up visits should a doctor want to send errant signals about polyethylene wear or infection.

Public database

For the last 20 years, Bergmann and colleagues have worked on smart hip prostheses containing a multichannel telemetry system which measures three-dimensional (3-D) forces in the joint and transmits them to a computer. To date, they implanted them in seven patients and the hip force data collected are contained in a publicly accessible database, which is currently active (OrthoLoad.com).

Currently, the group does similar work with shoulder, knee and spine implants. In all they have placed 12 smart implants in patients.

Bergmann and colleague Friedmar Graichen are also studying smart implants that detect friction-caused temperature rises around hip prostheses and instrumented spinal devices that record 3-D loads.

Bergmann believes his research is most useful for: providing realistic load data for testing implants preclinically; educating patients about safe postoperative activities; generating accurate musculoskeletal computer models for calculating internal body loads; and improving surgical techniques.

Added capability

According to Darryl D. D'Lima, MD, PhD, available devices can sense temperature, pH, blood glucose levels and record electrical activity of the heart and joint forces. But to be a truly smart implant, it has to have greater capabilities such as the ability to remotely turn on and off, collect data and be reprogrammed, he told *Orthopedics Today*.

Image: Theken Disc

Developers of the Theken eTibc implant embedded microelectronics in it and designed it with a proprietary polymer.

An orthopedist and engineer at the Shiley Center for Research & Education at Scripps Clinic, La Jolla, Calif., D'Lima has researched smart knee implants for a decade. He envisions applications that benefit patients and industry alike, such as sensors in a hip prosthesis that would indicate it is close to dislocating.

D'Lima, Clifford W. Colwell, Jr., MD, and others at Scripps developed the e-Tibia prosthesis, a total knee arthroplasty tibial component with an internal telemetry system that reports the impact on the knee from playing tennis or running.

"But it is not at the point where it can communicate with the patient. We need [sufficient] power to collect the data and measure the forces before we can tell the patient what the forces are," D'Lima noted.

Colwell recently presented the knee-force data they have tracked thus far in four patients with the prostheses.

Disc electronics

The eDisc implant (Theken Disc LLC), developed by Hanson E. Yuan, MD, and Scot D. Miller, DO, is a titanium lumbar total disc replacement device outfitted with electronic force sensing capabilities. Miller told *Orthopedics Today* the ability to measure whether or not patients were doing anything abnormal would help significantly.

The prosthesis, which is nearing clinical trials, runs on a rechargeable battery. Loads in the spine trigger its optional internal wireless electronics. Data are then captured, stored and analyzed.

Developers anticipate those with an eDisc will wear a beeper-like device that signals when they exceed a recommended load limit. Yuan and Miller implanted the device in Asbourn in 2005 to test its data collection and storage capability.

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- Information on Prof. Bergmann's work can be found at www.julius-wolff-institut.de. The public database can be accessed at OrthoLoad.com.