WALKING PAIN-FREE AGAIN

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The Art of STEM Communication

ORTHOPEDIC DEVICES AND THE MEDICAL INDUSTRY

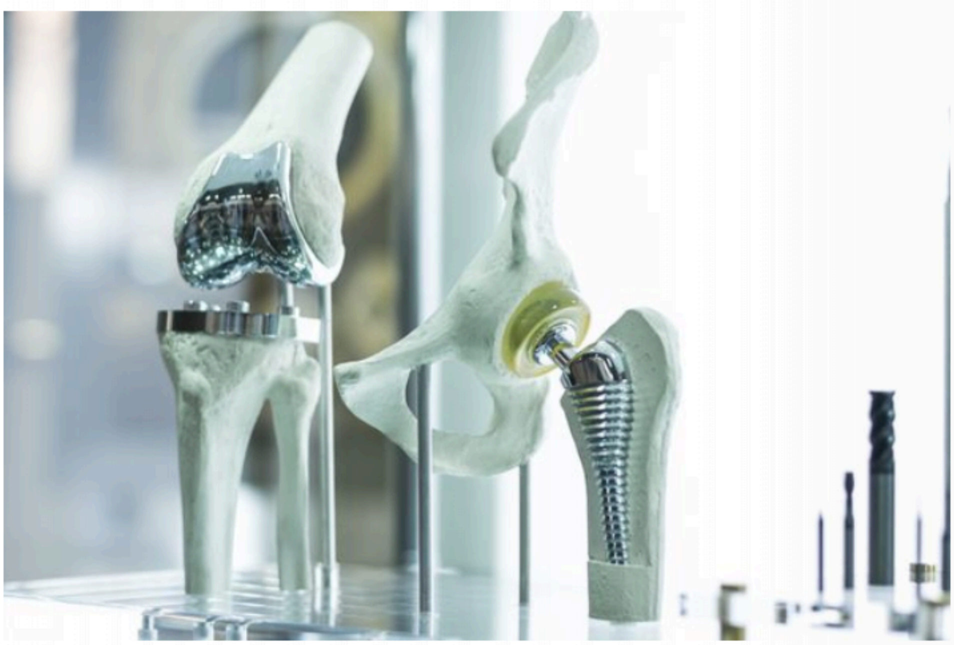
What do Bo Jackson, President George Bush, and Arnold Schwarzenegger all have in common? Artificial joints. They, along with 850 thousand people each year, have undergone hip or knee replacement surgeries, giving them the ability to move freely again.

At UC Berkeley, an interdisciplinary team of engineers from Professor Lisa Pruitt's Medical Polymer Group are working with surgeons to develop novel biomaterials for orthopedic implants. By improving the strength and longevity of the artificial joints, researchers hope that one day knee and hip replacements can be safely recommended to patients of all ages and circumstances.

Professor Lisa Pruitt
(Courtesy of Berkeley Mechanical Engineering Faculty)

As humans age, the joints in the body can wear down due to constant motion. This is especially the case for athletes and heavier individuals, as the force on the joints is much greater. Eventually, the cartilage, or the protective tissue around the joints, can deteriorate. The bare-bones will then begin rubbing against each other, causing extreme pain and rendering simple activities like walking unbearable. To solve this, surgeons rely on replacing the damaged joints with orthopedic implants, commonly known as artificial implants.

According to the American Association of Orthopaedic Surgeons, most people who undergo knee replacement surgery are between the ages of 50 to 80. Data shows most implants to have an 85% chance of lasting for more than 20 years, a key reason that the procedure is safe and effective. Engineers of Berkeley's Medical Polymer Group are finding even newer, better ways to improve the longevity and strength of implants to ensure a pain-free life for patients.



(Courtesy of Medimodel Team)

BIOMECHANICS & KNEE IMPLANT:

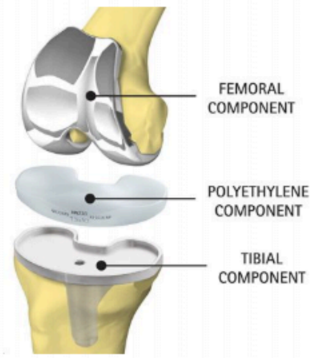


***Figure 1**. Diagram of a total knee components*

Medical implants are designed from materials that work well with the body and are compatible with the living tissues. Ultra-high molecular weight polyethylene (UHMWPE) is the perfect material for manufacturing implants. Polyethylene is a simple yet versatile plastic that can be used to produce grocery bags or spun to make bulletproof vests. Polyethylene is an inert material, which means it causes no reaction with nearby human tissues. This is very important when designing implants, as the material needs to be compatible with the biological system it is interacting with.

The human body contains a complex system of joints and connective tissue, a system that helps inspire ongoing innovation and improvement in the medical field. In the industry of biomechanics—the study of structure and motion of living organisms—Professor Pruitt and student researchers at the Medical Polymer Group are looking to encompass engineering applications and biomaterials knowledge to improve orthopedic implants.

Before knee implants make their way onto the operation table, they start as a powder form of the polymer polyethylene. It is then placed under high pressure and temperature to be compressed into molded blocks. A CNC milling machine then cuts out the tibial inserts, which act as the rotating platforms for joints to move without pain. The patient with severe knee pain would then undergo a knee replacement surgery and regain the ability to walk again. However, how long can this pain-free life last for?

***Figure 4**. UHMWPE block (left) is carved into the tibial insert (right).*

BIOMECHANICS & KNEE IMPLANT:

A knee replacement can help patients regain mobility, yet it is far from durable as a real knee. The plastic used in these implants such as polyethylene degrades just like how the bottom of a pair of sneakers wears out over time. Inside the body, knee implants are placed under stress and fatigue due to the kinematic motions that the joints experience from daily activities such as walking or simply bending your knees to get up.

Typically, implants can last elderly patients for the rest of their lifetime due to limited exercise and light movement. Professor Pruitt explains, "If you take [a knee implant] and put it in a 20-year-old, young and active college student, that is a different story." To put it simply, the younger you are and the more active you are, the more worn out the knee implants will become. These younger patients would often need several revision surgeries during their lifetime, which may come with a lower success rate compared to their initial knee surgery.

The retrieval of the original implant requires additional bone to be carved away to smoothly take out the insert without causing further damage to the knee. This means that the insertion of a new replacement device will be more difficult and complicated due to the increased loss in tissues and bones from the extraction site.

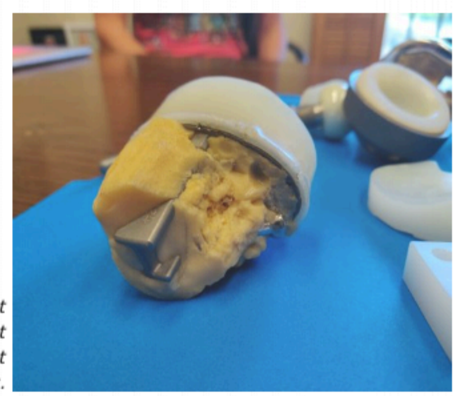


Figure 2. *A retrieved tibial component that shows slight wear damage in vivo. Still intact are the bone fragments that were grafted out from the revision knee replacement surgery.*

Current Technology of Orthopedics Implants

Working from the existing knowledge and testing of polyethylene, Professor Pruitt is exploring better techniques and processes to help make the material last longer inside the body, minimizing the need for revision surgeries. For biological improvement, Pruitt's team is using antioxidant enzymes and vitamins to coat the implants to stimulate host tissue to accept the implants as noninvasive parts and to prevent them from triggering an inflammatory reaction during the healing process.

Pruitt has also created optimal cross-linking patterns to help increase the longevity of implants. The process of cross-linking introduces a bond, sort of like a grappling hook, to connect one polymer chain to another polymer chain so that they are held tightly in place. The research lab saw that cross-linked polyethylene implants have stronger structural integrity than that of conventional polyethylene implants using computerized simulation of joint movement. Thus this ensures that the implants won't deteriorate as quickly as how traditional knee implants would.

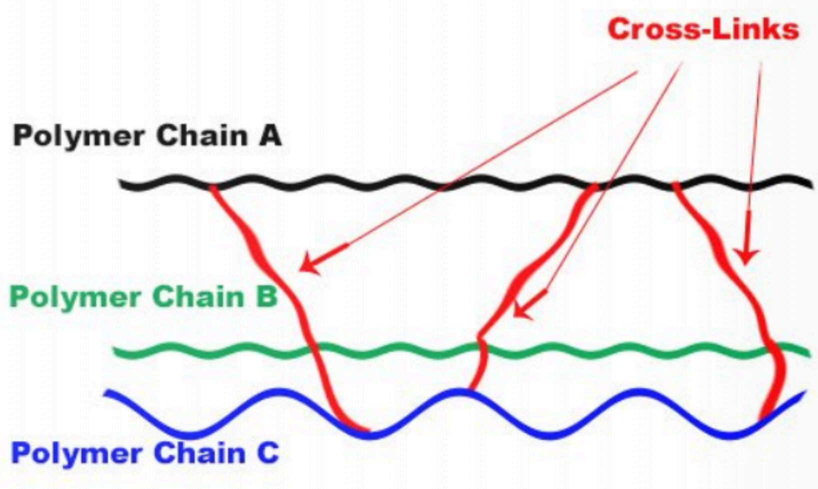


Figure 3. *Demonstration of cross-links connecting a polymer chain to another.*

Ethics and Innovation in Engineering

Quality over Quantity


Unsplash by Diego PH

As the market for knee implants expands to the younger demographics, there is an increasing need for better-lasting and stronger orthopedic devices. Yet when it comes to innovation of biomaterials, no one can reach a definite conclusion on how a new material would behave inside the body without having to put human test subjects at risk. Therefore, Professor Pruitt is very adamant that designers go back and improve their previous work rather than falling into the temptation to push out new and cool innovations that might fail.

When asked about what she envisions for the future of the medical industry, Professor Pruitt highlights the growing market for personalized medicine tailored medical treatments for each patient's needs, which doctors can accurately determine from a simple examination. For example, a computer-aided design (CAD) model can be used to create custom implants best suited for the individual's needs based on an MRI scan using additive manufacturing techniques such as 3D printing.

Personalized medicine

Unsplash by Daniel Frank

The potential for innovations in the medical industry is endless. Professor Pruitt believes that this innovative spirit should be nurtured and pushed at Berkeley. She has designed classes to expose students to the field of biomaterials and collaborated with the Lawrence Hall of Science to introduce kids to medical device technology and engineering.

She wishes for Berkeley engineers to bring their skills and what they've learned into other areas of engineering. And most importantly, she hopes that everyone can put their heart and soul into societal good.

Figure 5*. Materials used for "Body by Design" outreach activities and ME C117 Structural Aspect of Biomaterials*

"I encourage Berkeley students to put in their heart and soul for their talent to be used for societal good."

PROFESSOR LISA PRUITT

Berkeley Engineering