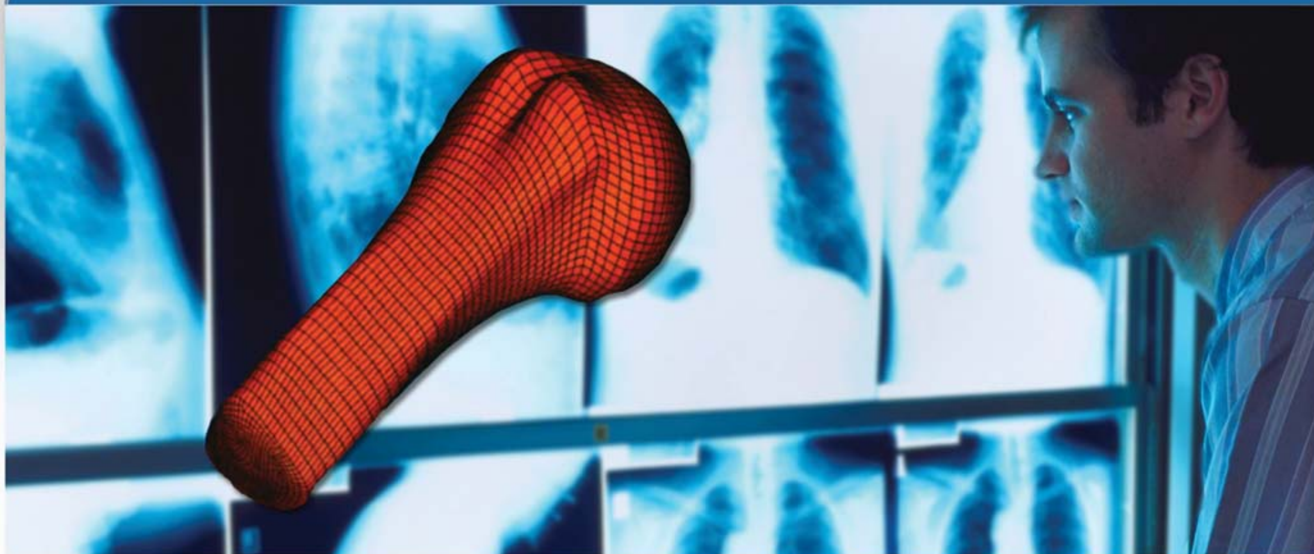
Altair HyperWorks Success Story



THE SCRIPPS RESEARCH INSTITUTE

Biomedical Research at the Scripps Clinic: Modeling Orthopedic Implants with Altair HyperWorks

Altair

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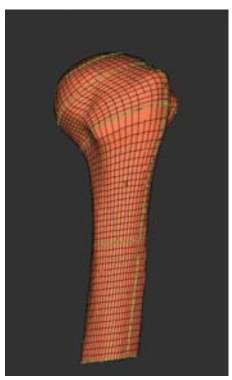
The Engineering Framework for Product Design™

Every year, countless people — regardless of their age or level of physical activity — begin to experience the effects of osteoarthritis, a degenerative joint disease. As we age, the cartilage that cushions the joints begins to deteriorate. The head of the adjacent bones begin to break down from the friction, causing pain in the joint. When the condition worsens and non-surgical remedies are exhausted, surgeons may recommend joint replacement.

Typically, titanium alloy implants are lined with plastics that act as cartilage and are fixed in place with cement or screws by the surgeon. The implants can give patients a new lease on life, dramatically reducing pain and improving mobility. However, questions naturally arise in the patient's mind: How much range of motion will I have in the new joint? How much strength will I recover? And how long will the new joint last?

The Shiley Center for Orthopedic Research and Education (SCORE) at the famed Scripps Clinic in La Jolla, Calif., is using Altair HyperWorks software tools to make it easier to answer questions like these.

CT Scan of a human shoulder

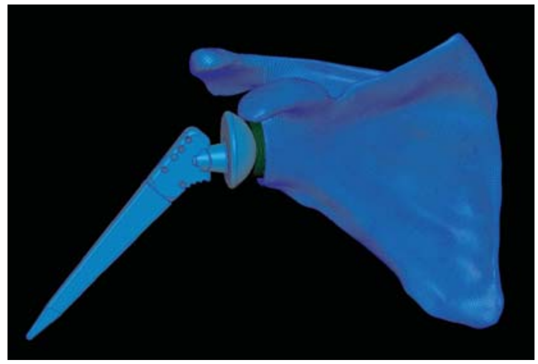


Solid Mesh of the bone, created in HyperMesh

Shoulder Arthroplasty: Modeling Bones and Implants

"Shoulder arthroplasty is a reasonably successful procedure," said Dr. Darryl D'Lima, director of SCORE's Orthopedic Research Laboratory (ORL). "But from an engineering standpoint, it's still poorly understood and [the implant is] poorly designed. The procedure is normally only recommended for patients over 65, because the implant is not expected to last more than 20 years. Now, we're using HyperWorks to get a better understanding of the biomechanics involved in joint replacement.

"We did about 50 computerized tomography (CT) scans of normal shoulders and compared them with 50 scans of shoulder-replacement patients. Now, we want to find out which implant features would be most beneficial in terms of fixation — attachment to the bone — and shoulder function. That's where HyperMesh comes in."



Finite element model of a total shoulder arthroplasty

SCORE scientists use Mimics 3D-image processing software to merge the CT image slices of a patient's shoulder into a 3D volume and export the surface of the bone.

"We take the surface of the bone as the equivalent of CAD geometry," said D'Lima. "Then, we create a solid mesh in HyperMesh and send it back to Mimics. Based on the CT scan — in which bone that is denser and stronger shows up as whiter – Mimics assigns material properties on an element-by-element basis and exports the file back to HyperMesh. We then have a high-fidelity surface with material properties that is unique to the patient."

"As far as I know, HyperMesh is the only program that allows us to mesh complex organic bone surfaces and the CAD surfaces of the implant."

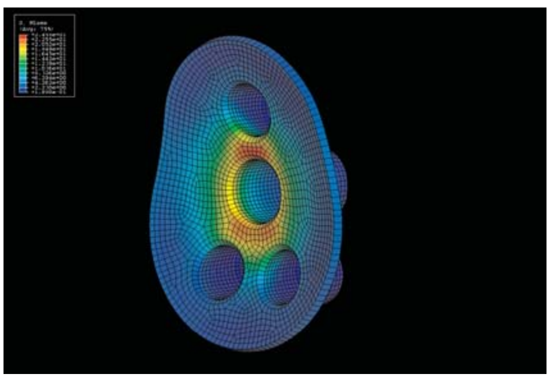
Dr. Darryl D'Lima
Director
SCORE's Orthopedic Research Laboratory (ORL)
Scripps Clinic

Virtual Shoulder Surgery with HyperMesh

Using HyperMesh, the team removes the diseased bone from the model of the patient's shoulder and replaces it with an implant, including the cement that fixes it in position.

"As far as I know," said Dr. D'Lima, "HyperMesh is the only program that allows us to mesh complex organic bone surfaces and the CAD surfaces of the implant. HyperMesh does all the pre- and post-processing. It's the glue between Mimics and our stress analysis solver."

The ORL's work on shoulder replacement is designed to help orthopedic surgeons in three ways. First, it helps surgeons choose the best off-the-shelf implant product for each patient. Second, it helps them refine their surgical techniques. The ORL found, for example, that increasing the thickness of the cement mantle from 0.5mm to a consistent 2.0mm could improve stress distribution and increase the longevity of the implant. The third area of potential improvement is in the area of attachment or fixation. Some implants include screws that are inserted into the bone through a cone that allows up to 30° variation in entry angle.



Von Mises stresses at the surface of the cement layer, which bonds the implant to the bone.

"In the past," said D'Lima, "surgeons would simply insert the longest possible screw into the thickest part of the bone. Now, we can tell them not only where the bone is deepest, but also where it is denser and stronger. They can simulate the procedure in our facility."

A Breakthrough: Modeling a Meniscus

In 2005, Dr. D'Lima and his team were attempting to model replacements for the meniscus, the crescent-shaped knee cartilage that often gets torn. It was a difficult two-week process.

The team made an outline of the meniscus in a modeling package and imported it into a pre-processor. Changes were made on an element-by-element basis before the mesh could be exported into an analysis deck. Each time they wanted to change the curvature or the thickness, the team needed to start the modeling process from scratch.

"Terrence Smith, Altair's Account Manager, told me that HyperMesh could do what we needed in much less time," said D'Lima. "I told him, 'I don't believe you, but here's the meniscus, and here's a picture of what I want it to look like.' Not only did he have to match the shape but the material properties in different directions as well. Orientation of the elements was crucial. Smith turned it around in a day or two. So we went through a few tutorials, and our output was amazing. The fact that we could actually do what we wanted was amazing."

D'Lima now starts with a 3D image of the patient's meniscus, segmented from magnetic resonance imaging (MRI) scans and uses HyperMesh to build a finite-element analysis model of the entire knee. He uses mesh morphing to tweak parameters to determine how changes affect contact stresses. Then, the doctor replaces the meniscus virtually and anchors it with simulated sutures to approximate a normal meniscus. Next step: he uses HyperStudy to run optimizations to see how much he can change shape parameters.

OptiStruct: Modeling a Window of Stress

Today, a great deal of research is focused on developing longer-lasting joint prostheses. But bone strength also affects implant life. If the stress from the implant is too high, it erodes the bone. If the stress is too low, the bone cells are not sufficiently stimulated. The bone cells around them dissolve and the implant loosens. It's a biological process that's very difficult to model. Dr. D'Lima is using Altair OptiStruct to tackle the problem.

"OptiStruct has two functions: topology and shape optimizing," said Dr. D'Lima. "We're playing with both functions to see if we can program an optimal window of stress transfer, modeling the bone as elements and transferring the load to the prosthesis. If we can model this process, we can model an implant, not only in terms of the initial surgical decision, but also in terms of optimum bone response for long-term wear."

All these research paths now being pursued at SCORE's Orthopedic Research Laboratory lead in the same direction: better, longer-lasting implants for patients with degenerative joint disease. HyperWorks has become a key toolset in this work that can affect the quality of life for millions of people every day.

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