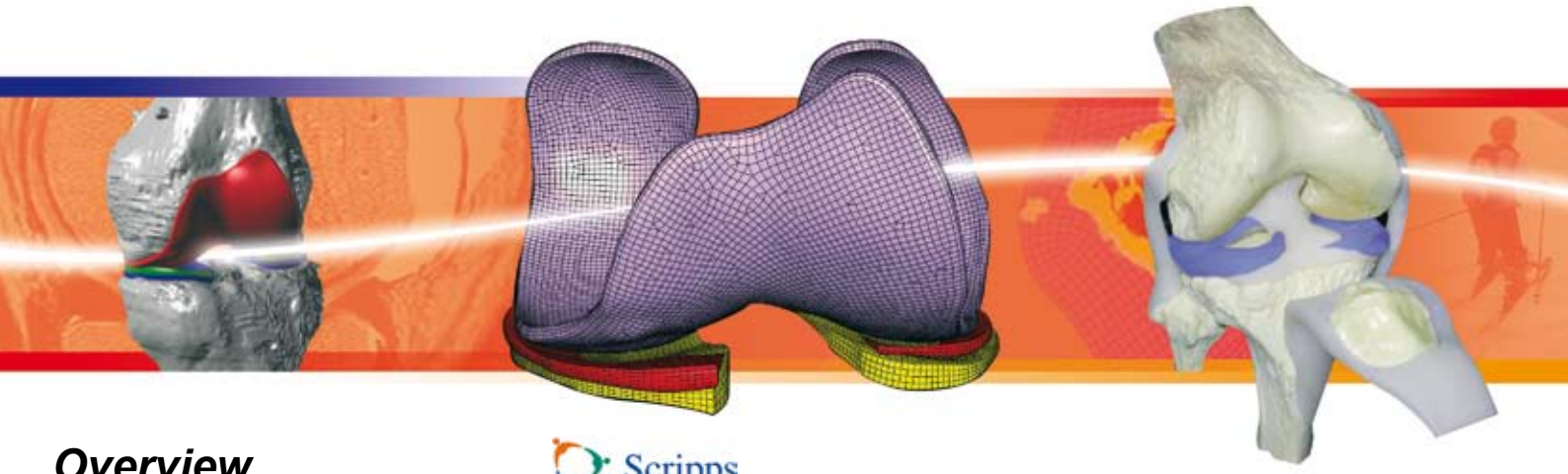
Scripps

Using Abaqus FEA from SIMULIA to probe the biomechanics of knees



Overview

Challenge

The Scripps Clinic in California wanted to give patients with knee injury viable solutions to achieve optimum knee function

Solution

Scripps health researchers use Abaqus FEA from SIMULIA to optimize new designs and explore surgical alternatives

Benefits

Abaqus FEA helps researchers model complex material properties, customize knee replacements to each patient, and optimally position a replacement meniscus in its new knee environment

"Abaqus FEA can represent the complex characteristics of a meniscus and provides the advantage of being able to stack all of the material properties into the same model."

Darryl D'Lima
M.D. Ph.D, laboratory director
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Knees are the body's Achilles heel

The knee is at particular risk for damage, arthritis, or both as we grow older. Mother Nature designed the human knee to last about 30 years, so as life spans across the globe continue to increase, so do the problems associated with knees.

Researchers at the Orthopedic Research Laboratories at the Shiley Center for Orthopaedic Research & Education (SCORE) at Scripps Clinic, a nonprofit, community-based health care delivery network in San Diego, California, are analyzing radio telemetric data sent by tiny computer chip implants added to patients' knees during surgery, which record the stresses on the knee joint during various activities. "It is our goal to study the effects of a whole range of movements on knee health," said Darryl D'Lima, M.D. Ph.D, laboratory director.

Scripps researchers needed to understand and address the problem of damage sustained deep inside the knee to the meniscus. In the past, surgery involved removing all or part of the damaged meniscus only to see patients return years later with osteoarthritis (OA). "If we'd only had finite element analysis (FEA) back then, surgeons would have known that tissue removal was the wrong way to go," said D'Lima. "The meniscus provides load sharing, contact stress amelioration and stability - all of which we can now study with FEA," said D'Lima.

Finite element analysis models the knee

D'Lima's research team is using Abaqus FEA software from SIMULIA to make increasingly complex virtual computer models of human knee components on which they can test a variety of potential replacement parts and surgical techniques.

Some of the data used to set up the FEA models comes from those earlier implant patients. "The sensors in our patients' knees provided us with force measurements that we were able to use as load inputs for our FEA analyses of the meniscus," said D'Lima.

DASSAULT SYSTEMES

MRI and FEA team up to study knee function

Achieving optimum knee function requires matching the size and shape of the replacement to the patient, duplicating its complex material properties and figuring out how to attach it in place. The replacement also has to survive wear and damage over the lifetime of the patient. “For each of these challenges we are finding that FEA, combined with magnetic resonance imaging (MRI), provides the tools we need to study the alternatives.” Design engineers can convert two-dimensional MRI “slices” into stacked, 3D models, which for example detail bone and meniscal cartilage.

Representing complex material characteristics

“The first, and toughest, modeling challenge was representing the material properties of the meniscus accurately since every possible complexity exists within the same material,” said D’Lima. A meniscal model needs to be nonlinear elastic, have plasticity and describe how the material properties change with time. The meniscus also behaves differently in tension than it does in compression, so it’s important to show in which direction the stresses are being applied. “Abaqus FEA can represent every one of these characteristics and it provides the advantage of being able to stack all of the material properties into the same model,” explained D’Lima.

FEA helps evaluate alternative surgical techniques

Another research challenge for the SCORE group was the question of how best to fix a replacement meniscus in place in its new knee environment. Here again FEA provided a useful analysis tool: by incorporating strength and stiffness data from different materials as well as ‘virtual stitches’ into their FEA knee models researchers could study contact stresses. In this way, they were able to get the same mechanical fixation without having to resort to invasive surgery.

Customizing meniscal replacements with optimization software

D’Lima then focused on optimizing knee replacement to each person who needs it by identifying what shape is best for a particular individual, what material properties will work best in that person’s knee, and making recommendations about securing the implant surgically. To generate and explore the algorithms that best describe the ‘perfect’ meniscus for a single patient, D’Lima’s group has recently begun employing SIMULIA’s Isight for simulation process automation and design optimization. “Isight is a very useful tool for customization,” says D’Lima. “We’re using it to optimize the material properties and shape of the meniscus.”

Smart FEA looks promising for future ‘mechanobiology’ research

As to the final question about future wear and damage of any meniscus, original or replacement, D’Lima next is looking to apply Abaqus FEA to “mechanobiology,” the study of how biological tissues respond to mechanical forces. “We want to be able to predict how your meniscus will behave, and how its cells change properties, under different stresses,” said D’Lima. “To model such processes, we are hoping to work with SIMULIA to develop ‘smart’ FEA elements that would both ‘sense’ stresses and change their mechanical properties as a result.”

With the pace of research accelerated by FEA and optimization, should you eventually need a meniscus, or even a whole knee replaced, the technology is on the way to provide you with the most appropriate spare parts possible.

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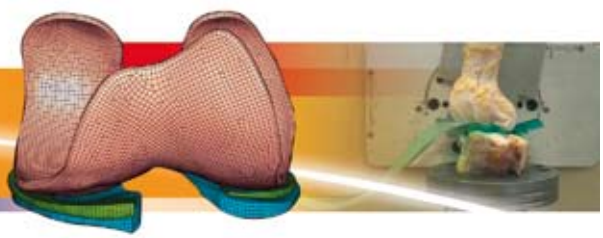
SIMULIA



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