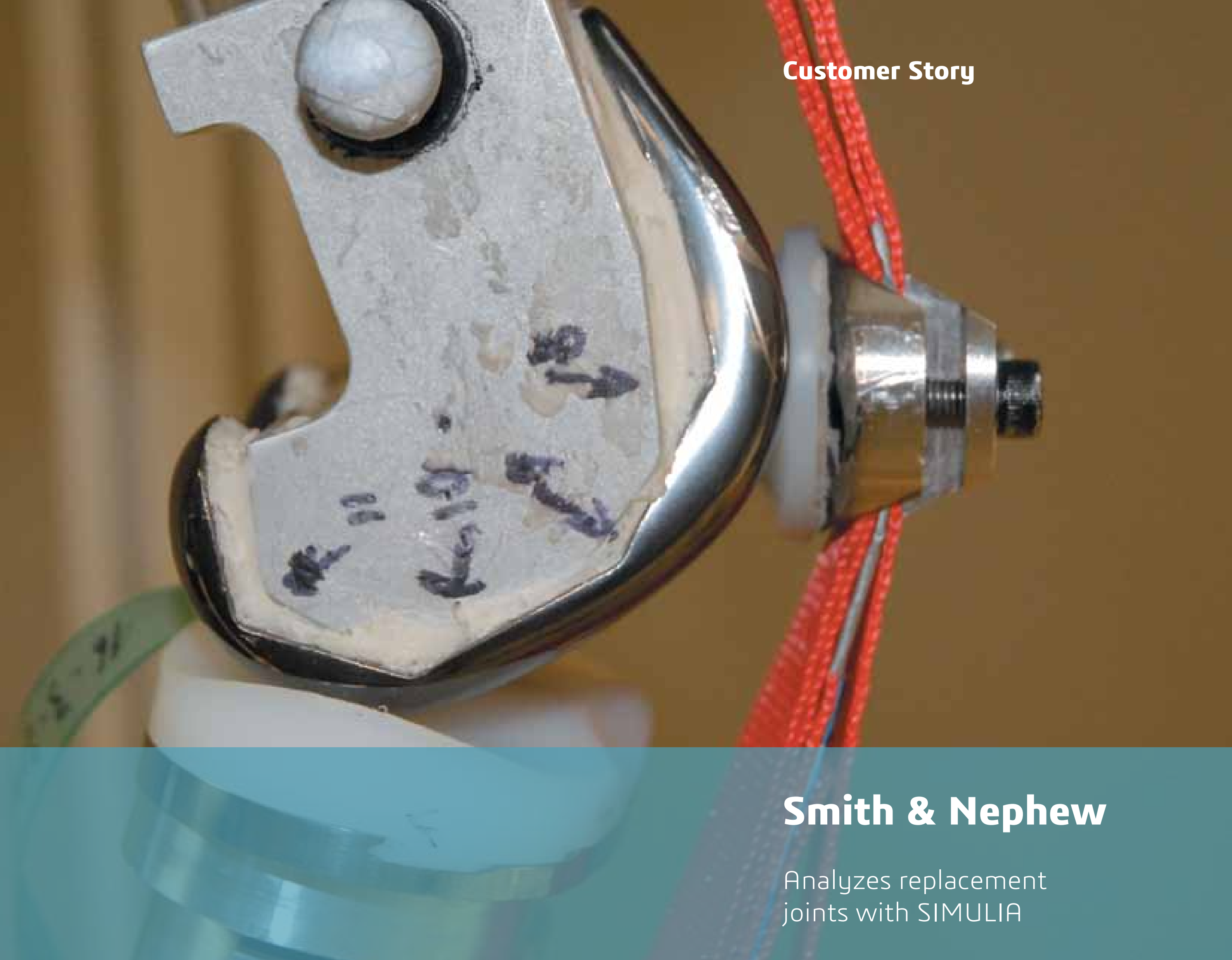

Customer Story

Smith & Nephew

Analyzes replacement joints with SIMULIA

Abaqus is helping us get ever-closer to designs that let Total Knee Arthroplasty patients do everything they want to for a full, active life after surgery.

Bernardo Innocenti
Lead Project Manager for Numerical Kinematics, European Centre for Knee Research, Smith & Nephew

Challenge
To accurately simulate the kinematics of replacement joints and the interaction of biological and man-made materials to improve patient outcomes.

Solution
Analysis with Abaqus from the Dassault Systèmes SIMULIA brand allows researchers to accurately predict the performance of replacement joints, plus how they will wear over time.

Benefits
Smith & Nephew succeeded in accurately modeling the in vivo contact of the femoral cam and the tibial post for the first time, informing future design refinements and guidance to surgeons.

DASSAULT SYSTEMES

European Centre for Knee Research
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As the largest joint in the body, the knee bears up to five times the body's weight with each step. Given these stresses, time alone can bring lifestyle-changing wear and tear to the knees' anatomical structures. Aging, too, can cause severe arthritis, producing pain and limiting mobility. Total knee replacement – performed about 580,000 times a year in the U.S. alone – is the most common treatment.

Total Knee Arthroplasty (TKA), the most common procedure, replaces damaged or diseased joint surfaces of the knee with metal and plastic components sized and shaped to fit. Knee implants have been shown to perform well for at least 15-20 years in more than 95 percent of patients, most of whom achieve a range of motion from zero to about 120 degrees.

TKA is not a perfect solution, however. Since the physiological range of motion of a normal knee ranged up to 135 degrees, some TKA patients can't return to their previous levels of activity. Some patients' bones also exhibit an atypical response to the metal implants, even though they are biocompatible. As lifespan increases, the durability of implants must increase as well.

Smith & Nephew, the United Kingdom's largest medical technology company, founded the European Centre for Knee Research in Leuven, Belgium, to drive research and innovation aimed at achieving greater understanding of knee kinematics, improved mobility and device robustness for knee patients.

With 150 years of experience, Smith & Nephew is an industry leader in orthopedic reconstruction and trauma. Although it operates a number of R&D centers around the world, "the Knee Centre is unique because it's focused solely on research," says Bernardo Innocenti, M.E., Ph.D., and the center's Lead Project Manager for Numerical Kinematics. "We submit all projects to a scientific advisory board, in which several high-level orthopaedic researchers are involved. This advisory board supervises our protocols to ensure that all research is done in the most scientific and ethical way. Our results are important not only from the researcher's point of view but from the designer's point of view as well. We provide great research tools and work in collaboration with surgeons, scientists and companies."

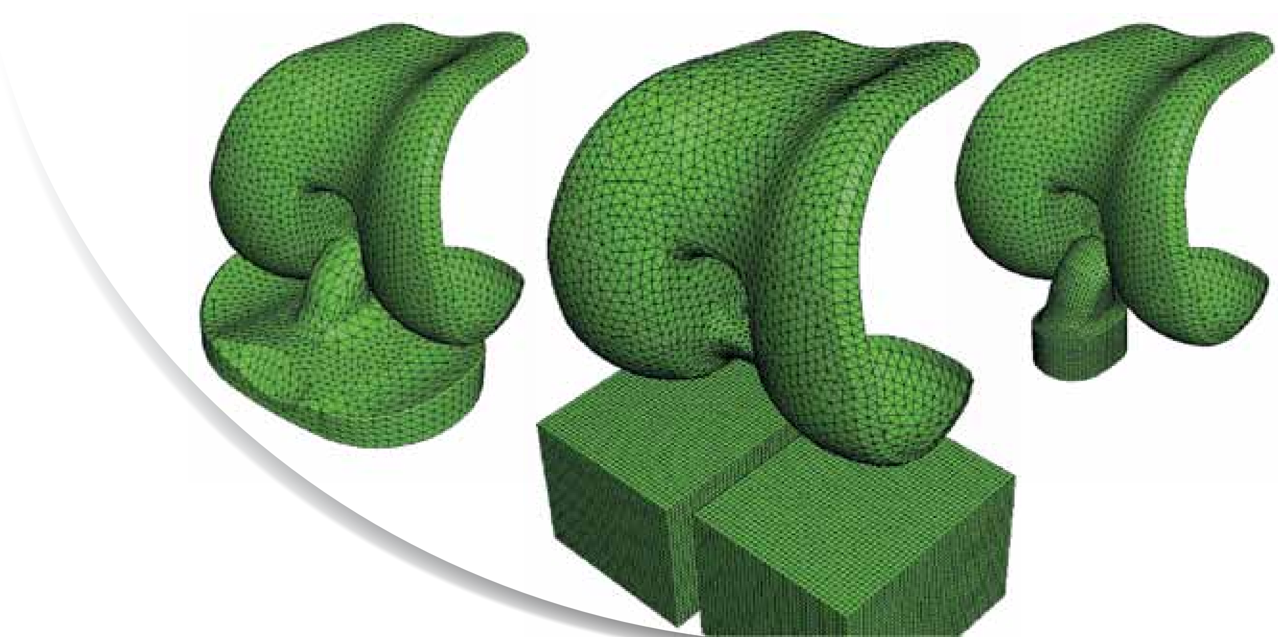
A typical knee model? No such thing.

Innocenti and his colleagues won the Knee Society's Mark Coventry Award for the best Basic Science Paper in 2009. Their study of the kinematics of an in vivo replacement knee used a novel combination of videofluoroscopy (a type of radiography that, unlike a static X-ray, gives a real-time look at bones inside a moving leg), and numerical modeling with finite element analysis (FEA), to look at contact position in patients who had undergone a full knee replacement.

Another study used FEA for realistic simulation of leg bone resorption where the tibia contacts a metal implant. Still other areas of research have included comparing different geometries of implant models and their effects on gait and knee kinematics.

"We work very closely with surgeons who come to us if they find a particular issue with a patient that they want to solve, or they see

Previous page: *Smith & Nephew mounts its knee prostheses in test rigs to validate the Abaqus FEA results. The Knee Center testing team uses SIMULIA's Isight optimization software to identify the correct positioning of strain-recording instruments and the design and ideal thickness of mechanical clamps.*



Abaqus FEA models of Smith & Nephew replacement knee components used for evaluation of the contacts between the different parts. The full model (left) with the original femoral (upper) and tibial (lower) components used for the sensitivity analysis was then modified (middle) for the condylar contact points and (right) for the post-cam contacts.

something out of the ordinary in their clinical practice and are looking for an explanation," Innocenti says. "What I like best about my work is that there's really no such thing as a 'typical' model – every project is different and exciting."

Abaqus FEA helps go inside the knee

All Knee Centre studies use Abaqus Unified FEA from SIMULIA, the Dassault Systèmes brand for realistic simulation. Engineers at Smith & Nephew have used the software for product design and development for years. "Abaqus FEA is fundamental in this game because it enables us to estimate rapidly and precisely the effects of different parameters in the design or performance of a TKA," Innocenti says. "When I joined the Knee Centre I had not used Abaqus before, but I found it very easy to work with. Modeling is very straightforward, yet it adapts to whatever complexities I want to introduce, and design changes are easy to execute."

Abaqus FEA accurately simulates the performance of both biological and man-made materials. "When you replace a knee, you are trying to replicate the behavior of biological materials, like bones, cartilage and ligaments, with non-biological ones such as titanium, stainless steel and polyethylene," Innocenti says. "I have everything I need for simulating the performance of all these materials in Abaqus, whether it is bone or metal or something more complicated like the viscoelasticity of soft tissues or polyethylene."

A notable challenge with modeling the artificial knee is that its mechanics vary greatly over time. As the joint moves, the loads and stresses on the contact points change over the entire range of motion. Also, every replacement knee operates in a unique body environment. Videofluoroscopy of a TKA patient's leg in motion is an accepted technique for monitoring this functionality. Videofluoroscopy only shows the behavior of the leg bones and metal inserts, however, not the soft tissues or the polyethylene insert that cushions the contact between the upper and lower parts (the femoral and tibial components) of the prosthesis. This is the challenge that Innocenti and his colleague Luc Labey, M.E., Ph.D., overcame with their award-winning research using Abaqus FEA.

Visualizing the challenge with FEA

Their study examined five osteoarthritis patients, each of whom had received Smith & Nephew's JOURNEY Bi-Cruciate Stabilized Knee System, a guided-motion knee implant specifically designed to produce more natural kinematics after TKA. The patients performed a number of exercises while being analyzed with fluoroscopy: rising and sitting, stair climbing and step up / step down. The resulting kinematics data became input for Abaqus FEA models of the knee implants.

Smith & Nephew's European Centre for Knee Research in Leuven, Belgium, is dedicated to achieving greater understanding of knee kinematics for improved mobility and device robustness for knee patients.

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Putting the FEA models through the same movements as those performed by the patients allowed Innocenti's team to estimate the contact points between the femoral and tibial components with a high degree of accuracy, taking into account the modulating effects of the polyethylene part that is undetectable with videofluoroscopy. The FEA analysis supported previous contact point displacement measurements derived from fluoroscopy alone, but with smoother, more credible and consistent patterns, demonstrating that the JOURNEY BCS patients' new knees were working as intended.

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>
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> *Lead Project Manager for Numerical Kinematics, European Centre for Knee Research, Smith & Nephew*

In addition, the models enabled the *in vivo* analysis of the contact between the femoral cam and the tibial post for the first time. "We were able to validate our technique with experimental results that produced a very high-quality metric," says Labey, who is head of team testing. "Our findings can be incorporated into both future design refinements and recommendations we make to surgeons today."

Validation of their Abaqus models has given Innocenti's team confidence to extrapolate their data to a wider range of questions about TKA longevity. "How these materials behave over time is critical to our work because an understanding of wear is very important with prostheses," Innocenti says. FEA also produces results significantly faster than physical testing. For example, Smith & Nephew recently obtained clearance for a 30-year wear performance claim using the LEGION Primary Knee System with VERILAST technology, a unique combination of Smith & Nephew's proprietary OXINIUM alloy and a highly cross-linked polyethylene, for the articulation. This was based on a large wear simulator study of 45 million gate cycles, which took almost three years to perform. By "walking" their Abaqus virtual knee prostheses through accelerated test cycles, however, the Smith & Nephew team simulated the effects of five years of walking in less than one week.

Future research with realistic simulation

Innocenti sees great potential for Abaqus in future research as well. "To be able to model more specifically and accurately all the biological systems around the knee bones, the soft tissues, the menisci, is a major goal," he says. "FEA could be a fundamental piece in this refinement due to its intrinsic ability to provide rapid output and sensitivity studies."

The ultimate aim of total knee replacement is to have a prosthesis that behaves as naturally as possible. "Abaqus is helping us get ever-closer to designs that let TKA patients do everything they want to for a full, active life after surgery."

(Top) Numerical model of a Total Knee Arthroplasty

(Bottom) Finite element analysis of the Patello-Femoral Interaction

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