PRESS RELEASE

Optimized Therapy for Cruciate Ligament Injuries

Researchers from the Fraunhofer Institute for Digital Medicine MEVIS, the University Medical Center Freiburg, and Stryker Leibinger GmbH & Co. KG have been awarded the Research Prize for Digitalization in Orthopedics and Trauma Surgery 2024 for their publication entitled "Validation of a Finite Element Simulation for Predicting Individual Knee Joint Kinematics." The award ceremony took place on October 25, 2024, during the German Congress for Orthopedics and Trauma Surgery (DKOU 2024) in Berlin.

Knee injuries are among the most common conditions in orthopedics. Treatment planning typically depends on radiological images captured using computed tomography (CT), magnetic resonance imaging (MRI), or X-ray. These images, however, have a limitation: they are taken when the knee is at rest, whereas most knee issues occur during movement. Researchers from Fraunhofer Institute for Digital Medicine MEVIS and the University Medical Center Freiburg have developed a novel method within the PLANK project ("Planning and navigation platform for the individualized care of cruciate ligament injuries") that enables therapy planning for cruciate ligament ruptures using dynamic modeling instead of static images.

Predicting the ideal position for cruciate ligament fixation

The knee joint connects the femur (thighbone), tibia (shinbone), and patella (kneecap) within a shared joint cavity. Between the femur and tibia lie two cartilage cushions, the menisci, which increase the joint surface area and act as shock absorbers. Various ligaments, including the anterior and posterior cruciate ligaments (ACL and PCL), stabilize the knee. Reconstruction of the cruciate ligament after injury typically involves using a tendon taken from the patient's thigh. This new ligament is then screwed to the tibia under tension. The position and tension of the new ligament graft have a large effect on the knee's mobility. Previously, physicians relied on their experience to determine these parameters. The simulation developed within the PLANK project now allows them to use computer modeling to find the optimal position for cruciate ligament fixation. "With our decision support system, knee surgeries can become more patient-specific," says Dr.-Ing. Elin Theilen, Principal Scientist for Modeling and Simulation at Fraunhofer Institute for Digital Medicine MEVIS. "We expect improved patient outcomes as the therapy can be tailored and optimized for each individual," she adds. "This will also help prevent long-term issues such as cartilage damage or osteoarthritis."

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The simulation is based on a virtual 3D model of the patient's knee, which physicians can view and rotate freely on a computer screen. It allows them to analyze the knee's dynamics, focus on specific structures, and gather information about potential pressure and stress distribution within the joint. To create the model, the researchers segmented the anatomical structures using static MR images of knee joints. They employed the finite element method (FEM) to calculate the pressure and stress distribution, dividing the structures into small, pyramid-shaped elements. Motion and stress relationships are then calculated at the connection points of these elements using mathematical equations.

Simulation shows how the cruciate ligament changes under load

The FEM model was validated at the University Medical Center Freiburg with eleven healthy volunteers. The Department of Orthopedics and Trauma Surgery has a customized MR-compatible loading device that supports knee imaging in various positions (extension, internal, and external rotation) and under different loads. This system allowed researchers to observe how structures like the cruciate ligament change during movement. The FEM simulations achieved an average translation accuracy of 2 mm and an angular accuracy to within 1 degree compared to the reference knee position. "Given this high level of accuracy, our FEM model is well-suited for making individualized decisions on how to best restore the stability and functionality of the knee after various injuries," says Prof. Kaywan Izadpanah, Section Head of Orthopedics and Trauma Surgery at the University Medical Center Freiburg. The FEM model is not limited to cruciate ligament ruptures. It can be applied to other knee injuries, such as implant treatments, fractures, or comorbidities.

The PLANK project involved Fraunhofer Institute for Digital Medicine MEVIS, the University Medical Center Freiburg (Departments of Orthopedics and Trauma Surgery and Diagnostic and Interventional Radiology – Medical Physics) as well as Stryker Leibinger GmbH & Co. KG. The project coordination was managed by Stryker Leibinger GmbH & Co. KG. The project ran from October 2018 to March 2022 and received approximately €1.5 million in funding from the German Federal Ministry of Education and Research (BMBF) as part of the "Individualized Medical Technology" program.

Fig. 1 Dr.-Ing. Elin Theilen (3rd from right) and Prof. Kaywan Izadpanah (3rd from left) at the award ceremony on Oct. 25, 2024, in Berlin. Center: Xavier Langlois (Brainlab AG) along with board members of the German Society for Orthopedics and Trauma Surgery.

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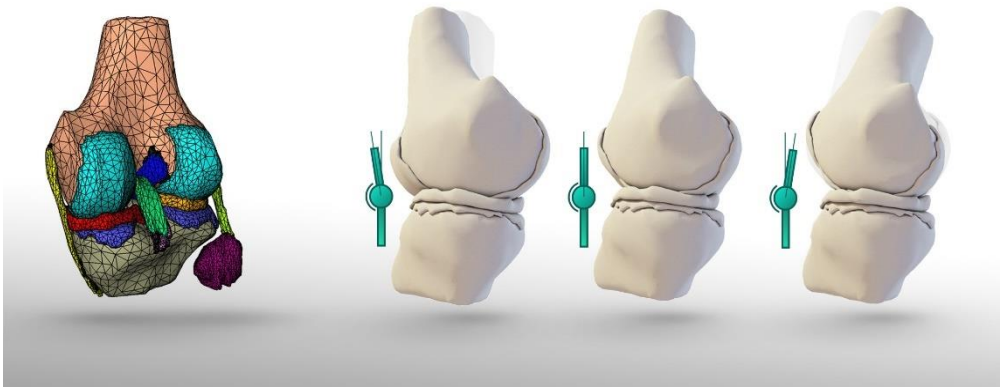

Fig. 2 A finite element simulation model of the knee joint (left) enables the dynamic prediction and analysis of various joint positions, such as hyperextension, resting position, and 20° flexion, from left to right (MRI dataset University Medical Center Freiburg).

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Embedded in a network of clinical and academic partners**, Fraunhofer MEVIS** develops practice-oriented software solutions for image- and data-based early detection, diagnosis and therapy. The focus is on cancer and diseases of the cardiovascular system, brain, breast, liver, lung and musculoskeletal system. The goal is to detect diseases earlier and more reliably, tailor treatments to the individual and make therapeutic success measurable. In addition, the institute develops software systems for industry partners as a means of analyzing image-based studies on the effectiveness of drugs and contrast agents. To achieve its goals, Fraunhofer MEVIS works closely with medical technology and pharmaceutical companies, providing solutions for the entire innovation chain from applied research to certified medical devices.

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