Healthcare industry BW

Research on the durability and longevity of artificial joints

In Germany alone, several hundred thousand patients are given an artificial hip, knee or shoulder joint every year. While the operation itself has long become orthopaedic routine, the implants have potential for improvement as they do not last a lifetime in all cases. As the situation currently stands, one in ten patients need to have worn artificial joints replaced around 10 years after implantation. Prof. Dr. Jan Philippe Kretzer and his team of researchers in the Laboratory of Biomechanics and Implant Research at the University Hospital in Heidelberg are studying what limits the longevity of implants and how durability can be improved. Kretzer's laboratory is fully equipped to carry out realistic simulations of the state of implants and develop new material and prosthesis concepts.

Prof. Dr. Jan Philippe Kretzer and his team of seven biomechanical engineers at Heidelberg University Hospital are looking at ways to make artificial joints more durable.
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The replacement of a natural with an artificial joint is a very common surgical intervention. In Germany, around 180,000 people a year are given an artificial hip joint, around 160,000 an artificial knee and around 25,000 a new shoulder joint. Joint replacement surgery becomes necessary when joints wear out due to arthritis and other diseases. Gradual damage of the joint over many years is often associated with immense pain. Artificial joint implants have become routine. Although both artificial and surgical methods are now fairly sophisticated, implants do not always last a lifetime. In Germany alone, around 25,000 replacement operations are performed every year to replace artificial prosthesis components. In many cases, it is impossible to use the same type of joint; a larger implant has to be used, which does not always function as well as the first artificial joint.

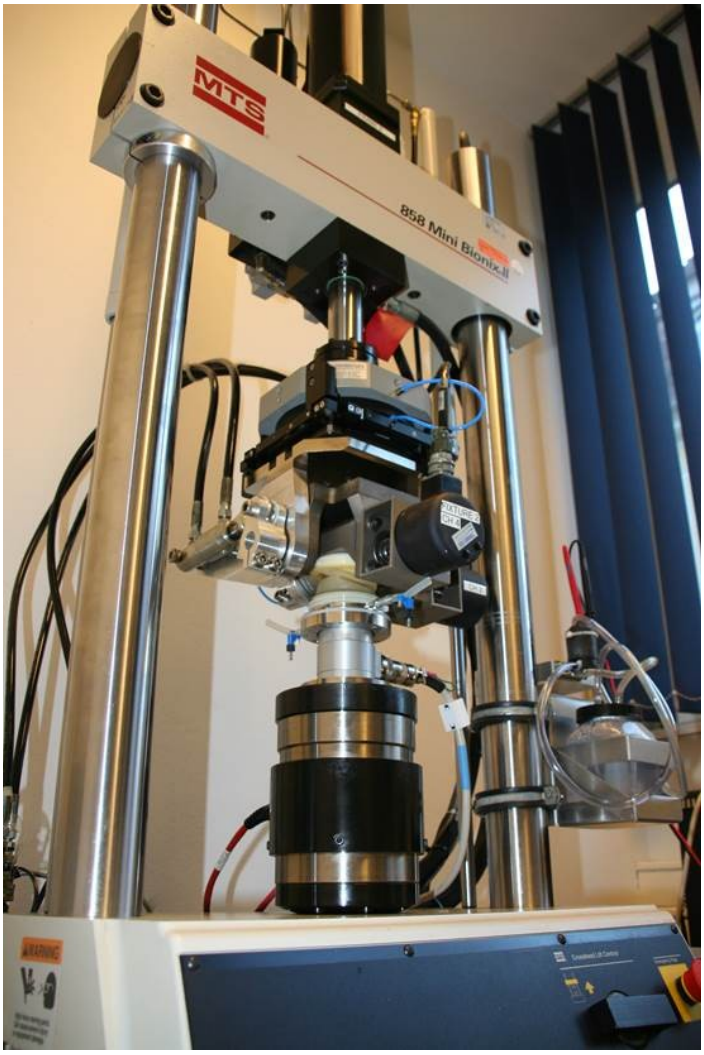
Prof. Jan Philippe Kretzer and his team in the Laboratory of Biomechanics and Implant Research at the University Hospital of Heidelberg are working on new artificial joint concepts to improve this situation in the future and extend implant life. "We want to understand why implants fail and we are working on improving them," explains Kretzer. The scientists take into account processes that lead to the wear and tear of implants, as well as factors that influence their longevity. As far as wear and tear is concerned, the researchers are specifically focused on tribology, which Prof. Kretzer, an engineer by training, refers to as the scientific study of wear and friction of surfaces in motion, a common concept in mechanical engineering. He comments: "We are interested in the material that is released as the artificial joint wears out, how material and design, i.e. implant geometry, affect this process and which mechanisms are triggered."

Artificial joints are put to the test

The biomechanical engineers from Heidelberg simulate as realistically as possible in the laboratory what happens to people with an artificial joint. For this purpose, they have designed special machines that generate movements and loads. "In the tests, the joint under investigation is moved continuously for three months," says Kretzer. This corresponds to the load to which a working artificial joint is exposed over a period of two to three years. This helps us understand what would happen if a prosthesis were produced with a particular material." Besides investigating the impact of wear and stress on the durability and friction of new implant materials, the researchers from Heidelberg also study the components, including micrometre-sized particles, which are released into the joint area as a result of the hard metal surface rubbing against the bone. "We analyse micrometre-sized because these can trigger reactions in patients. But we are only looking at the mechanical part. The biological investigations are done by cooperation partners who study their effect in living cells," says Kretzer.

In the biomechanical laboratory, the researchers test both novel and commonly used implants. "We are investigating aspects such as the influence of surgical methods and patient activities on implant longevity. We are also carrying out the investigations required before implants are placed on the market. We do this using standardised load types, following which the implants then either receive marketing authorisation or not," says Kretzer. "At present, many different implant models from many different manufacturers are on the market, and many different implantation techniques are used. This makes choosing the right joint and surgical method quite difficult, including from the patient's point of view. However, most prostheses work quite well, especially hip prostheses. Some patients even forget that they have an artificial hip joint. This is not always the case with knee joints. The number of patients not satisfied with their new knee joint is far higher than those with new hip joints."

Test on human and plastic bones



The hip simulator realistically simulates what happens with an artificial hip joint once implanted.
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In addition to tribological issues, the biomechanical engineers from Heidelberg are working on another comprehensive research area to attempt to find out why prostheses need to be replaced after around ten years. During surgery, the artificial implant is pressed very hard into the bone, so that new bone grows around and into the new joint. However, the mechanical connection between implant and bone can be lost due to movement and friction, and the prosthesis begins to loosen in an aseptic process. "In the days and weeks after surgery, minor movements between prosthesis and bone might occur, and integration is only successful if these movements are not too big. We want to find out why bone starts to grow into the prosthesis. Sometimes this does not happen, and we want to find out why as well. In addition to this so-called primary stability, the biomechanical engineers are also exploring the implants' long-term stability. "In general, bone needs a specific mechanical stimulus before it grows around and into implants. This stimulus changes upon implantation. We want to find out how the stress ratio changes, which conditions favour or prevent integration and how the flow of forces changes in bones." Such tests are carried out on real bones as well as plastic bones with very similar biomechanical properties.

Clinicians are also needed

Kretzer and his team also work with clinicians to include clinical findings in their studies. For example, clinicians use X-ray stereometric analysis (RSA) to predict the long-term performance of prostheses: Two images are taken simultaneously and converted by powerful image processing software into three-dimensional images. This is done before and after surgery; long-term studies are also carried out. "We are interested in what actually happens with the bone and the prosthesis," says Kretzer. "We have already carried quite a lot of these studies and found that that the reconstruction process around the implant is usually completed after two years. After two years, we can attempt to predict the likely lifespan of the implant." Kretzer finds that interdisciplinary cooperation with clinicians is of crucial importance. "This issue cannot be approached from one direction alone, which is why we work closely with clinicians," concludes Kretzer.

Although Kretzer is often asked which prosthesis or surgical method he would recommend, he finds it very hard to say. "Optimal treatment depends on many factors and needs to be done in very close cooperation with the treating surgeon. We are not seeking to develop the best ever prosthesis, but rather make researchers and clinicians think about how artificial joints and methods can be improved. "Some of our ideas have been aimed at developing new materials but this is just one of many things we do. The most important thing for us is to better understand the overall system and help ensure long-term durability, so that we can contribute as much as possible to avoiding the need for implants be replaced."