

# Improving Joint Replacement Materials

Dr Stefano Mischler

Dr Anna Igual Munoz

Dr Yueyue Bao

Professor Dr Brigitte Jolles-Haeberli

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Hip and knee replacements are key for the health and well-being of many people.

Unfortunately, the materials used in these procedures are known to wear and corrode once placed within the human body.

Dr Stefano Mischler and his team from École Polytechnique Fédérale de Lausanne, together with Professor Dr Brigitte Jolles-Haeberli and her team from Lausanne University Hospital in Switzerland, have conducted exciting new research that advances our understanding of the factors influencing corrosion in the human body. Their work has exciting implications for the future monitoring of implant conditions, particularly valuable in the face of our increasingly ageing population.

## Joint Replacement Surgery

Joint replacement surgeries are among the most common elective medical interventions in people over 60 years old. They are performed to help people regain the use of joints, including hips and knees, which have been damaged by degenerative diseases such as osteoarthritis or trauma. Over a million people in the USA undergo hip or knee replacement surgery each year, and with global populations increasingly ageing and increasing high-level recreational sports, this type of surgery is going to become more common around the world.

In this type of surgery, the damaged parts of the joint are replaced with high-quality man-made materials such as metal alloys, including titanium and cobalt-chromium-molybdenum (CoCrMo), primarily used for their strength and resilience.

Joint replacement surgery helps improve people's quality of life by reducing pain, restoring mobility and, subsequently, their independence. However, the materials used do not last forever in the body, and the average hip replacement lasts approximately 20 years before additional surgery is needed to either repair or replace it.

To improve joint replacement surgery, Dr Stefano Mischler and a team of scientists from École Polytechnique Fédérale de Lausanne and Professor Dr Brigitte Jolles-Haeberli at Lausanne University Hospital set up an important collaboration. Their goal is to revolutionise understanding of how these materials corrode within the body and to develop materials that last as long as possible, thus reducing the need for additional surgery in people with joint replacements.

## Implant Corrosion in the Body

To improve the performance and longevity of these implant materials, it is essential to understand how they deteriorate in the human body. So far, studies investigating these metals have only been performed in laboratory studies using simulated body fluids – which may not accurately represent the conditions in the body. These laboratory studies have shown that the durability of these metals is dependent on a wide range of factors (including those relating to the individual patient). Furthermore, the different factors have only been studied individually. As such, the interactions between various factors as they may occur in the body are not yet fully understood.

To address this knowledge gap, the collaborative team of scientists and clinicians conducted a series of experiments to investigate the corrosion behaviour of implant materials in real human conditions to help predict the lifetime of joint replacement implants.

Professor Dr Jolle-Haeberli, a skilled hip and knee surgeon, extracted synovial fluid (the liquid found in joints that helps them move smoothly) from more than 170 patients during planned elective arthroplasty with patient consent. The pH, colour, and viscosity of the extracted fluid were assessed to help understand how the materials react in different patients. The ability of the synovial fluid to conduct an electrical charge allowed the use of electrochemical techniques to investigate the interaction between the implant materials and the synovial fluid and determine how likely the materials were to corrode and how fast this would happen. The obtained corrosion rates from experiments



(proportional to the metal ion release from the implant material into the human body) were compared to the metal ion levels in patients' urine and found to correspond very well. Therefore, these new experiments could be considered a good marker for the reactivity of a patient toward specific implant material.

Titanium and CoCrMo are often combined in implants. For example, a hip replacement may be made up of a CoCrMo ball attached to a titanium stem. In theory, this combination may increase corrosion in the body if one material is more noble than the other – otherwise known as galvanic corrosion. With the present data, no significant risk of galvanic corrosion in synovial fluid was observed between CoCrMo and Titanium.

Alongside electrochemical corrosion, joint implants are also affected by physical friction and wear and tear caused by movement and mechanical loading. The mechanical wear damages the metal implant, allowing the potentially corrosive synovial fluid to enhance its effect and increase the implant damage rate. The combined effect is known as tribocorrosion and is one of the main causes of joint implant degradation. Dr Mischler is an expert in this phenomenon, and the team combined tribocorrosion models with their electrochemical experiments in synovial fluid to calculate the overall degradation rates of hip replacements.

### **Implant Material Corrosion Rates are Patient-specific**

A key finding (supporting the team's previous work) was that corrosion rates of both titanium and CoCrMo implant material vary with the patient in which it is implanted. The team found that the patient's synovial fluid impacts the lifespan of metals used as implants in multiple ways. Some molecules in the fluid react with

the implant and increase the degradation rate, whereas other molecules, such as proteins, can stick to the implant, protecting it from corrosion. They found no risk of galvanic corrosion between the two types of metal as they have very similar electrical properties when submerged in human synovial fluid.

The team also reported that corrosion rates in the study correlated well with levels of metal ions in the patient's urine. This is a particularly exciting finding as it may be used in the future to understand how long an implant may last in an individual patient, reducing the need for more invasive techniques.

### **Electrochemical Techniques in Clinical Medicine**

The unique collaboration between École Polytechnique Fédérale de Lausanne and Lausanne University Hospital has highlighted the value of electrochemical testing in investigating the longevity of joint replacement implant material. The team's findings show that metal implant degradation rates are specific to individual patients due to variations in synovial fluid and physical wear factors. This means that the same implant will last for a different amount of time in different patients and emphasises the need for a non-invasive way to measure implant condition. The team's work demonstrates that the corrosion rates of both titanium and CoCrMo implants in human synovial fluid match closely with the rate at which metal ions are released into the patients. Importantly, this suggests that testing the level of metal ions in patients' bodies through a simple urine test could be used to monitor the condition and corrosion of their joint replacement implant.



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## MEET THE RESEARCHERS



### Dr Stefano Mischler

École Polytechnique Fédérale de Lausanne, Institute of Materials, Tribology and Interface Chemistry, Lausanne, Switzerland

Dr Stefano Mischler obtained his PhD from the Swiss Federal Institute of Technology, where he is now head of the Tribology and Interface Chemistry Unit, where he leads research on surface chemical effects in tribology, biotribology and biocorrosion, tribology in microfabrication processes, and wear protection methods. He has published over 100 peer-reviewed journal articles and several book chapters. In addition to his research, Dr Mischler provides PhD and MSc supervision and teaches both undergraduate and postgraduate courses.



#### CONTACT

[stefano.mischler@epfl.ch](mailto:stefano.mischler@epfl.ch)



### Dr Anna Igual Munoz

Dr Anna Igual Munoz received her PhD from the Technical University of Valencia and has subsequently worked at the University of Virginia and École Polytechnique Fédérale de Lausanne,

where she is currently a senior scientist responsible for research projects related to electrochemical corrosion and tribology. Dr Igual Munoz sits on the Editorial board of the Journal of Bio- and Tribo-Corrosion and is a reviewer of the Spanish National Foundation and the European Commission. She also supervises and teaches at undergraduate and postgraduate levels and has eight teaching-related publications.



#### CONTACT

[anna.igualmunoz@epfl.ch](mailto:anna.igualmunoz@epfl.ch)



### Dr Yueyue Bao

After obtaining an MSc from the University of Science and Technology Beijing, Dr Yueyue Bao was awarded a PhD in the electrochemical behaviour of Ti and CoCrMo alloy in human synovial fluids. Dr

Bao's main research interests are focused on metal and implant materials, tribocorrosion, and electrochemistry. She has presented her work at international conferences. She has received multiple awards and scholarships for her work, including the Miyoshi Outstanding Graduate Student from the University of Science and Technology Beijing and an Academic Merit Scholarship from Hohai University.



#### CONTACT

[yueyue.bao@epfl.ch](mailto:yueyue.bao@epfl.ch)



### Professor Dr Brigitte Jolles-Haeberli and team, Lausanne University Hospital, Switzerland

Professor Dr Brigitte Jolles-Haeberli founded the Swiss BioMotion Lab (SBML) with Dr Julien Favre in 2014, and continues to lead this laboratory with him. In parallel to her academic activities, she is a senior consultant orthopaedic surgeon in hip and knee surgery at the Hirslanden clinics in Lausanne and the COO of the Department of Musculoskeletal Medicine (DAL) at CHUV. In 2023, she was elected to the renowned French Academy of Surgery in recognition of decades of excellence in orthopaedics as a surgeon, instructor, and researcher.



#### CONTACT

[brigitte.jolles-haeberli@chuv.ch](mailto:brigitte.jolles-haeberli@chuv.ch)



#### FUNDING

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#### FURTHER READING

Y Bao, A Igual Munoz, B Jolles, S Mischler, [Assessment of in-vivo corrosion of Ti and CoCrMo joint implants by electrochemical measurements in human synovial liquids](#), *Electrochimica Acta*, 2024, 476, 143708. DOI: <https://doi.org/10.1016/j.electacta.2023.143708>



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