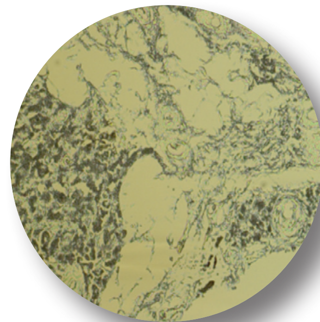
Case Study

Study of metal distribution and speciation in human tissues

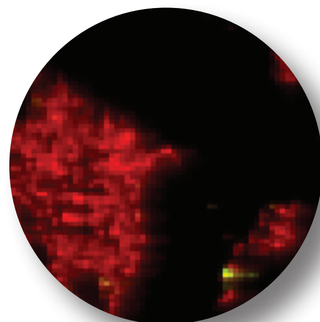
The Problem

Since 1996, approximately 1.5m patients have had metal-on-metal (MOM) hip replacements worldwide. This technology has been shown to work well in the medium term, even for highly active patients; however, young patients require this device to operate for up to 50 years. Significantly, in up to 10% of patients the implant has to be removed prematurely, within five years of implantation. Therefore, a better understanding of the mechanism of failure is needed to develop fully biocompatible implants, for which there has been a predicted soaring demand over the next twenty years.



The Challenge

All types of MOM hip use cobalt-chromium-molybdenum (Co-Cr-Mo) implants which generate 1 trillion metal nanoparticles from the two metal surfaces per year of patient use. The properties of wear species derived from Co-Cr-Mo orthopaedic implants have been studied for many years and it has been generally found that the wear debris found in tissues is abundant in chromium and deficient in cobalt. However, due to very low metal concentrations, studies of speciation in the tissue specimen cannot be fully explored using standard laboratory equipment.



The Solution

Scientists and surgeons from Imperial College London, UCL's Institute of Biomedical Engineering, the Royal National Orthopaedic Hospital and the Medical Research Council used Diamond's beamline I18 to perform X-ray Fluorescence (XRF) mapping and X-ray Absorption Spectroscopy measurements. These were used to analyse the distribution, and chemical state of metal-derived wear debris in tissue surrounding MOM hips.

The Benefits

Comparing failed MOM hips with tissue from Metal-on-Polyethylene hips, chemical standards and metal discs, the team found that the most abundant implant-derived species was Cr(III) orthophosphate. They also identified other metallic species that may represent intermediate steps in the corrosion process of metal alloys in human tissues. The use of specialised X-ray techniques available only at the synchrotron make it possible to achieve huge progress in the field of human biocompatibility to hip replacements.

"This is the first time synchrotron radiation has been used to chemically characterise implant derived tissue from MOM hips. We have demonstrated the usefulness of synchrotron techniques in being able to identify low concentrations of material and in determining the metal speciation. As well as providing insights into the cause of failure of MOM hips, we have shown that the technique has potential as a valid method of biocompatibility testing for other materials, and to correlate chemical speciation with the clinical mode of failure, such as infection or allergic response."

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