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In vivo investigation of nanoscale silicon nitride particles

Jayna Patel, S Lal, S P Wilshaw, B von Rechenberg, K Nuss, R M Hall and **J L Tipper**
University of Leeds, UK

Introduction: Biocompatible coatings, such as silicon nitride (SiN), may improve the performance of joint replacements. SiN particles dissolve, which would minimize any associated reactions. Furthermore, the ions produced are non-toxic. In this study, SiN particles were investigated for biocompatibility and isolated using a novel methodology for further analysis.

Methods: Commercial nanoscale SiN particles, or clinically relevant CoCr or titanium particles generated by pin-on-plate simulation, were injected into the right stifle joint of rats at a volume of 0.018 mm3 of particles. After seven days of in vivo exposure, animals were euthanized, and the intact treated and contralateral non-treated stifle joints were formalin fixed and either decalcified and processed histologically for H&E staining or subjected to a particle isolation protocol. The isolation protocol involved enzymatic digestion with papain (1.56 mg. mL-1) and proteinase K (1 mg. mL-1, with two subsequent replenishments), and use of sodium polytungstate (SPT) for density gradient ultracentrifugation. Residual SPT was removed and recovered particles were filtered and analyzed by high resolution scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectroscopy (EDX) for elemental analysis. Imaging software (ImageJ) was used to determine size and morphologies (aspect ratio and circularity) of the particles. Particles not subjected to the isolation procedure were analyzed for comparison.

Results and Discussion: SiN particles were aggregated, relatively spherical and up to 60 nm in size, with a modal size range of 20-30 nm. Differences in size and morphology of SiN and CoCr particles before and after isolation were statistically insignificant (KS tests, $p>0.05$). Titanium particles showed no aggregation characteristics, were of varying morphology, and had a size range from 0.1-100 μm, with a modal size of 10-15 μm. Titanium particles were too few before and after isolation to statistically analyze, though size and morphologies were similar. Elemental analysis validated particle composition. Particles were not detected in non-treated stifle joints, demonstrating that particles were not a result of contamination. Initial particle and tissue quantities were low compared to human periprosthetic tissue samples, indicating technique sensitivity. In the histology analysis, CoCr injected joints displayed necrosis, which was absent from SiN and titanium injected joints. Inflammation was greater in the CoCr samples.

Conclusion: Overall the isolation methodology successfully enabled retrieval and characterization of SiN particles, in addition to CoCr and titanium particles. Histological analysis indicated that SiN is more biocompatible than CoCr. Future work aims to further evaluate the histology sections through immunolabelling and semi-quantitative scoring.

Biography

Jayna Patel is pursuing her PhD at the University of Leeds. Her research involves wear particle isolation and the evaluation of joint replacement materials for biocompatibility. Previously, she studied Biological Sciences at Lancaster University.

jaynapatel1@gmail.com

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