INTRODUCTION:
In a recent study, we showed the presence of ultra-high molecular weight polyethylene (UHMWPE) wear particles and periprosthetic inflammatory reactions around retrieved total disc replacements (TDRs). [1] The limitation of that study was the inability of polarized light microscopy to quantify submicron-sized UHMWPE particles. Submicron-sized particles are frequently observed in retrieved total hip and knee periprosthetic tissues and appear to be critical in the activation of the phagocytic inflammatory response. [2,3]

The aim of the present study was to quantify and determine the size and shape of submicron UHMWPE wear particles in periprosthetic tissues from retrieved TDR, to compare these findings with wear debris isolated from THA tissues, and to correlate the TDR wear debris with visible damage to the UHMWPE core.

METHODS:
Periprosthetic fibrous tissue was obtained from revision surgery of 5 SB Charité III TDRs (LINK, Germany). Revision was performed after 9 years (range 6–12 years) due to persistent back and leg pain. The tissue samples were compared with fibrous tissue from 5 revised metal-on-UHMWPE total hip arthroplasties (THA). Revision was performed after 14 years (range 11–16 years) due to wear and/or osteolysis.

Scanning Electron Microscopy (FEI XL30) was used to analyze concentration, size and shape of the UHMWPE particles between 50–2000 nanometer in size. Particle size was expressed using equivalent circle diameter (ECD, \(2\times\sqrt{\text{area}/\pi}\)). Particle shape was determined using aspect ratio (AR, major axis length/minor axis length) and roundness \(\frac{4\times\pi\times\text{area}}{\text{Perimeter}^2}\). The images were analyzed using a customized particle analysis macro in NIH Imagej. A MicroCT scanner was used (uCT80, Scanco Medical AG, Switzerland) to characterize surface damage of the TDR UHMWPE core.

To evaluate differences between TDR and THA Mann-Whitney U tests were used, and Spearman rho was used to correlate submicron UHMWPE particles with the surface damage of the core. Significance was assumed at \(p\)-values <0.05 using SPSS16.0. Mean values ± standard error of the mean (SEM) are shown.

RESULTS:
The mean concentrations of UHMWPE particles for TDR were 1.5 x 10^9/gram of tissue (range 1.2-1.8) and for THA 4.1 x 10^9/gram of tissue (1.8-10.9). The differences were significant \((p<0.01)\). The ECD for TDR particles (0.464 ± 0.050) was comparable to THA (0.528 ± 0.054) \((p=0.60, \text{Figure 1a})\). However, the particle number differed significantly in the 50-200, 400-600, 800-1000 and 1000-1250 nanometer ECD range between TDR and THA \((p=0.01, p=0.04, p=0.03, p=0.01, \text{respectively})\). The AR for the TDR particles (1.890 ± 0.044) was also similar to THA (1.944 ± 0.046) \((p=0.47, \text{Figure 1b})\). The only significant difference between TDR and THA was seen in the 1.25-1.50 AR range \((p=0.04)\) Additionally, the mean roundness of the particles was not significantly different between the two groups \((p=0.35, 0.578 ± 0.011 \text{ and } 0.566 ± 0.008 \text{ for TDR and THA, respectively, Figure 1c})\). Although, the roundness range 0.55-0.40 and 0.75-0.80 showed differences \((p=0.01 \text{ and } 0.02, \text{respectively})\).

Dome as well as rim wear patterns of the TDR cores showed large variations between patients, and as such no significant correlation was found between the rim and dome wear patterns and concentration, AR or roundness of the UHMWPE particles. However, a positive correlation \((p=0.04)\) was found between ECD and rim penetration (mm) of the TDR.

DISCUSSION:
To our knowledge, this is the first in vivo study to show the presence of submicron-sized UHMWPE particles in periprosthetic tissue after TDR revision surgery. The results showed lower concentrations of particles in TDR compared to THA. Despite differences in loading and kinematics between spine and hip, TDR UHMWPE wear particle size and shape were comparable to wear isolated from THA tissues. In THA tissues, submicron-sized UHMWPE particles have been shown to be critical in influencing the phagocytic inflammatory response and stimulating the production of proinflammatory factors. In THA, this response contributes to the development of osteolysis. Inflammation was also observed in the fibrous tissue of all 5 TDR patients, which may contribute to the development of neuroinflammatory induced pain. [1]

It is possible that the decreased concentrations of submicron sized UHMWPE particles are the reason osteolysis after TDR is not typically a cause for revision. For the single osteolytic TDR excluded from the study group, high concentration of UHMWPE particles were detected (2.58 x 10^9/gram of tissue).

The study of TDR patient tissues and retrieved implant components provides insight into the clinical performance and relevance of UHMWPE wear after lumbar TDR. A better understanding may ultimately help to improve the material and design of the prosthesis.

REFERENCES:

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