Retrieval Analysis of Titanium Nitride-Coated Orthopaedic Implants

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INTRODUCTION:

Ceramic coatings such as titanium nitride (TiN) have gained popularity as a surface modification technique for implants due to their excellent biocompatibility, wear resistance, and corrosion resistance. However, concerns exist regarding issues such as 3rd body wear, increased wear of ultra-high-molecular-weight polyethylene (UHMWPE), and cohesive failure of the coating. This study aims to evaluate the *in vivo* performance of TiN-coated knee and hip implants, specifically examining fixation interfaces, articulating surfaces, and wear-related damage.

METHODS:

A total of 8 arthroplasty retrievals (3 knee and 5 hip) were collected during revision surgery from multiple institutions. The TiN-coated implants were from 3 different manufacturers and included various designs. Implantation years ranged from 1993 to 2016. The cohort had an average implantation time of 4.25 years (range: 1.75 to 5.25) and 17.5 years (range: 0.25 to 26) for knee and hip implants respectively. Average patient BMIs were 37 ± 2.98 and 28.5 ± 4.09 kg/m^2 for knee and hip implants, respectively. The revised components included knee implants (3 femoral implants, 2 tibial trays, and 1 tibial insert) and hip implants (4 liners, 3 shells, 5 femoral heads, and 1 femoral stem). The reasons for revision were PE wear (2/8), loosening (2/8), pain (2/8), infection (1/8), and instability (1/8). In the hip analysis, the surfaces of femoral heads, the taper surface of the femoral stem, and the rim and articulating surfaces of polyethylene liners were evaluated using a semiquantitative scoring method [Higgs et al., 2013]. The knee analysis involved dividing the condyles and tibial trays into four zones and scoring accordingly [Arnholt et al., 2016]. Surface roughness was assessed using white light interferometry (WLI) on specified regions, and scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) were used for surface morphology, chemistry, and particle characterization.

RESULTS:

For hips, there was mild (2.4/4) corrosion for femoral head tapers; high scratching (2.6/3) was observed for femoral heads. For polyethylene liners the main mechanism was burnishing (2.4/3), followed by embedded debris (1/3) and scratching (0.8/3). The failure of coating was visually detected in 4 cases (3 femoral heads and 1 tibial tray (Fig. 1)). For knee implants low burnishing and scratching were observed (3.3/12) for both mechanisms. The knee surfaces proved to be hydrophilic according to the wettability. The roughness measured (Sa) for the knee retrievals was 90.7 nm with 90% CI [79,101.4]. The depth of the scratches observed on the tibial trays varied between 0.3 and 1.3 µm.

DISCUSSION AND CONCLUSION:

This study aimed to assess the *in vivo* damage of TiN coated knee and hip implants. The findings indicated that the primary damage mechanisms observed for TiN coatings were scratching, corrosion, and burnishing. Long-term femoral heads (25 years) showed cohesive failure of the coating, whereas short-term knee retrievals (less than 4 years) exhibited predominantly intact coatings, with only minor chipping and localized substrate exposure.