Polyethylene Wear in Reverse Total Shoulder Arthroplasty: Is Osteolysis at the Horizon?

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INTRODUCTION:

Reverse total shoulder arthroplasty (rTSA) is among the most common surgical interventions to alleviate pain and restore function in patients with glenohumeral joint disease. Typically, rTSAs use a spherical metal glenosphere that articulates with a polyethylene (PE) liner to restore motion and provide joint stability. In hip and knee arthroplasty, PE wear is well-known to cause inflammatory tissue responses, often resulting in osteolysis and implant failure. However, there is limited understanding of the effect of PE wear in the rTSA. This study aimed to quantify PE wear and characterize associated wear scars from normally articulating rTSA humeral liners. The corresponding periprosthetic tissue was analyzed for PE presence and tissue response.

METHODS:

Initially, 50 PE rTSA liners with periprosthetic tissue were available (retrieved between 2017 and 2023). Of these, 26 were in situ for 2 years or greater, with a mean of 4.6 years (95% CI, 3.4, 5.8). Revisions occurred for implant loosening (N=10), infection (N=4), pain (N=6), periprosthetic fracture (N=4), and pain with loosening (N=2). Wear volume and wear scars were quantitatively assessed using an optical coordinate-measuring-machine (RedLux). Wear was qualitatively assessed with a wear score (range: 1-14). Histological sections were prepared for H&E staining and Fourier transform infrared spectroscopy imaging (FTIR-I). The presence of macrophages was semi-quantitatively scored (1-mild to 4-severe). FTIR-I (Agilent) was conducted to generate chemical images of intracellular PE particle accumulation. Statistical analysis included Pearson's and Spearman's correlation.

RESULTS:

The median wear score across 26 liners was 4 (min. 1, max. 10). The macrophage scores were 1-minimal (N=1), 2—mild (N=4), 3-moderate (N=6), and 4-severe (N=15). Wear volume could only be assessed for 13 liners after excluding those with severe removal damage or excessive rim damage caused scapular notching. Ultimately, wear could only be quantified for nine cases. For the remaining liners, wear had not progressed enough to be detectable. The mean (± standard deviation) wear volume of the remaining liners was 73.4 (±59.5) mm^3, and the median (min., max.) wear volume was 44.5 (28.5, 210.3) mm^3, respectively. The mean and median volumetric wear rates (VWR) were 19.4 (± 16.6) mm^3 and 10.8 (7.29, 52.3) mm^3, respectively. The PE wear volume and rate did not correlate with wear score nor macrophage score. Wear rate correlated positively with a higher incidence of aseptic loosening (p=0.043). Heat maps indicated the maximum wear was generally located in the inferior-anterior region of the bearing surface. Three wear scars appeared symmetrical and offset from the center; two had a kidney shape, two indicated edge loading, and two indicated a shift in wear scar location. FTIR-I analysis showed PE particle accumulation in five cases. Intracellular PE accumulation correlated positively with time in situ (p=0.02).

DISCUSSION AND CONCLUSION:

Our results suggested a lower volume wear rate (VWR) compared to previous studies. The only other CMM study reported a wear volume range of 42.5 to 89.2 mm^3 in a study of four liners with 470 mm^3/year as the maximum wear rate. Another found the mean VWR of 114.5±160.3 mm^3/year across 32 liners using microCT [2] and 42±22 mm^3/year across 13 liners utilizing radio stereometric analysis. However, our study excluded liners with rim damage caused by scapular notching, as this wear model results from unintended contact conditions, leading to mechanical failure. Our focus is on wear generated during normal articulation and the associated PE wear that may result in inflammatory tissue responses and ultimately osteolysis. The shape of the wear scar varied among the liners, which may be related to patient activities, range of motion, and surgical implant alignment. Tissue analysis found a strong tissue response in most cases, and intracellular PE accumulation over time. Our study cohort was too small, and implantation duration was too short to establish a relationship between wear and tissue response.

Figure 1 Example of a heat map (left) generated from CMM data. This liner features a wear scar concentrated in the inferior-anterior quadrant of the bearing surface. The light intensity map (middle) and corresponding photo (right) of the liner provide additional context.

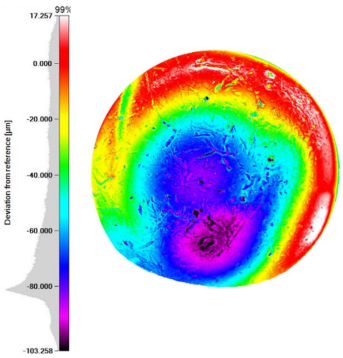

Figure 2 Heat map of a liner that experiences two overlapping, distinct wear scars, indicating a sudden shift, possibly due to dislocation or loosening.

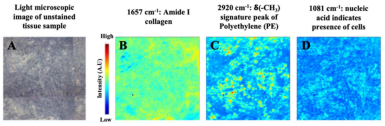

Figure 3 A) Light micrograph of unstained joint capsule tissue. FTIR-I chemical images at various wavenumbers show the presence of B) Amide I (collagenous tissue), C) accumulation of fine PE particles, D) phosphates indicative of nucleic acid (macrophages). PE particle-laden macrophages are present based on the overlap between C) and D).