MD-Vol. 94, Proceedings of the ASME Materials Division — 2000
Book of Abstracts
ASME 2000

MECHANICAL FAILURE OF ARTIFICIAL JOINT MATERIALS: WEAR AND FATIGUE

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Abstract:

Total artificial joint replacements are one of the most effective treatments for arthritis. Artificial joints are used to replace damaged cartilage and act as low-friction articulating materials in joints. During normal human walking, some of the materials used for artificial knee and hip replacements are subjected to both sliding articulation (relative motion) and cyclic loading. A common example is the CoCrMo alloy femoral surface of an artificial knee that articulates against an ultra-high-molecular-weight-polyethylene (UHMWPE) component. Other materials do not experience relative motion (at least not intentionally) and are subjected to only cyclic loading. An example is the poly(methyl methacrylate) or PMMA bone cement used to fix components of artificial joints into bones. In the case of articulating materials, both surfaces are susceptible to wear, from both second-body and third body (in the presence of abrasive particles) mechanisms. Wear of the UHMWPE has received considerable attention recently, since the polymer wear is far more obvious than the metal wear. The Biomaterials field is developing an understanding of the wear mechanisms and how to enhance the wear resistance of UHMWPE. The wear of the metal components has not received as much attention, yet materials wear as a couple; both surfaces play a role in the overall wear. In the UMBC Laboratory for Implantable Materials, we are investigating the mechanisms of CoCrMo alloy wear, and the effect of worn metal components on the wear of UHMWPE. Understanding the wear mechanisms of metal components may help to extend the life of artificial joints by allowing new articulating material combinations and joint designs. For non-articulating materials, fatigue failure is a primary concern. Fatigue of metal components is relatively rare. In the distal portion of an artificial hip, the metal hip stem is fixed into the bone by a layer of PMMA bone cement. The PMMA bone cement is far weaker and less resistant to fracture and fatigue than either the bone or the metal, and thus may be considered the mechanical "weak link" in cemented total joints. We are investigating the fatigue properties of PMMA bone cements, and studying the mechanisms of fatigue crack initiation. If we can determine how fatigue cracks start in bone cement, we may be able to develop, for example, new surgical procedures (e.g., bone preparation) that will reduce the likelihood of fatigue failure. New formulations of bone cement have been developed for both joint fixation, and also for bone repair or replacement. Understanding the failure mechanisms of bone cements may enable safe and effective new uses for new bone cements, and extend the lives of cemented artificial joints.