ABSTRACT

Knee arthroplasty, referring to surgical reconstruction of the knee joint, has its origins in the late 19th century as the treatment for severe joint degeneration resulting from osteoarthritis. UHMWPE has been used in knee replacements since it combines superior wear resistance along with high fracture toughness and biocompatibility compared to other materials.

Medical-grade polyethylene UHMWPE is a semicrystalline polymer that can be depicted as a set of ordered regions (crystalline lamellae) embedded in a disordered amorphous phase. Higher crystallinity gives a larger modulus of elasticity, superior yield strength, improved resistance to creep deformation and enhanced fatigue strength, all of which are desirable properties for joint components. Medical-grade UHMWPE orthopaedic implants are machined from stocks and sheets made from UHMWPE powders by compression moulding or ram extrusion and subsequent annealing.

Properties and performance of UHMWPE on the scale of microns or smaller, are all critical in understanding how UHMWPE wears. Therefore, the main goal of this project is the use of mechanical test methods like nanoindentation, testing along with the atomic force microscope (AFM) in order to describe and characterize UHMWPE. Thus, this work will describe quasistatic and dynamic indentation testing, for the characterization of UHMWPE knee implants and a comparison between them. Usually, the principal goal of such testing is to extract elastic modulus and hardness of the specimen material from experimental readings of indenter load and depth of penetration. The test procedure usually involves an elastic-plastic loading sequence followed by an unloading. The validity of the results for hardness and modulus depends largely upon the analysis procedure used to process the raw data.

Furthermore, some detailed analysis techniques are discussed for the calculation of mechanical properties of UHMWPE implants, which include the Oliver-Pharr method. Briefly, the geometric relationship between the tip and sample plays a role in the analysis of indentation data. The viscoelastic behaviour of UHMWPE is discussed too, as are approaches to study viscoelasticity in indentation testing. Wear behaviour was determined and related to changes in mechanical properties of the surface deformed UHMWPE, which has been recognized as being the main cause of failure in orthopaedic implants. Finally, a new approach in the analysis of UHMWPE implants is being demonstrated.