SUPERIOR WEAR RESISTANCE OF VITAMIN E ADDED UHMWPE TESTED ON KNEE JOINT SIMULATOR

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INTRODUCTION

Wear resistance and oxidative stability are the key factors to extend lifetime of artificial joints. Highly crosslinked UHMWPE has been found to have dramatically improved wear resistance in vitro, but it necessitates heat treatment after crosslinking in order to secure stability against oxidative degradation. However, recent studies have shown very low fatigue resistance of highly crosslinked and melt treated UHMWPE [1]. Fatigue resistance is very important since artificial joints are typically under cyclic loads and use of material with poor fatigue resistance is questionable.

Vitamin E added UHMWPE has been shown to have mechanical properties similar to virgin UHMWPE [2] as well as complete oxidative stability [3] and high fatigue wear resistance [3]. Therefore, this material is considered to be used to the knee joint replacement, which is under severe mechanical condition. The objective of this study was to evaluate wear resistance of vitamin E added UHMWPE on knee joint simulator.

MATERIALS

The implant used in this study was HTK-II, which was a flat surface type total knee joint. Test specimen was vitamin E added UHMWPE. UHMWPE GUR1050 powder was mixed with 0.3% vitamin E (dl-α-tocopherol) before consolidation. Tibial components of the knee joint were made from the mixed powder using direct compression molding (DCM) technique. Control specimen was direct compression molded UHMWPE GUR1050 without vitamin E. No sterilization was carried out prior to the testing.

METHODS

Six-station four-axis knee joint simulator (AMTI, Boston, MA) was used for the testing. Applied waveform is shown in Figure 1, where the maximum load was 2600N and the maximum flexion angle was 58°. Bovine calf serum diluted to 25% with 0.3% sodium azide was used as a lubricant. The lubricant was changed every 500,000 cycles. The test lasted for five million cycles.

Gravimetric wear was measured at 0.5 million cycles and every one million cycles. The specimens were weighed to the accuracy of 10μg together with weight control specimens in order to minimize the effect of water uptake. Geometric wear measurement was carried out by coordinate measurement machine (Mitsutoyo, Japan) at the end of the test (five million cycles).

Feedback data from the simulator was analyzed to determine frictional force generated at the articulating surface. Due to the flat surface geometry at the articulating surface, horizontal force measured by the six-axis force sensor beneath the tibial component was assumed to be equal to the frictional force generated at the articulating surface.

RESULTS

Figure 2 shows weight loss of the tested materials. Vitamin E added UHMWPE showed approximately 30% lower wear than that of control. Geometric measurement showed no marked difference between tested and control materials. Frictional measurement showed no substantial difference in friction between the two samples as shown in Figure 3.

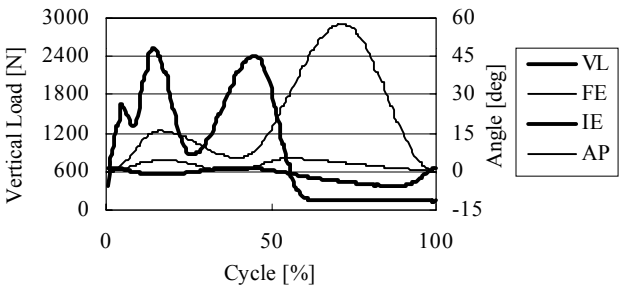

Figure 1. Applied waveform.

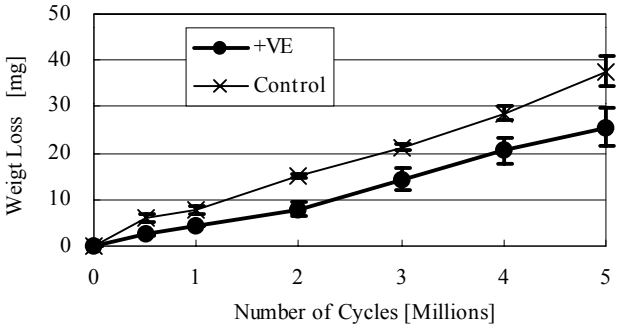

Figure 2. Weight loss due to wear on the knee joint simulator.

DISCUSSION

Highly crosslinked UHMWPE has superior wear resistance but inferior mechanical properties to virgin UHMWPE. Application of such material to the joints under severe mechanical condition such as knee joints may lead to catastrophic failure.

Vitamin E added UHMWPE has been found to have high durability against (so-called) delamination destruction, by addition of extremely small amount of vitamin E [4]. It has also been reported that the grain boundary becomes the place at which destruction takes place and the addition of vitamin E prevents crack propagation.

This study showed better wear resistance of vitamin E added UHMWPE than virgin UHMWPE that has not been oxidized or degraded. It also showed no extensive creep deformation.

Mechanism of wear is very complex and many factors are known to affect amount of wear. In this study, experimental conditions (e.g. lubricant, load, kinematics, surface topology and temperature) and friction generated at the bearing surfaces were the same for both vitamin E added UHMWPE and virgin UHMWPE. This result indicated superior wear resistance of vitamin E added UHMPWE was a result of improved mechanical properties such as fatigue crack resistance [4]. Vitamin E added UHMWPE is promising as a next generation material for joint bearing material.

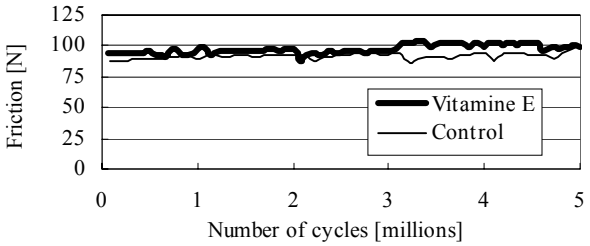

Figure 3. Frictional force measured during simulator testing.

REFERENCES

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