Development of a New In Vitro Patella Wear Tester in the Orthopedic Biomechanics and Biomaterials Laboratory

Brian R. Burroughs, Ph.D., Orhun Muratoglu, Ph.D., Harry Rubash, M.D., Daniel Estok, M.D., Murali Jasty, M.D., Andrew A. Freiberg, M.D., William H. Harris, M.D.

Orthopedic Biomechanics and Biomaterials Laboratory, Massachusetts General Hospital, Boston, Massachusetts

INTRODUCTION

The patellofemoral joint is a major source of complications following total knee arthroplasty and a leading cause for revision surgery. Patellar components are manufactured from ultra-high molecular weight polyethylene (UHMWPE). The main mode of patellar component failure is delamination. The adhesive/abrasive wear of patellar components contribute to the particulate debris burden. In the total knee arthroplasty, wear at the tibiofemoral and patellofemoral articulations is a problem for the integrity of the components as well as the tissue reaction to wear debris. When the adverse effects of use are manifested in the form of excessive damage to the polyethylene, such as delamination and component fracture, changes in the geometric conformity can initiate various instabilities, further leading to revision surgery.

Conventional UHMWPE components are packaged in an inert environment and sterilized by gamma radiation. During *in vivo* use, these components are exposed to oxygen. As a result, the material is subject to long-term oxidative degradation due to the reaction of persistent radiation-induced free radicals with oxygen. The fact that oxidized UHMWPE has reduced ability to withstand stress is of particular importance for the patellofemoral joint as contact pressures between the UHMWPE patellar component and an cobalt chromium (CoCr) femoral component exceeds the yield strength of UHMWPE.

Crosslinking UHMWPE with a electron beam radiation and subsequent melting has been shown to substantially increase oxidation resistance and hence reduce delamination. *In vitro* knee simulator tests have shown that adhesive/abrasive wear is also reduced with crosslinking of UHMWPE tibial inserts [1,3,4]. To date, there are no established *in vitro* standards to measure the performance of patellar components used in total knee replacements. The purpose of the present study was to design a patellofemoral joint tester and use this *in vitro* model to compare the damage modes of conventional and highly crosslinked UHMWPE patellar components. It is hypothesized that the oxidation resistant nature of highly crosslinked UHMWPE will provide patellar components manufactured from such material with improved damage resistance.

MATERIALS AND METHODS

The patellar components used in the present study were the sombrero-shaped Natural-Knee II® (NKII) components of size 3 with a thickness of 7-mm (Centerpulse Orthopedics, Austin, TX). The conventional components were machined from GUR 1050 ram-extruded bar stock and sterilized with gamma irradiation in an inert environment. The highly crosslinked components were machined from GUR 1050 ram-extruded bar stock following 95 kGy electron beam irradiation (Studer, Switzerland) at 125°C followed by melt-annealing. The highly crosslinked components were sterilized using ethylene oxide gas.

The patellar components were tested on a six-station knee simulator (Advanced Mechanical Technology, Inc., Watertown, MA) with each patella articulating against the trochlear grove a NKII size 3 left femoral components. Each patellar component was fixed into a stainless steel fixture with bone cement and fixed directly on top each hydraulic actuator of the knee simulator so that each patella was loaded directly against the trochlear groove of the femoral component. The patellar components were completely immersed in 100% bovine serum to maintain the lubrication of the articulation during the test.

Initial testing of conventional and highly crosslinked patellar components was carried out under conditions of optimal component alignment and simulated normal walking gait. Subsequent tests were developed to evaluate these two materials under more aggressive and adverse conditions. For each test, three components of each type were tested.

Dr. Burroughs is Research Project Manager, Orthopedic Biomechanics and Biomaterials Laboratory, Massachusetts General Hospital

Dr. Muratoglu is Deputy Director, Orthopedic Biomechanics and Biomaterials Laboratory, Massachusetts General Hospital

Dr. Rubash is Chief, Department of Orthopaedics, and Edith M. Ashley Professor of Orthopaedic Surgery, Harvard Medical School and Massachusetts General Hospital

Dr. Estok is an Instructor in Orthopaedic Surgery, Harvard Medical School and Attending Physician at Brigham and Women's Hospital

Dr. Jasty is Associate Clinical Professor of Orthopaedic Surgery, Harvard Medical School and Massachusetts General Hospital

Dr. Freiberg is Chief, Adult Reconstruction Service and Assistant Clinical Professor of Orthopaedic Surgery, Harvard Medical School and Massachusetts General Hospital

Dr. Harris is Alan Gerry Clinical Professor of Orthopaedic Surgery, Harvard Medical School and Director, Orthopedic Biomechanics and Biomaterials Laboratory, Massachusetts General Hospital **Please direct all correspondence and reprint requests to:**

Orhun Muratoglu, Ph.D.
Deputy Director, Alan Gerry Scholar
Orthopedic Biomechanics and Biomaterials Laboratory
Jackson 1206
Massachusetts General Hospital
55 Fruit Street
Boston, MA 02114
Tel. (617) 726-3869, Fax. (617) 726-3883

Supported by Centerpulse Orthopaedics, Inc. (Austin, TX)

In each test, the knee simulator controlled both flexion of the femoral component and patellofemoral contact force. For the initial normal gait test, the flexion kinematics were adopted from tibiofemoral measurements of Lafortune [2]. The waveform for the normal gait patellofemoral contact force was adapted from that measured one year post-operatively in a telemetric distal femoral replacement by Taylor et al. [5].

RESULTS AND DISCUSSION

Initial testing under normal conditions in both the conventional and highly crosslinked patellar components exhibited a scar that extended between the medial and lateral edges. The scar was narrower in the dome area and wider near the medial and lateral extremes. The scar area grew larger as the test proceeded to five million cycles. In addition, the patellar components exhibited global plastic deformation at the proximal and distal edges. The primary direction of this deformation was towards the femoral component, i.e. posterior. The differences between the conventional and highly crosslinked patellar component were unremarkable. It should be noted that the patellar components used in this initial test had not been subject to any accelerated aging and therefore lacked any substantial oxidation which might lead to delamination and gross damage of the components.

Subsequent testing under more aggressive and adverse conditions was conducted with patellar components which had been exposed to an accelerated aging environment intended to simulate long-term oxidative changes. The results of these more aggressive tests demonstrated a notable difference in the ability of these materials to withstand such conditions. The results of these most recent tests will be reported in a future communication.

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Eric Giza, Susan Schultz, Renn Crichlow, and Conrad Wang enjoy another Rod The Long Bone concert.