Injectable Lubricants for Prosthetic Joints

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Statement of Purpose: Wear of orthopaedic implants, such as those used in total hip arthroplasty (THA) or total knee arthroplasty (TKA), has long been recognized as the principal cause of degradation and failure of the implants. The particulate wear debris generated from articulation between two moving parts of the prosthetic joints can initiate a cascade of adverse tissue responses, leading to osteolysis and aseptic loosening of the components. Thus, improvement of tribological properties of implant materials is synonymous to the improvements of biocompatibility and longevity for prosthetic joints. To date, efforts to solve this problem have been directed towards the development/application of new materials with superior tribological properties. The present study is based upon a markedly different viewpoint into the problem; instead of developing and/or applying new materials for implants to resist wear, we aim to reduce the wear of implants by administering lubricants to prosthetic joints. This is primarily based upon recent development of polymeric lubricant additives that are water-soluble and improve anti-friction and anti-wear properties of a variety of engineering materials, including metal alloys, polymers, and ceramics, which happen to be the same types of materials for orthopaedic implants. In this paper, injectable lubricants comprised of water-soluble polymers in aqueous buffer solutions are specifically targeting to lubricate and reduce the wear production of ultrahigh molecular weight polyethylene (UHMWPE) materials. A first set of experiments for the proof of concept, lubricating efficacy and mechanism, and screening of working lubricants in model synovial fluids such as serum are presented. In addition, in-vitro cytotoxicity tests of the screened lubricants are presented and discussed.

Methods: Pin-on-disk tribometry was employed to assess the lubricating capabilities of external lubricants for the sliding contacts between UHMWPE and CoCrMo tribopair. External lubricants were formulated by dissolving commercial amphiphilic triblock copolymers, PEO-PPO-PEO (as known as "Pluronics"), specially "F127", "F108", "P105", and "F68", in aqueous buffer solution (HEPES, 1 mM with no extra salts). The concentration of the amphiphilic copolymers was varied from 0.1 % (1 mg/ml) to 20 % (200 mg/ml) in HEPES buffer solution. In addition, homopolymeric PEO and PAA have also been tested. For comparison, various biopolymers, including hyaluronic acid (HA), bovine submaxillary mucin (BSM), bovine serum albumin (BSA), and alginic acid (AA), have been tested as lubricant additives. A number of control tests, for example, to investigate the influence of temperature, longevity, composition of model synovial fluid, aging of implants, have been tested. For in-vitro cytotoxicity tests, cell morphology and standard MTT tests have been performed by employing by employing murine fibroblast (L929 fibroblasts) and murine osteoblast (MC3T3).

Results: Tribological tests have shown that all the lubricants display immediate reduction in the coefficient friction upon injection into serum in which the sliding contacts between CoCrMo pin and UHMWPE disk are taking place. A representative example, the case where 1 ml of F127 solution (20%) injected into 2 ml of serum is shown in Figure 1 (The final concentration is thus diluted to 1/3, i.e. 6.7%).

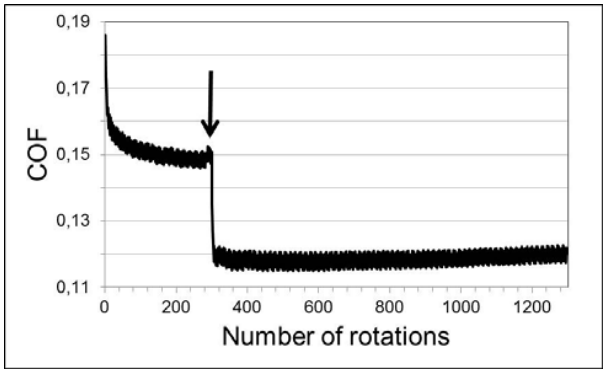

Figure 1. 1 ml of F127 solution (20%) injected (arrow) into serum solution at 300 rotations immediately reduced the coefficient of friction, and persisted to the end of tests (1,300 rotations, ca. 38 m).

The efficacy of reducing the coefficient of friction was roughly proportional to the concentration of lubricant additives. Influence of temperature e.g. 22° C vs. 37° C was insignificant, and the lubricant additives were similarly effective for aged or damaged UHMWPE and CoCrMo materials. In another model synovial fluid, where 3.5 mg/ml hyaluronic acid was added to serum to further emulate real synovial fluid, however, the efficacy of reducing friction coefficient was somewhat retarded. While the homopolymeric lubricant additives were also effective in reducing the friction forces, although to a much less extent compared to amphiphilic copolymers, none of the biopolymers tested show lubricating effect. In-vitro cytotoxicity tests have shown that more hydrophilic copolymers, F127 and F108, are more favorable in cell viability, as tested from both cell morphology and MTT tests (by exposing to the lubricants up to 5% concentration and 1 week).

Conclusions: The results in this work supports that this approach, i.e. injection of external lubricants for prosthetic joints, has a high potential to be effective in reducing friction and wear, and ultimately improving the longevity. It is currently sought after to extend the tests for animal and human subjects.