INTRODUCTION
Hemiarthroplasty, for the replacement of one side of a joint with a metal or alumina ceramic prosthesis that articulates directly against cartilage, has been used widely for the hip, shoulder, and other joints since the 1950’s [1]. However, histological studies on dogs confirmed that implants made of rigid materials such as metal or ceramic cause progressive cartilage wear and degeneration [2]. Contradistinctively, a histological study of a Polycarbonate-Urethane (PCU) implant against cartilage in the sheep knee has been shown to produce very little cartilage degeneration [3]. Specifically, the hydrophilic and compliant PCU material has a similar compressive elastic modulus as cartilage (20MPa, two orders of magnitude lower than metal and ceramic) and promotes fluid-film lubrication through elasto-hydrodynamic lubrication, similar to that reported for natural synovial joints [4]. Nonetheless, we hypothesized that the performance of PCU could be improved further by employing a lubricious polystyrene-brush coating (15μm). This coating should reduce friction by means of fluid entrapment to the level of cartilage-on-cartilage. The goal of this study was, therefore, to evaluate whether this lubricious coating of the PCU’s articulating surface could be beneficial in reducing wear and friction and potentially offer better chondroprotection in case of a PCU hemiarthroplasty (e.g., hip or knee).

METHODS
A pendulum simulator composed of a vertical loading axis and horizontal rotating fulcrum was designed in order to simulate continuous gait loading of a natural porcine hip joint (Fig. 1a). The simulator was capable of providing with measurements of the vertical axial load and rotational moment of the fulcrum axis. Fresh-frozen porcine hip joints (N=3) were defrosted and exposed from soft tissues (e.g. muscle and fat) surrounding the acetabular and femoral components, except for the joint capsule which was left intact. The acetabular component was placed in a rotating cell attached to the fulcrum at an angle of 45° and secured with bone cement. Subsequently, the femur (20cm long) was fixed to the vertical load axis. The cell was filled with bovine serum as lubricant. The artificial PCU buffer was tested by replacing the natural acetabular component with a similarly orientated buffer of analogous size (46mm diameter). Six buffers made of PCU coated with polystyrene polymer brushes were tested.

Simulations of 70,000 load cycles were conducted on natural joints and hemiarthroplasties of the various PCU buffers, by applying a vertical load of ~55kg and 60° rotational amplitude applied simultaneously at 1Hz. After articulation, the femoral head was colored with India ink and scratches were examined and mapped under microscope. Width and length of each scratch were measured macroscopically and microscopically (Figs. 1b, 2), and the total injured area (product of width and length of all scratch) in each specimen was calculated. Finally, the difference in injured area between groups was evaluated via t-test. In addition, the moment developed in the fulcrum axis under a constant load of 100kg, was measured, to simulate lubricant starvation.

RESULTS
We found that cartilage-on-polystyrene-coated-PCU and cartilage-on-cartilage groups were indistinguishable (p=0.05). In addition, the microscopical examination of an intact femoral cartilage after 70,000 load cycles showed predominantly negligible scratching. Interestingly, the moment measured for the coated PCU was found to be ~1.6-times lower, and less affected by lubricant depletion compared to the non-coated PCU (Fig. 4).

DISCUSSION
In this study, we evaluated the amount of cartilage damage associated with articulation of cartilage against polystyrene-brush-coated PCU as a potential hemiarthroplasty material. Previous findings in sheep showed that minimal changes associated with joint remodeling, occurred within a 9 months study duration, and on the whole, cartilage was preserved well [3]. Nonetheless, our results indicate that PCU performance can be improved further by an additional lubricious polystyrene-brush coating, able to provide boosted lubrication when lubricant-layer typically breaks down. Coated PCU demonstrates exceptional wear results, comparable to those attained for articulation of cartilage against PCU (Fig. 3). Importantly, it is stable, as its performance was minimally affected by 70,000 load cycles. In addition, a future in-vivo sheep study of coated PCU hemiarthroplasty will be conducted.

REFERENCES