Bodyweight Effect on Polyethylene Wear in Ultra-Congruent Knee Prostheses
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INTRODUCTION:
The wear of the polyethylene component is a key factor in the long term success of total knee arthroplasty. It has been associated to osteolysis progression, aseptic loosening, and macroscopic damaging of the implant. An important effort has already been done to understand the relevant parameters related to the polyethylene wear phenomenon, but it is still considered as multifactorial.

In addition to clinical studies, experimental mechanical knee simulators are commonly used to analyze the polyethylene wear of total knee prostheses. This technique is however time consuming and is rather expensive. Numerical simulators are also used to predict the wear, using the same testing protocols as the knee simulators [1, 2], with the advantage to more easily perform parametric data.

Patient weight is assumed to be a relative contra indication for total knee replacement. Clinical studies comparing obese and nonobese patients are contradictory. In addition, the effect of the patient weight on wear is not clear, particularly with ultra-congruent prostheses.

Therefore, the goal of this study was to evaluate the effect of the patient weight on the volumetric wear rate of a mobile ultra-congruent knee prosthesis.

METHODS:
A numerical musculoskeletal model of the knee was used to evaluate the effect of the patient weight on the polyethylene wear [3]. The model included the femur, the tibia and the quadriceps muscles: rectus femoris, vastus intermedius, vastus lateralis and vastus medialis. Muscle activations were estimated from EMG data and were synchronized by a feedback algorithm. The geometry of the tibia, femur and patella were reconstructed from CT data. An mobile bearing ultra-congruent posterior stabilized knee prosthesis (FIRST, Symbios, Switzerland) was positioned in the reconstructed bones by a senior surgeon (Fig. 1). A loaded squat movement was actively controlled by the quadriceps muscle, balancing the patient bodyweight (BW). Frictionless contacts were considered between tibio-femoral and patello-femoral surfaces. Polyethylene components were elastic, while metallic and bony parts were rigid. The linear wear was predicted from the Archard’s law [4], with a pressure dependent wear factor measured experimentally [5]. Linear wear was then extended to volumetric wear rate (mm³/million cycles). Three flexion angles were considered: 30, 60 and 90 degrees. Four values of patient bodyweight were tested: 60, 80, 100 and 120 kg.

RESULTS:
The volumetric wear for 1 million cycles of a loaded knee flexion at 30° remained below 40 mm³ (Fig. 2). The wear rate was approximately 3-fold higher for a flexion of 60°, and 5-fold higher for a flexion of 90°.

When the two extreme patient weights were compared, the volumetric wear rate was not proportional. A double weight indeed increased the wear by 1.5 for 30° of flexion, 1.4 for 60° and 1.2 for 90°.

DISCUSSION:
The wear of the polyethylene insert is a critical issue in total knee arthroplasty. Although patient weight has been reported to be one of the possible causes for excessive wear, there is no clear recommendation. This study showed that a double bodyweight do not induce a double polyethylene wear.

The numerical musculoskeletal model was used to predict wear rate caused by a loaded squat movement at 3 flexion angles. A 30° flexion can be assimilated to walking, 60° to stair climbing, and 90° to rising from a chair. For one year of normal daily activities, 1 million walking cycles is usually assumed. The value predicted here was within the range of wear reported in the literature. It also consistent with un-published data of wear obtained by a wear simulator (ISO 14243-1.2) with this prosthesis. It has been proposed that normal activity represents 85% of walking and 15% of stair climbing [2]. Accounting for stair climbing or chair rising in wear predictions would reduce the effect of the patient bodyweight, which has less effect as the load of the activity increase.

The wear algorithm predicts the linear wear, but do not actually change the shape of the articular surface. This limitation is reasonable to predict the ware rate during the first year after surgery, which corresponds approximately to 1 million cycles, but should be improved to predict a long term wear [1]. The strength of this model is to simulate a loaded movement controlled by muscle, instead of a predefined set of fixed forces, torques, displacements or rotations. It was however limited to the squat in the present study.

To conclude, this numerical study provided consistent data, and predicted that polyethylene wear is not proportional to patient weight, at least for this mobile ultra-congruent knee prosthesis. As a consequence, these data indicated that this type of knee prostheses could be used with overweighted patients who would otherwise not be accepted for this surgery.

REFERENCES:

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