DEVELOPMENT AND VALIDATION OF A FINITE ELEMENT MODEL TO PREDICT PATELLO-FEMORAL WEAR IN TKA

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Introduction

Experimental patello-femoral (PF) and femoral-tibio (FT) wear tests can be used to quantify wear in an implant but these procedures are expensive and time consuming. Therefore, a validated numerical model could be useful to predict wear in less time with less cost. For these reasons, the aim of this study was to develop and validate a numerical methodology to predict PF wear in TKA. Initially, the wear model was calibrated using the results of an experimental roll-on-plane wear test. The developed wear model was applied to predict PF wear and validated comparing the numerical predicted wear with experimental wear results.

Methods

Wear model

The adhesive/abrasive wear behavior was determined using the Archard model [Archard, 1953] with the Sarkar modification [Sarkar, 1980], in which linear wear h is determined as:

$$h = k_w\, p\, s\, \sqrt{(1 + 3\mu^2)} \qquad (1)$$

in which: k_w=wear factor, p=contact pressure, s=sliding distance, μ friction coefficient.

Roll-on- plane calibration

Three blocks of UHMWPE (GUR 1020) underwent a $6x10^6$ cycles experimental roll-on-plane wear test (Fig. 1a). The full experimental test was reproduced by finite element analysis (FEA) (Fig. 1b) and the wear model was calibrated, adjusting k_w, during the simulation as illustrated in Figure 2. The geometry of the block was updated every 500.000 cycles.

Patello-femoral wear prediction

Three patellar and femoral components were tested for $2x10^6$ cycles in a wear simulator (Fig. 1c) [Vanbiervliet, 2011]. The full experimental test was numerically analyzed in a FEA model (Fig. 1d). The PF wear was predicted using the calibrated wear model (Fig. 2). Experimental wear data and numerical wear prediction were finally compared.

Results

Roll-on- plane

Using a k_w = 1.83x10-8 mm^3/Nm, the results of the numerical simulation show a linear wear of 0.127 mm, very close to the linear wear measured experimentally (0.125 mm, SD =0.01mm).

Patello-femoral

The numerical model results show a total volume wear of 0.38997 mm^3 after $2x10^6$ cycles while the mean wear volume measured experimentally for the same number of cycles for three samples, is 0.37660 ± 0.326 [Vanbiervliet, 2011].

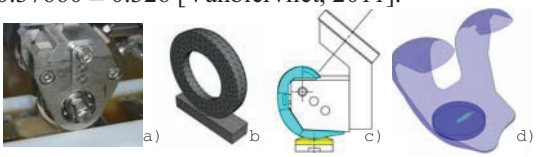

Figure 1: a) detail of roll-on-plane experimental machine; b) numerical roll-on-plane simulation; c) PF experimental model (scheme); d) PF numerical model

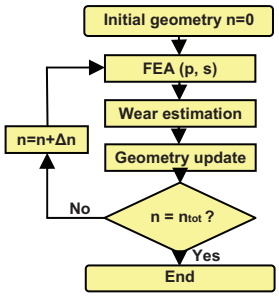

Figure 2: flow chart of the wear estimation in the finite element model

Discussion

In this study a wear model was developed and calibrated comparing an experimental and a numerical roll on plane test. The wear model was later validated comparing the wear predicted by the numerical model and from experimental test of $2x10^6$ cycles of walking. The validated wear model can be used to predict wear between PF and FT articulations for several configurations to predict a TKA long-term performance for a specific patient and to optimize and improve implants designs.

References

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