TKP Tibial Tray Failure Due to the Fatigue Wear

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From the qualitative evaluation of the two retrieved implants (Fig. 1) we could conclude that the fatigue wear debuted with some wear pitts of the contact surface and delamination (especially in the peripheral medial part of the tibial insert) but, in time, severe damages occur (gross delaminations, massive losses of polyethylene).

![Figure 1: Two retrieved polyethylene inserts showing (a) pitting and (b) severe delamination](image)

The methodology for predicting the fatigue wear phenomena combines FE analyses of active loading cycles of relevant routine activities with a summation technique that is based on computation of a cumulative estimator of damage. A FE model of the artificial joint contact was used (see Fig. 2) for all analyses.

![Figure 2: (a) Finite element model used in analyses and (b) the contact paths for all three cases considered](image)

The model includes one femoral condyle and one half (the medial one) of the polyethylene insert, and of the metallic tibial tray. For deformable parts (the tibial parts) solid brick elements with 8 nodes and 3 DOF’s per node (all three translations) are used.

The femoral condyle having a thoroidal shape with a radius of 22 mm in the sagittal plane (the flexion plane), and a radius of 30 mm in the transversal plane was considered rigid.

The routine activities considered relevant for this study are the active cycles of the normal walking, stair descending and stair ascending activities. The compressive force is applied to the tibial tray (as distributed pressure on the lower basis of it). The contact mechanism includes rolling and sliding of the two joint surfaces – the femoral condylar thoroidal surface and the planar surface of tibial insert; the friction obeys the Coulomb law with a constant friction coefficient of 0.12.

For every activity a damage estimator could be computed from the variation of the shear maximum principal stress in every element (Sathasivam et al):

$$D_f^k = \sum_{i=1}^{1} \frac{1}{2} \left| \tau_{i+1} \right| - \left( \left| \tau_{i+1} \right| + \left| \tau_i \right| \right)$$

where:

- $D_f^k$ - damage function for activity $k$
- $\tau_i$ - shear maximum stress on elements for time $t_i$

The effect of all activities could be cumulated by evaluating a weighted sum:

$$D_f^{tot} = \sum w_k D_f^k$$

where the weights are depending on the frequency of the activity.

Performing the dynamic analyses of the contact between the femoral metallic condyles and the polyethylene tibial insert (in the conditions described above) one could determinate the characteristics of the contact mechanism in the artificial knee. For example, the trajectories of the contact spot for all three activities are plotted on a sketch of the medial part of the polyethylene insert (see Fig. 2).

Using the cumulative estimator defined in formula (2) the areas were the damage is likely to occurs could be identified from the cumulative distributions plotted in Fig. 3 (the L-shaped region of different colour).

![Figure 3. The damage score map (a) at the contact surface, (b) in the subsurface](image)

A method combining the Finite Element Method for evaluating the contact mechanism in an artificial knee joint with a summation technique based on a damage estimator was successfully used in order to predict the areas were the damage is likely to occur.