FINITE ELEMENT ANALYSIS OF TOTAL DISC REPLACEMENT WEAR

+*Mittelholtz, K; *Pedersen, DR; *Mendoza, SA; #Mayer, HM; #Siepe, C; @Hall, RM; *Brown, TD
+University of Iowa, Iowa City, IA
#Spine Center Munich
@University of Leeds
Kimberly Mittelholtz, 2168 Westlawn Building, Iowa City, IA 52242, Tel: (319)335-7539, Fax: (319)335-7530
kimberly-mittelholtz@uiowa.edu

INTRODUCTION:

In TDR designs involving metal-on-polyethylene bearing couples, long-term polyethylene wear is a substantial concern. Computer simulation of wear, by means of the Archard [1] sliding-distance-coupled formulation, has proven to be a valuable adjunct to physical wear testing for various appendicular total joint replacement implants. The purpose of this study was to implement sliding-distance-coupled wear measurement formulation to the case of TDR, using ProDisc® as an illustrative design.

METHODS:

Manufacturer-provided CAD drawings of the implant (Figure 1) were used as the basis for constructing a FE model of the implant's bearing surfaces (Figure 2). The superior endplate was represented by a rigid concave spherical surface with a radius of 14.6 mm. The polyethylene disc was modeled as a deformable convex spherical cap with a radius of 14.25 mm, and meshed with continuum hexahedral elements. The convex member had an elastic modulus of 1400 MPa and Poisson ratio of 0.3, to reflect the material properties of ultra-high molecular weight polyethylene (UHMWPE). Loading and rotation parameters, according to ISO/DIS 18192-1, were applied to the concave member.

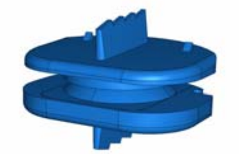

Figure 1. CAD model of the implant

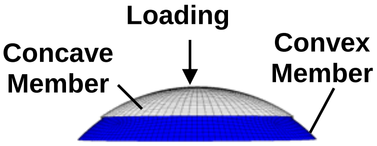

Figure 2. FE model of the bearing surface

Wear depth w per duty cycle at any point (θ,ϕ) on the bearing surface equals the sum of the product of a wear coefficient k, contact stress σ, and sliding distance s (Eqn 1). The wear coefficient used was 1.07×10^{-6} $mm^3N^{-1}m^{-1}$. Contact stress distributions were obtained from the convex member's bearing surface, at 13 discrete instants of the prescribed loading cycle. Sliding distances of points on the concave member's surface were determined from the kinematics of the cycle at the same 13 instants.

$$w(\theta,\phi)=\sum_{i=1}^{\#\,inc} k\,\sigma_i(\theta,\phi)\,s_i(\theta,\phi) \qquad \text{[Eqn 1]}$$

To reflect conformity changes due to progressive wear on the bearing surface of the convex member, adaptive remeshing was invoked by radially repositioning the nodes of the bearing surface. Convergence testing showed that numerically well behaved wear solutions were obtainable for remeshing update intervals of two months. By reapplying the rotations and loads to an updated model with a remeshed convex member, new contact stresses and sliding distances were obtained. This repeated adaptive remeshing process simulated long-term polyethylene wear [2].

RESULTS:

Figure 3 illustrates the cumulative linear wear after 1 million cycles. At the end of one year, the wear rate of the AP-loaded model was 2.92 mm^3/yr, while the non-AP-loaded model was 2.79 mm^3/yr.

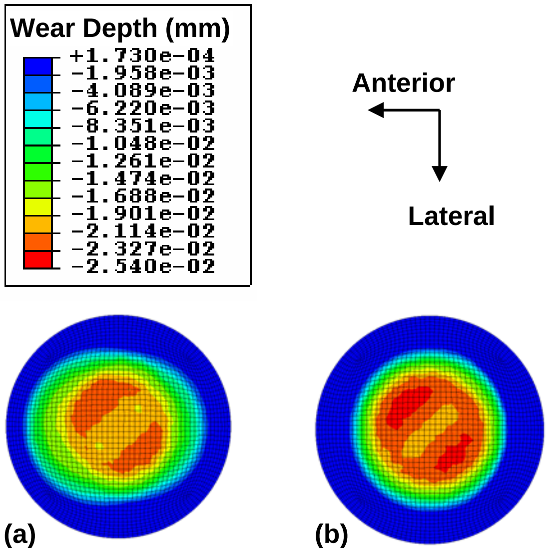

Figure 3. Wear depth after one year **(a)** with AP force **(b)** without AP force

DISCUSSION:

These results suggest that the results of TDR wear testing using physical wear simulators are likely to be moderately different, depending on whether or not an AP loading component is included.

REFERENCES:

[1] Maxian et al., *J Biomech*, **29**(5), 687-692, 1996.
[2] Maxian et al., *J Orthop Res*, **14**, 668-675, 1996.
[3] ISO/DIS 18192-1.

ACKNOWLEGEMENTS:

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