Response to Dr. Robert W. Mann

Gerard A. Ateshian

Dr. Mann's assertion that experimentally-based results trump those of theory is only as convincing as the validity of the results. As Dr. Mann himself acknowledges in his comment, the analysis of the fluid flow in his study was based on a finite element model, not on direct experimental measurements [1]. Only the boundary conditions used for the finite element analysis were based on experimental data. Therefore, their conclusion supporting the weeping mechanism is only as good as their finite element modeling assumptions, which have a major limitation.

The limitation of their study is that ''Strains in the porous layer are assumed uniaxial, i.e., displacements of the matrix are constrained to the vertical (radial) direction . . . '' [1]. It can be shown from the basic law of conservation of momentum that under the assumption of uniaxial displacement along the vertical direction, the gradient in fluid pressure can only vary along that same direction. Thus, from Darcy's law, the direction of fluid flow can only occur in the vertical direction as well. Since the cartilage-bone interface is modeled as impermeable, the only direction in which the fluid can flow is out the surface, to satisfy the conservation of mass. Therefore, the ''weeping'' mechanism appears to be a foregone conclusion when assuming uniaxial displacement as in the model by Macirowski et al. [1].

In contrast, our study, as well as those of Hou et al. [2] and Hlavacek [3,4] allow both axial and radial displacements and reach a different conclusion about the direction of fluid flow. All theoretical models are based on a set of assumptions and we welcome questions about the assumptions we made in our own study. However, we respectfully disagree with Dr. Mann's opinion that his uniaxial finite element results are more compelling than our two-dimensional analysis.

References

[1] Macirowski, T., Tepic, S., and Mann, R. W., 1994, ''Cartilage Stresses in the Human Hip Joint,'' J. Biomech. Eng., **116**, pp. 10–18.
[2] Hou, J. S., Mow, V. C., Lai, W. M., and Holmes, M. H., 1992, ''An Analysis of the Squeeze-Film Lubrication Mechanism for Articular Cartilage,'' J. Biomech., **25**, pp. 247–259.
[3] Hlavacek, M., 2000, ''Squeeze-Film Lubrication of the Human Ankle Joint With Synovial Fluid Filtrated by Articular Cartilage With the Superficial Zone Worn Out,'' J. Biomech., **33**, pp. 1415–1422.
[4] Hlavacek, M., 1993, ''The Role of Synovial Fluid Filtration by Cartilage in Lubrication of Synovial Joints-H. Squeeze-Film Lubrication: Homogeneous Filtration,'' J. Biomech., **26**, pp. 1151–1160.

