FUNCTIONAL IMAGING REVEALS MODEST STRAIN CONCENTRATIONS ASSOCIATED WITH IMPLANT MICROMOTION USING MODIFIED BAK INTERBODY CAGES

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Introduction: Interbody fusion cages are increasingly used in the treatment of spinal disease and injury in order to stabilize movement and promote arthrodesis of the vertebral bodies, but the micromechanics of the interaction between the cage and the adjacent host bone is not fully understood. This information has bearing on post-surgical therapy protocols, prediction of long-term bone tissue changes, and optimization of cage design. In order to gain insight into this problem, we used functional microCT imaging to directly evaluate implant micromotion and full-field vertebral body strains in explanted motion segments from a baboon model. It is believed that functional fusion will be related to the extent of implant fixation, and that specific strain fields will be associated with fused and unfused samples.

Material and Methods: The study involved skeletally mature male baboons instrumented in the lumbar spine with one of three configurations of 11mm dia. x 20mm BAK interbody fusion cages (all procedures followed institutional and animal use and care guidelines). The cages, containing 2, 8, or 12 transverse holes, were randomized among the implant sites. Motion segments including the implants were retrieved 4-months post-op. In order to improve microCT imaging, posterior elements were removed from the specimens prior to testing. Specimens were mounted at the endplates in aluminum platens using PMMA, and placed within a microCT system that allows specimen loading during imaging. Projection images were obtained at approximately 1000 angular increments with no applied load, and at compressive loads of 150N, 300N, and 450N. Subsequent tomographic reconstructions were produced with a 50-micron voxel resolution. Mid-sagittal sections were extracted from the scans and animated through the loading sequence to assess relative motion between implant and vertebral bodies. The motion was quantified by measuring the change in distance between implant and adjacent bone from zero load to 450N compression at both the superior and inferior interfaces. Mid-frontal sections were also extracted in order to define a region of interest for making strain measurements. Digital volume correlation (Bay et al. 1999) was then used to measure continuum-level strains throughout three-dimensional volumes of interest immediately adjacent to the implant.

Results: MicroCT data sets revealed variable amounts of micromotion between the implant and adjacent bone (Figure 1). Presence of organized bone tissue in intimate contact with the implant was associated with fusion of the cage with the adjacent vertebral body (no motion), while radiolucency at the implant interface was associated with lack of fusion (motion). The 8-hole cage design appeared to provide the most consistent fusion (Table 1). Completely unfused and partially fused samples were associated with strain concentrations adjacent to the implant, while fully fused samples showed lower magnitude uniformly distributed strains (Figure 2).

Discussion: The unique aspect of this study is the functional tomographic imaging. In addition to providing detailed information about tissue morphology around the implants, it provides a means for quantifying both implant micromotion and trabecular bone strains. This indicates the immediate status of the implant and suggests adaptations that are likely to occur after longer implantation times.

Conclusion: In this model, fusion was variable. Lack of fusion and partial fusion were associated with scalloped radiolucency adjacent to the implant (motion), while full fusion was associated with intimate bone-implant interface (no motion). Partially and completely unfused samples exhibited higher magnitude strain concentrations adjacent to the implant while fully fused samples showed lower magnitude more uniform strains.

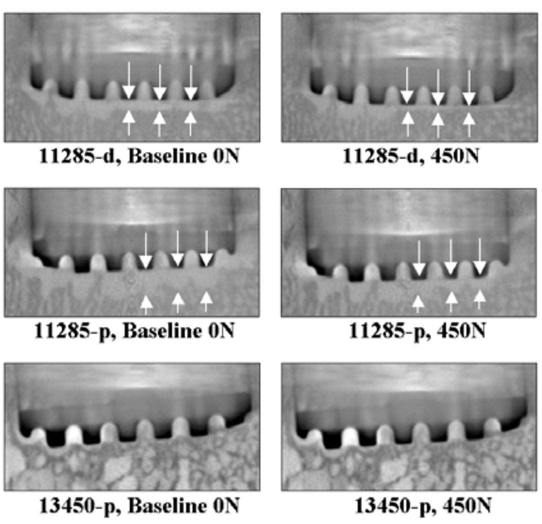

Figure 1 – Mid-sagittal slices through microCT data sets at the bone-implant interface for evaluating micromotion; (top) completely unfused, (middle) partially fused, and (bottom) fully fused.

Table 1 – Implant motion (mm) for each cage group based on functional imaging.

		Relative Micromotion Between Bone and Implant (mm)				
		Sample				
		1	2	3	4	Average
# of Cage Holes	**2**	1.30	0.55	N/A	N/A	**0.93**
	8	0.00	0.60	0.00	0.65	**0.31**
	12	1.00	0.85	1.05	0.00	**0.73**

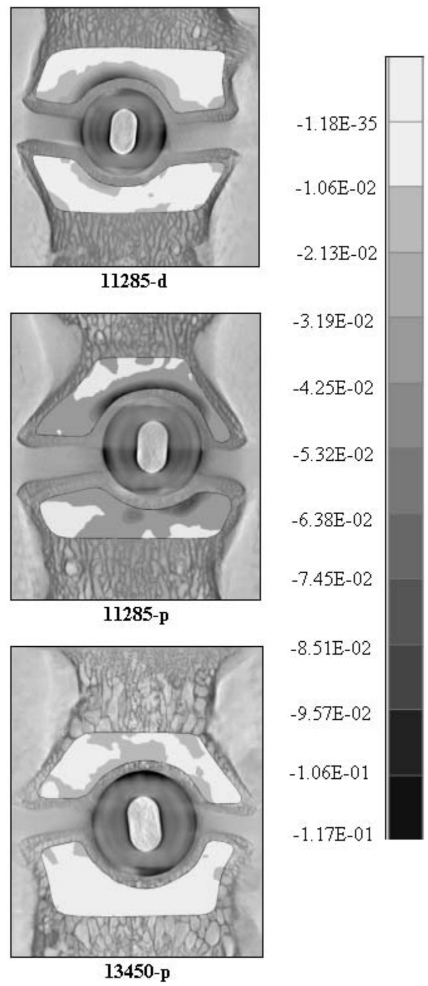

Figure 2 - Minimum principal strain superimposed on microCT data for (top) completely unfused, (middle) partially fused, and (bottom) fully fused specimens.

References:

Bay, BK, et al. (1999). *Experimental Mechanics*, **39**, 217-226.