MESH-MORPHING ALGORITHMS FOR GENERATION OF SPECIMEN-SPECIFIC FINITE ELEMENT MODELS OF RAT TAIL VERTEBRAE

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Purpose: Considerable effort is often required to produce specimen-specific models suitable for finite element modeling. We hypothesize that it is possible to produce accurate specimen-specific models by adapting a pre-existing model using morphing techniques. Here we present two algorithms for morphing and demonstrate their use to quickly prepare specimen-specific models of rat tail vertebrae.

Methods: Two *natural* specimen-specific FE models of caudal rat vertebrae were reconstructed from µCT images following a standard iterative process of semi-automated segmentation and surface and tetrahedral volume meshing. Two methods, automated wrapping (AW) and manual landmarks (ML) were used to deform, or *morph*, one of the natural models (the *source*) onto the other (the *target*). In AW, a triangulated spherical surface was used to wrap source and target, providing a mapping from source to target surfaces. In ML, 108 landmarks were manually placed on corresponding locations on the surfaces of both source and target. The Bookstein method was then used to define a smooth transformation from the surface of the source to the surface of the target. Morphing for the interior of the source was interpolated from the morphing of the surface. The three models of the target (natural, AW-morphed and ML-morphed) were then used to simulate the mechanical response of the vertebra to longitudinal loading. We evaluate the fidelity of the morphing by comparing the distance between surfaces of the natural and morphed models, the number of distorted elements, and the magnitudes of the longitudinal components of the strain fields predicted with the simulations.

Results: Both morphing algorithms were successful in producing models of the target vertebra suitable for FE simulation while preserving the quality of the mesh (Table 1). Whereas AW morphing produced a surface closer to the target, ML guaranteed correspondence of the landmark locations between source and target (Figure 1), which allows for direct comparisons of the biomechanical response predicted with the simulation.

Conclusions: Mesh-morphing techniques allow production of specimen-specific FE models of caudal rat vertebrae. Predictions of deformation, strain and stress of the target vertebra under longitudinal loading have only minor differences between morphed and individually generated models.

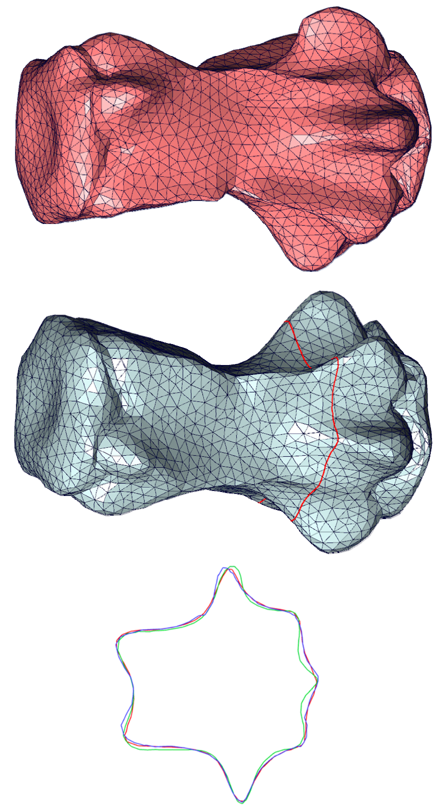

Figure 1 Surfaces of the Source Natural (Top) and Target Natural (Middle) models. Comparison of a cross section of the Target Natural (red line), AW (blue) and ML (green) surfaces (Bottom).

	Mean distance to natural surface	Mean % strain	Nodal difference in % strain. Morph vs. Natural (mean ± SD)	Distorted Elements
Target Natural	-	-4.26	-	0 / 36769
Automated Wrapping	188 µm	-4.04	0.0076 ± 0.346	28 / 54798
Manual Landmarks	322 µm	-4.15	0.048 ± 0.336	9 / 54798
Source Natural	-	-	-	10 / 54798

Table 1