Influence of Mechanical Stimuli in Growth Plate Morphological Evolution during Long Bone Development

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ABSTRACT

The growth plate is a cartilaginous structure that is responsible for long bones growth through a process known as endochondral ossification, which allows continuous ossification of the cartilage within the growth plate. Throughout development, the growth plate experiences several changes in its morphology that include the appearance of interdigitations, known as mammillary processes, and changes in its curvature. We hypothesize that mechanical stimulation alters growth plate mechanical environment, which leads to changes in physeal shape. Thus, in order to test this hypothesis, we developed a mathematical model representing progressive ossification of a simplified femoral epiphyseal geometry, with an initial flat growth plate shape, in response to several mechanical stimuli (shear, Von Mises and hydrostatic stresses, and fluid velocity). Epiphyseal geometry was modeled as a 2-dimensional poro-elastic finite element model that was subjected to dynamic compressive loading. This loading represented cyclic forces from muscle contractions or daily activities. Results show that mechanical loading affects the mechanical environment of the growth plate, and the resulting shapes depend mainly on the mechanical stimulus that was tested. In all tested stimuli, we observed the appearance of both mammillary processes and changes in growth plate curvature; that is, the transition from a flat geometry to a concave one. Based on these results, we concluded that changes in growth plate mechanical environment may lead to alterations in its shape.