

IS THERE A MECHANICAL REGULATION OF BONE FORMATION IN SPINAL FUSION?

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Introduction

Lumbar interbody fusion using cages is one of the most reliable treatment options for degenerative spinal diseases. Currently, many cage designs are available in the market; however none of them is completely successful, as reflected by non-union rates ranging from 7 to 30%. Cages are made of very different materials (e.g. metals, polymers) and they present a large range of morphological configurations (e.g. solid, ring), leading to distinct mechanical conditions within the fusion region. Mechanical conditions are known to largely influence bone regeneration [Klein, 2003] in long bones, however their role on spinal fusion remains largely unknown. The aim of this study was to investigate how the local mechanical conditions (strains, stress, fluid flow) created by different cage designs might influence bone tissue formation during the spinal fusion process.

Methods

We developed an iterative computer model to simulate the time course of tissue formation during spinal fusion. The model included the vertebral bodies, the intervertebral space and a spinal cage (Fig. 1). In each time step, tissue formation was regulated by the local mechanical conditions [Prendergast, 1997] within the regenerating region, determined using finite element techniques. The temporal and spatial evolution of tissue formation was investigated for two different cage designs (a solid and a ring cage) and two different levels of stiffness: 1 (soft) and 100 (stiff) GPa.

Results

Bone formation and maturation started in the most inner region of the intervertebral space and extended over time to the outer region, forming a defined callus shape (Fig. 1a). Model predictions showed a strong influence of cage stiffness and configuration on the fusion outcome (Fig 1b-e). A softer cage

showed a more favourable mechanical stimulation for the regeneration of bone, leading to higher amounts of bone tissue formation. For the stiffer cage, better fusion outcome was predicted with a centered solid cage compared to a ring cage (Fig. 1c & e). Stress shielding was observed in the central hollow region of the ring cage, which was more pronounced for the stiffer cage (Fig. 1c).

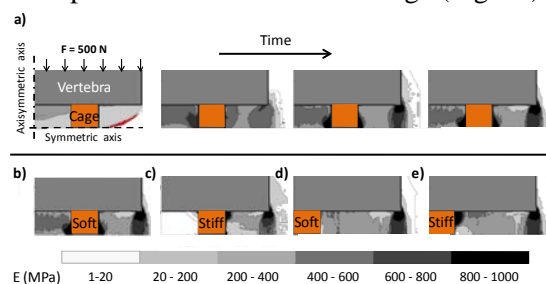


Figure 1: a) Prediction of bone formation during spinal fusion. b-e) Fusion outcome with two different cage designs (ring and solid) and two levels of stiffness (soft and stiff).

Discussion

Mechanical conditions have an influence on bone regeneration. We investigated the effect of the mechanical environment created by different cage designs on the fusion outcome. We observed that cage design, both morphology and material properties, play a key role in the mechanical conditions within the fusion region and therefore the time course of the fusion process. In the future such understanding may be used to optimize the design of spinal fusion implants to guide and foster bone formation and inter-body fusion.

References

- [1] Klein et al., J Orthop Res, 21: 662-669, 2003.
- [2] Prendergast et al., J Biomech, 30, 539-548, 1997.