Effect of rate and frequency on bone regeneration during distraction osteogenesis

H Isaksson, CC van Donkelaar, R Huiskes, K Ito
Eindhoven University of Technology, Department of Biomedical Engineering

Introduction

- The aim was to use a mechano-regulation algorithm based on deviatoric strain and fluid flow to simulate bone regeneration during distraction osteogenesis, and evaluate the influence of distraction rate and frequency on the bone regeneration pathways.

Methods

- The model was based on an earlier experimental study that evaluated bone segment transport in ovine tibial shaft defects (20, 45 mm) over an intramedullary nail (Fig. 1a).
- Distraction started at post operative day 1 with rate of 1 mm/day until defect was closed. Additionally, rates of 0.5 mm and 0.25 mm/day and frequencies of 0.5 mm 2 times/day and 0.25 mm 4 times/day were evaluated.
- Depending on the magnitudes of deviatoric strain and fluid velocity calculated in the FE, cells that migrated and differentiated into fibroblasts, chondrocytes or osteoblasts (Fig. 2). Cell type dependent matrix production was simulated by adding fixed charges and allow swelling. Tissues were modeled as linear poroelastic.

Results

- The predicted bone formation pattern due to changes in distraction rate or distraction frequency was overall similar to experimental observations by others (Fig. 4 & Fig. 5).

Discussion

- Mechano-regulation based on deviatoric strain and fluid velocity can predict bone formation during DO.
- Lower distraction rate (< 1 mm/day) increased the time needed for complete ossification. Higher distraction frequencies (2 or 4 times/day) decreased time needed for complete ossification. Hence, were beneficial on the bone regeneration process.
- Decreased rate or increased frequency resulted in higher relative amounts of intramembranous bone formation compared to endochondral bone formation via cartilage intermediate.
- This promising model might be used to optimize and evaluate variations in DO treatment protocols.

References