Effect of rate and frequency on bone regeneration during distraction osteogenesis

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Introduction

- The aim was to use a mechano-regulation algorithm based on deviatoric strain and fluid flow[1] 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[2] 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 1mm/day until defect was closed. Additionally, rates of 0.5mm and 0.25 mm/day and frequencies of 0.5mm 2 times/day and 0.25mm 4 times/day were evaluated.

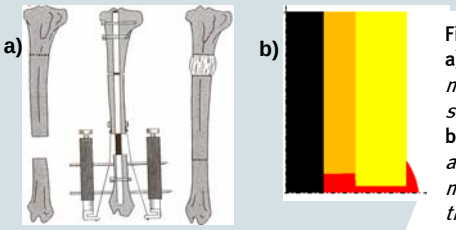

Figure 1 a) *Experimental model for bone segment transport* b) *2D axisymmetric FE model of ovine tibia.*

- Depending on the magnitudes of deviatoric strain and fluid velocity[1] 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[3]. Tissues were modeled as linear poroelastic.

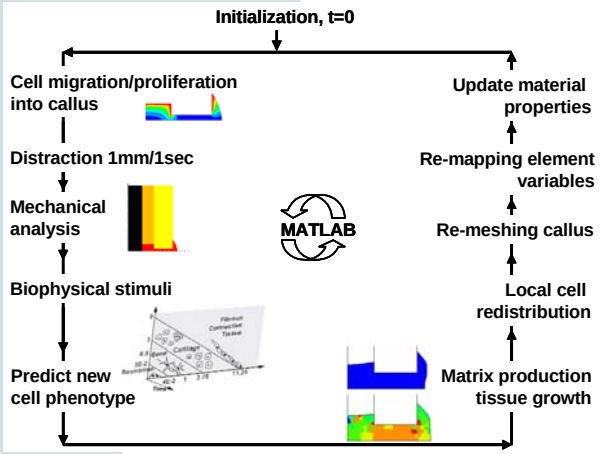

Figure 2 Model to predict tissue differentiation.

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)

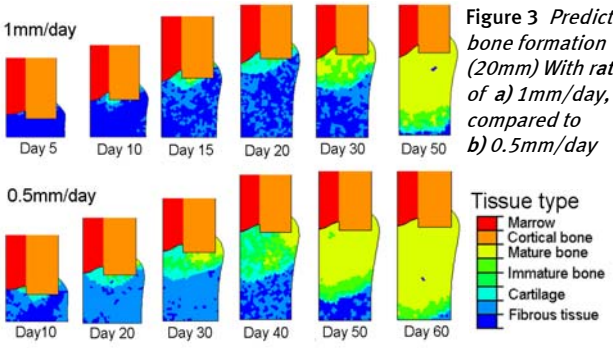

Figure 3 *Predicted bone formation (20mm) With rates of* ***a)*** *1mm/day, compared to* ***b)*** *0.5mm/day*

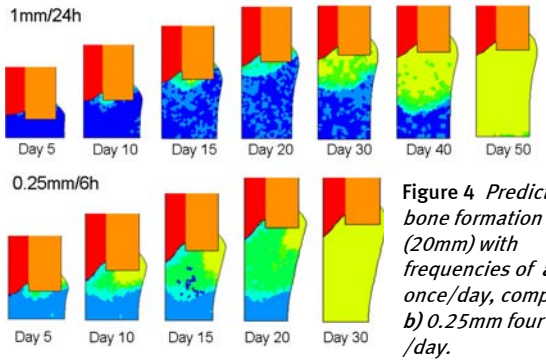

Figure 4 *Predicted bone formation (20mm) with frequencies of* ***a)****1mm once/day, compared to* ***b)*** *0.25mm four times /day.*

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

[1] Lacroix D, J Biomech, 2002 [2] Brunner UH, CORR, 1994
[3] Wilson W, J Biomech Eng, 2005