Novel Mechanobiological *in silico* Model for Osteoporotic Bone to Investigate Cementless Hip Implant Osteointegration

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Summary

This study introduces a novel mechanobiological computational model to simulate osteoporotic bone osteointegration. The model integrates mechanical loading and biological activities that occur within the bone during femoral hip implant integration. The dynamic model simulated 28 weeks of healing in both a healthy and osteoporotic patient. Future work will use this model to design improved cementless hip implants for osteoporotic patients.

Introduction

Approximetly 500 million people are dignosed with osteoporosis worldwide resulting in 2.7 million fractures in the hip joint [1]. Total hip replacements (THR) are commonly used for treating hip fractures, especially in osteoporotic patients where osteointegration is often impaired [2]. While cemented implants have been widely used, they pose risk for long-term aseptic loosening which is the cause of 66% of revision surgeries [3]. There is a need to explore cementless implants to better understand osteointegration in osteoporotic bone and improve implant longevity. Mechanobiological models for predicting bone growth have been developed for healthy bones [4], however models for osteoporotic bone remodeling have not yet been developed. This study aims to develop a mechanobiological model to predict osteointegration in osteoporotic bone simulating post THR cases.

Methods

A computer model adapted from Alshammari *et al.* [4], was developed to simulate osteoporotic bone osteointegration, as shown in **Figure 1.**

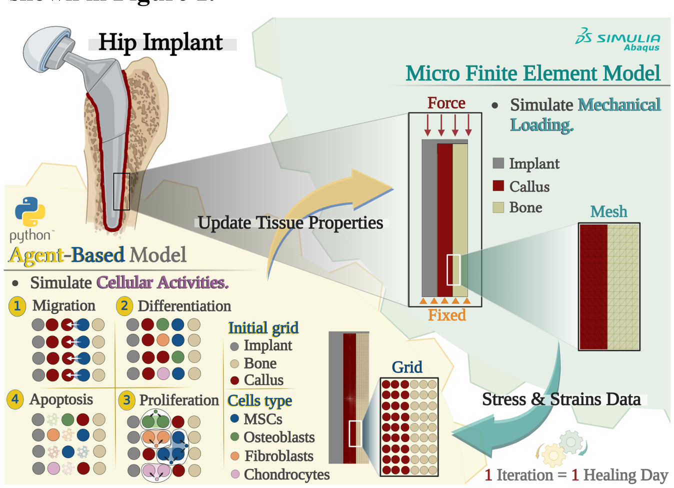

Figure 1: Mechanobiological model showing the iterative workflow between the finite element and agent-based methods.

The computer mechanobiological model implements the finite element method (Abaqus/ CAE 6.18) coupled with an agent-based cell model (Python 3.13). Cell behaviour, bone formation and mechanical stress was calculated for a 28-week duration for a healthy and osteoporotic THR femoral implant.

Results and Discussion

Differences in bone formation between healthy and osteoporotic cases can be observed in **Figure 2**.

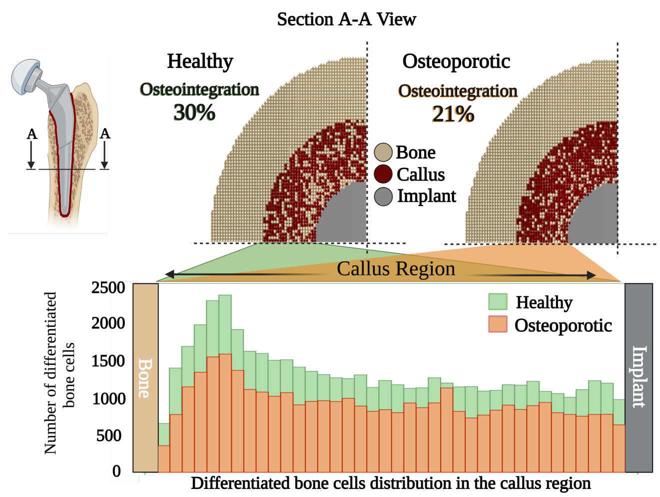

Figure 2: The bone formation in the callus region after 28 weeks of osteointegration (osteoporotic bone typically has a more porous structure and reduced bone formation capacity).

The model shows a 9% reduction in bone formation for the osteoporotic case compared to the healthy case, which is similar to the real world mechanobiology [5].

Conclusions

This study produced a novel mechanobiological model for osteoporotic bone osteointegration with an THR implant. The model represented a real case scenario showing differences in bone formation and behaviour in healthy and osteoporotic bone. Future work could use the model to incorporate features such as drug impregnated hydrogel tissue scaffolds into THR designs, as they have been found to enhance osteointegration in osteoporotic bones [2].

References

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