**THE USE OF GROOVED AND POROUS COLLARS IN PROMOTING EXTRA-CORTICAL BONE GROWTH: AN EXPERIMENTAL AND FINITE ELEMENT STUDY**

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## INTRODUCTION

Bone cancer occurs mainly in children and adolescents below the age of 20. A reconstruction using massive prosthesis is required to restore limb functions after the removal of the tumor [1]. The long-term survival of the implant depends on the successful osteointegration of the bone with the prosthesis, but mechanical fixation in patients is difficult to predict and aseptic loosening is the primary reason for implant failure [2]. The use of a hydroxyapatite (HA)-coated grooved collar has been demonstrated to encourage extra-cortical bone formation (Fig. 1), leading to an improved survivorship of the implant from 75% to 98% at 10 years [3]. However, osteointegration of the HA collar only occurs in 70% of all cases. Therefore, it is necessary to develop time-dependent simulation models and algorithms to predict the extent of adventitious bone formation in the grooved collar, and to use these algorithms to evaluate the performance of 3D-printed porous collar designs, which is believed to improve fixation.

## METHODS

A Finite Element (FE) model was used to approximate the geometry of the femur at the diaphysis, using data from computed tomography (CT) scans. The bone was virtually implanted with different collar designs made of commercial grade titanium and assigned isotropic material properties. A bone remodeling algorithm based on strain energy density, where the rate of bone adaptation is controlled by the difference in the current strain energy per unit mass against a reference value [4], was combined with a new concept of bone osseo-connectivity to determine the external shape changes of bone developing in the soft tissue envelope. Loads associated with typical walking conditions were applied to the model. The algorithm was implemented using custom-written subroutines in a FE solver (Marc 2015). The bone adaption results for the grooved collar designs were verified against clinical studies at different time stages. No patients were recalled specifically for this study; all data was obtained from postoperative radiographs from previous retrospective studies [3].

## RESULTS AND DISCUSSION

The FE results for the grooved collar were shown to correspond well with the process of bone growth (Fig. 1). Remodeling occurred primarily at the base of the collar and the bone stock, and bone ingrowth was predicted into the first row of grooves, matching with radiological observations. Bone growth at the shoulder of the implant and the collar was also predicted, due to the presence of high stress concentrations, which is not seen clinically. Soft tissue remodeled to an elastic modulus of about 2GPa, a typical value of trabecular bone.

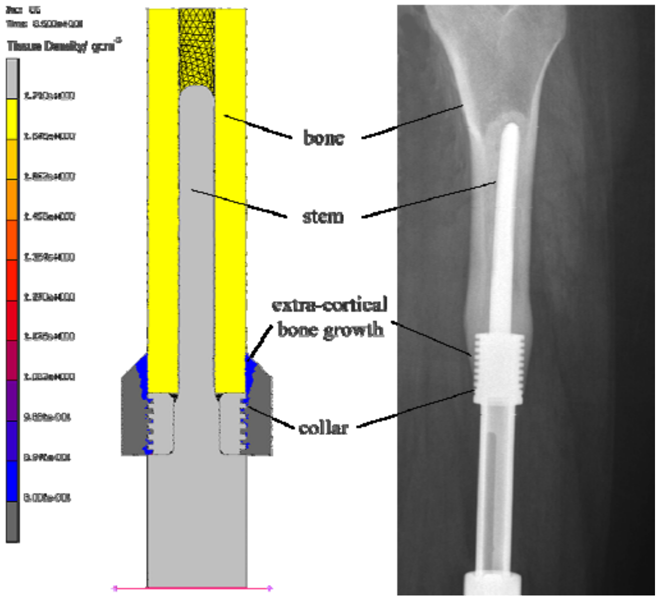


**Figure 1**: Left: Predicted bone growth (blue) with elastic modulus of approximately 2 GPa around an implanted grooved collar (light grey) and cortical bone shaft (yellow). Right: Good correspondence with X-ray results taken 12 years after implant insertion, where there was adventitious bone formation and good osteointegration with the HA-coated collar.

Comparing the performance of the porous collar design with the grooved collar, the former has a lower overall structural stiffness and promoted the formation of a larger volume of bone with higher elastic modulus within the porous structure.

## CONCLUSIONS

The developed simulation algorithm allowed the assessment of the performance of third generation implant designs before they are manufactured, reducing the need for animal testing. The modelling approach thus shows potential to be developed further for the optimization of implant collar designs and for predicting bone ingrowth into porous structures.

## ACKNOWLEDGEMENTS

This work was funded by Orthopaedic Research UK (grant #515).

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