EVALUATING THE APPROPRIATE SCREW FASTENING TORQUE IN CORTICAL BONE - A VALIDATED FINITE ELEMENT MODEL

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Introduction

Osteoporosis is the most common bone disease, contributing to over 3.5 million fragility fractures each year in the EU [1]. Managing these fractures costs €37 billion each year with a 25% increase predicted by 2025. Fracture fixation in reduced density osteoporotic bone is a surgical challenge and failures are common, occurring in 15-40% of cases [2]. It is hypothesised that the torque used to fasten bone screws during fracture fixation significantly influences the holding strength of screws and thus the likelihood of fixation failure.

The aim of this study was to develop a validated finite element model capable of predicting the effect of different insertion torques on the holding strength of cortical bone screws for a range of bone densities and cortical thicknesses.

Methods

Experimental tests (n=100) were conducted to evaluate cortical screw pull-out strength using bovine tibiae (4-5 months). The bone density (assessed using CT-images) and cortical thickness of each specimen were recorded. Screws were inserted using a range of insertion torques, and the pullout strength was measured for each (Instron 5967, High Widcomb, UK). Additionally, the effect of stress-relaxation was investigated by imaging the surface of the bone surrounding the screw immediately after screw fastening at logarithmic intervals up till 17 hours post-fixation (Fig.1). Strains were evaluated using digital image correlation (Ncorr v1.2, G.I.T., USA).

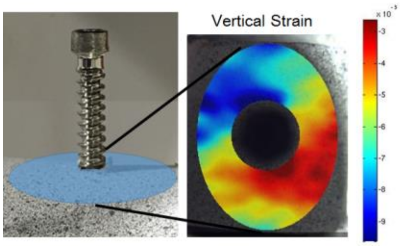

Figure 2: Experimentally measured surface relaxation strains around the screw at 17 hours post-fixation.

An axisymmetric finite element (FE) model was developed based on the experimental tests (Fig.2a). An idealized screw geometry incorporating screw threads was based on CT-images (Simpleware ScanIP, Exeter, UK). Using a maximum tensile strain failure criteria, (considering the tensile yield strain of cortical bone to be 1.0%), the FE model was used to predict the pull-out strength for the variables considered (Ansys 15.0, USA).

Results

Significant stress relaxation was found to occur post-fixation, with the strain distribution appearing to be related to the proximity of the thread to the surface (Fig.1). There was good agreement in predicted and measured pullout force versus mean cortical thickness (Fig.2b).

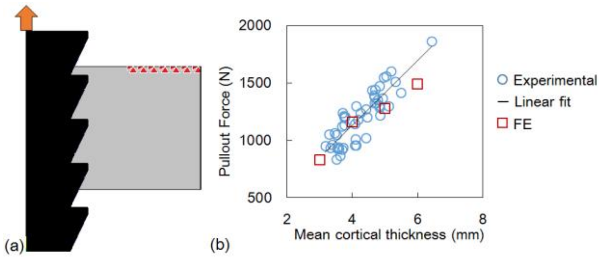

Figure 2: Experimentally measured pullout forces and FE predictions for varying cortical thickness using screws inserted with 1Nm torque.

Discussion

Although relatively simple, the developed validated model is capable of predicting cortical bone screw pullout strength for a range of bone densities and cortical thicknesses. This study found that significant stress-relaxation occurs post-fixation, in line with previous literature [3]. Currently, the effect of screw insertion and stress-relaxation is not included in the models. The relationship between fastening torque and axial screw preload is well defined [4], thus screw insertion torque can be reasonably approximated in this way. We aim to incorporate both of these effects to understand the post-fixation screw mechanics and further improve our modelling predictions. Our intention is to develop this model into a patient-specific tool providing surgeons with guidance regarding appropriate screw fastening torques for different bone qualities. This tool has the potential to enhance construct stability and reduce the incidence of failures. The developed model could also be used as a design tool for screws.

References

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Acknowledgements

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