DEVELOPMENT OF A CONTINUUM AND FREE BOUNDARY CONDITION MODEL OF THE PELVIS FOR ACETABULAR FRACTURE PATTERN PREDICTION

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INTRODUCTION

The shape of the pelvis, its bone density distribution, mechanical properties and trabeculae orientation depend on its muscle attachments and loads transferred. This gives rise to a high diversity of mechanical interactions and an irregular geometry [1]. Fractures of the acetabulum occur when there is an unusually high interaction force between the femoral head and the acetabular socket, usually originated by high impact crashes. Because of the broad range of motion of the femur, there is an infinite number of impact points and directions of force transmission. This results in a wide scope of possible fracture lines and anatomical features affected, complicating their reduction. It is believed that the structural properties of the trabecular bone have a significant role to play in predicting fracture patterns and informing surgical management.

In free boundary condition modelling of the pelvis, no fixed boundary conditions are applied to the bone and the pelvis is supported by its ligaments and muscles alone, becoming a more accurate representation of the *in vivo* environment [2].

Some pelvic studies assume the bone to be isotropic with an inhomogeneous distribution of properties extracted from CT data [1]. This assumption does not explain the directionality of the trabecular structure or the orthotropic properties which have been verified [3]. 2-D modelling of the femoral head with orthotropic bone properties has been proven to produce a good match with the trabecular orientation of the bone in its physiological state [4].

This abstract introduces a novel finite element modelling method in which the bone is considered to be an orthotropic material that adapts its structure to match local stimuli.

METHODS

The proposed continuum model aims to describe trabecular bone density distribution and structure within the pelvis. At the moment, verification of the optimisation process is being undertaken by modelling trabecular bone cubes, where a cube composed of 1000 elements with the same orthotropic material orientations (aligned with the global axis system) and properties (Young's Modulus, Shear Modulus and Poisson's Ratio) is submitted to pre-defined boundary conditions and loads through an iterative process until it reaches a state of convergence.

After each iteration, the principal strains of each element are extracted from its centroid. The new material orientations for each element are rotated to match with the orientations of the principal strains found and the material properties are also updated proportionally to the absolute value of these principal strains (Figure 1). When the absolute values for the minimum and maximum principal strains are within 1000-1500 µstrain (which corresponds to the remodelling plateau without bone loss or gain) [5] or when the difference between *step n-1* and *step n*'s orientations is negligible the model achieves a convergence state, after which the material properties will remain unchanged.

Comparison of calculated bone material distribution with expected results provides verification for the model.

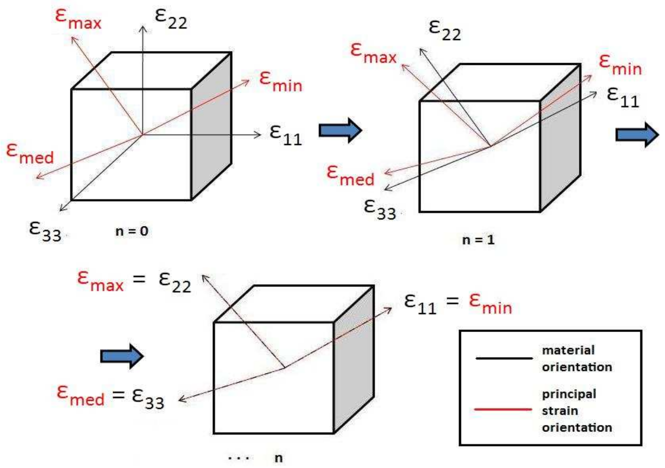

Figure 1 – Scheme of the evolution of an element's material orientations throughout n steps of the iterative process.

RESULTS AND DISCUSSION

Preliminary 2D and 3D results for a bone square and cube show good agreement with known optimised structures. Algorithm improvement and optimisation is currently being undertaken and this model seems to be adequate and feasible for continuum free boundary condition modelling of the pelvis.

CONCLUSIONS

Although in an initial stage of development, early results of the continuum model have shown good conformity with bone material properties distribution.

Development of this algorithm and its application to finite element modelling of the pelvis will help in assessing directionality of the trabecular structure, allowing acetabular fracture pattern prediction. A better mechanical understanding of these fractures will be achieved, contributing towards the improvement of the existing surgical approaches, devices and instruments used to reduce and fixate the pelvic fragments.

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