SUBJECT-SPECIFIC FE MODEL FOR THE PREDICTION OF THE RELATIVE MICROMOTION IN A TOTAL HIP IMPLANT: VERIFICATION AND VALIDATION

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INTRODUCTION

The most common reason for the aseptic loosening of cementless hip stem is the lack of primary stability as the presence of an excessive relative micromotion at the bone-implant interface [1]. Despite pre-clinical validation has remarkably improved over the last few years, some important factors affecting implant biomechanics have still to be considered. Most of the previous numerical studies on hip arthroplasty were based on the solid model of a composite femur replica. However, subject-specific factors (skeletal anatomy, mechanical properties, implant position) are needed to produce helpful outcomes for clinical practice. In addition, these models were developed using time consuming structured meshes frequently lacking of careful verification and validation phases.

Aim of the present work is the development of a Finite Element (FE) model of an implanted femur taking into account the specificity of subject as well as the planned surgery technique parameters.

Specific aims are the verification of the numerical accuracy of the FE model and the analysis of the predicted relative micromotions compared to experimental results (validation).

METHODS

The 3D model of an intact cadaveric femur, taken *in-vivo* for clinical purpose, was generated from the CT dataset using a previously validated procedure. A linear convergence test on seven meshes with increasing refinement levels was performed to ensure the numerical accuracy of the model. Afterward, the position of an anatomic cementless hip stem (ANCAfit, Cremascoli-Wright, Italy) inside the femur was defined by a skilled surgeon using a pre-operative CT based software (Hip-Op, B3C, Italy). Surgical parameters and hip stem geometry were then imported within the FE model. An unstructured mesh was generated for both femur and hip stem consisting of tetrahedral elements (Figure 1*a*). The coefficient of friction was set to 0.3. Frictional contact was modeled at the bone-implant interface by means of face-to-face contact elements.

The peak compenetration was recorded since it must be very small to get a good level of numerical accuracy. The validation process ensured that the numerical model accurately predict the physical phenomenon it was designed to replicate. This was assessed by comparing the predicted history of sliding micromotion at the femur calcar level to *in-vitro* experimental measurement of Intra-operative Stability Assessment Console (ISAC) [2] replicating the same boundary conditions (Figure 1*a*). Two indicators were selected to judge the quality of the model: the root mean square error and the peak error of predicted micromotions.

RESULTS AND DISCUSSION

Over the seven generated meshes, the percentage error in energy norm and the differences in terms of stress, strain and displacement were less than 2.2%. The model that guarantee the best compromise among computational time and accuracy was chosen (40460 elements). The peak compenetration was 3.2 microns, less then previously reported best value [3].

The model predicted the sliding micromotions measured experimentally with an average (RMS) error of 12 μm and a peak error of 21 μm (Figure 1*b*). The errors are comparable to those reported in studies with synthetic femurs and clearly acceptable for most applications. The different pattern of predicted versus experimental micromotions is explainable through a small volume of very soft cancellous bone in the femoral endosteum that may exceed the yield strain limit, e.g. 0.78% (Figure 1*b*). This hypothesis is confirmed by other measurements on different cadaveric femurs that have shown a similar pattern of experimental micromotions.

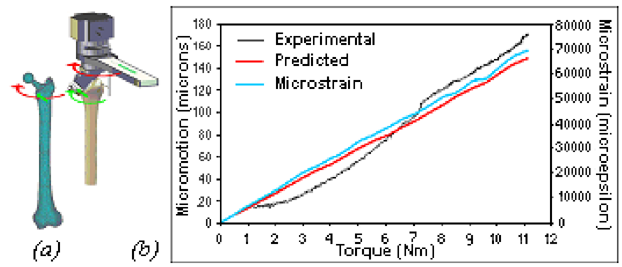

Figure 1: *(a) FE model and the applied boundary conditions compared to experimental set-up used as benchmark problem; (b) Predicted and experimental micromotions over the applied torque. Peak microstrains over the entire FE model are also reported.*

CONCLUSIONS

Verification and validation are necessary preliminary steps to consider any finite element model predictions of scientific value. Using the method proposed it was possible to asses the confidence of predicting the bone-implant relative micromotions account for the patient and surgeon. Furthermore, unstructured mesh was proved to have the same degree of accuracy of the more time-consuming structured meshes.

REFERENCES

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