EVALUATION OF THE INFLUENCE OF THE EMBEDMENT SURFACE GEOMETRY ON RESULTS OF FINITE ELEMENT HIP STEM ANALYSES

Christian May, Matthias Büsse, Andre Butscher

RMS Foundation, Bettlach, Switzerland

Introduction

To predict stresses in femoral stems occurring during tests according to ISO standards [1] and to allow for design comparisons between different stems, Finite Element Analyses (FEA) are commonly employed (e.g. [2]). However, such studies generally assume plane embedding material surfaces on the top, neglecting the curved nature of such surfaces occurring upon usage of many common embedding materials in experimental testing due to capillary forces. The aim of this study is twofold: (1) to assess the error incurred by the assumption of a flat embedding surface and (2) to develop a model allowing to obtain realistic simulation results using a plane surface at an appropriately chosen level.

Methods

A commercially available femoral stem implant has been embedded in PMMA (Young's modulus E=3.2 GPa, Poisson ratio ν=0.4) and scanned with a 3D-scanner (100-Optics), resulting in a model as depicted in figure 1.

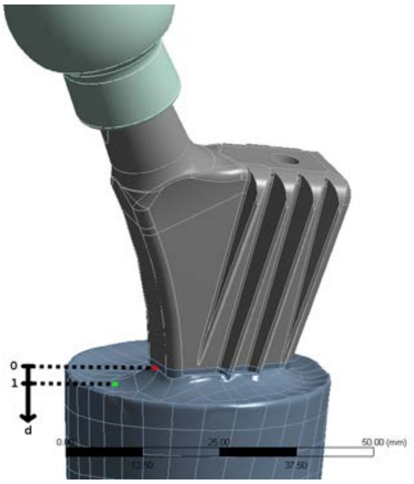

Figure 1: Model of the embedded femoral prosthesis as acquired from the 3D scanner.

A dimensionless parameter d has been introduced to characterize a height level, where 0 denotes the highest level of the scanned PMMA embedding (marked red), while 1 coincides with the lowest point of the scanned surface (marked green). A parameter study has been performed by setting up FEA simulations using plane embedding surfaces at levels varying from d_{min}=0 to d_{max}=1 with a static load of 2300N applied as defined in [1]. The results were then compared to simulations of the scanned exact PMMA surface.

Results

For a given largest cone diameter of 43 mm, comparing the exact geometry to plane surfaces at a level d, the equivalent stresses and total displacements are best represented at d between 0.3 and 0.4.

The maximum error due to an inappropriate choice of the plane amounts to 11% in the maximum equivalent stress and 41% in the displacement.

For illustrative purposes, the equivalent stresses at two points on the stem, located one millimeter above the top PMMA level, are plotted in figure 2.

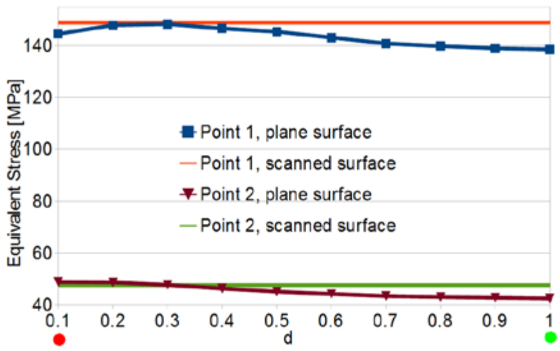

Figure 2: Equivalent stresses occurring at two points on the stem in the plane surface models compared to the exact geometry model.

Discussion

The curved geometry of the embedding material should not be neglected and can be represented by a plane surface at an appropriately chosen level. Further studies should focus on the influence of the assumed bonded contact as well as on the influence of PMMA material properties. We thank A. Niederhauser (BFH-TI Biel) for performing the 3D scans.

References

[1] ISO 7206-4

[2] M. Pekedis, H. Yildiz, J. Biomedical Science and Engineering, 2011, 4, 643-650