DIGITAL VOLUME CORRELATION OF BONE-SCREW INTERFACE AT DIFFERENT TIGHTENING LEVELS

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Introduction

Stripping during screw insertion occurs with an incidence as high as 50% [1]. With an increase in age and osteoporosis, overtightening is more likely as surgeons try to achieve torques similar to that observed in young healthy bone. Stripping torque can be predicted based on the torque at head contact [2]. The question remains however, "how tight is tight enough?".

Due to the diffusion of *in situ* biomechanical imaging (mainly via micro-CT), digital volume correlation (DVC) has become a powerful tool to measure full-field internal deformations in trabecular/cortical bone [3] and bone-biomaterial systems [4]. This ongoing study uses a custom developed computer-controlled screw insertion device to perform time-elapsed micro-CT imaging of the bone-implant interface, in combination with DVC. The aim is to quantify the deformation of the trabecular bone at each rotation step with increased tightening torque.

Materials and methods

Excised human femoral heads were evaluated. Cancellous lag screws (7.0mm outer diameter) were inserted by step-wise tightening between head contact and stripping using a novel testing device within the microCT scanner [5] (Skyscan model 1076, Skyscan-Bruker, Belgium). At each time point, micro-CT datasets (resolution 17 µm/voxel) were obtained of the bone-implant interface. Insertion torque, compression under the screw head and angular rotation were simultaneously measured throughout insertion.

The screw was masked out from the micro-CT images ("CTAnalyzer", Skyscan-Bruker, Belgium). DVC ("DaVis 8.3", LaVision, Germany) was then used for registrations of the scans at two different tightening levels (60% and 100% of the difference between head contact and maximum torque) with the reference scan (head contact), providing the full-field strain developed at the bone-screw interface. Strain uncertainties were computed from sequential scans of a volume of interest distant from the screw region. Error minimization with sufficient spatial resolution was achieved with a multi-pass approach and final sub-volume of 64 voxels [3].

Results

DVC was able to compute the strain experienced by the bone tissue around the screw for the two different tightening levels. Significant deformation occurred within the peri-implant bone, decreasing radially (Figure 1). Depending on the region, the calculated principal tensile strains ranged from 0 to ~20000 µε for the 60% tightening and up ~50000 µε for the maximum tightening (Figure 1).

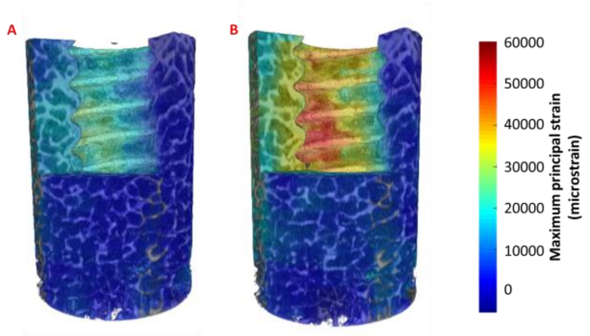

Figure 1: Principal tensile strain distribution obtained by using DVC on micro-CT scans of the trabecular bone around the screw, for tightening levels of 60% (A) and 100% (B). External diameter of the trabecular volume of interest depicted: 11mm.

Discussion

Our preliminary findings indicate that during screw tightening, most of the deformation occurs in trabeculae close to the screw and decreases radially, in accordance with the finite element predictions reported in literature [6]. The local strains calculated by DVC suggest that at 100% tightening, areas of bone tissue in contact with the screw experienced yielding [7]. Interestingly, the magnitude of maximum local strains appears to be higher than the yield strains for bone reported in the literature [7].

DVC was able to couple deformation visible at the bone-screw interface with the strain field produced in trabecular bone, at different levels of tightening. This procedure can be useful for validation of finite element models in future.

References

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