

FEASIBILITY OF 3D MICROMOTION MEASUREMENT AROUND A LOADED HIP STEM USING μ CT IMAGING

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INTRODUCTION

It has been established that primary stability of femoral stems is a determinant of the clinical success of cementless total hip arthroplasty [1]. Excessive interface micromotions may lead to a peri-implant fibrous tissue formation resulting in aseptic loosening of the implant [2]. The effect of micromotion on the tissue outcome remains still unclear. However, it is becoming increasingly clear that interstitial fluid flow is the primary mechanism by which bone cells perceive changes in their mechanical environment [3]. Therefore, to estimate the interstitial peri-implant fluid flow, a detailed measurement of simultaneously normal and tangential micromotion, is required.

The objective of this study is to assess the feasibility of the micromotion measurement on human cadaveric femur with micro computed tomography.

METHODS

A sps-standard hip stems (Symbios Orthopédie) was implanted in a fresh human cadaveric femurs by a surgeon following standard clinical practice. Iron filings were placed on the surface of the implant to measure the micromotion. The implant was loaded on the neck of the implant close to the center of the femoral head at peak walking load [4]. The load was applied with a mechanical device designed for the purpose (Figure 1). The femur was cemented distally to the loading device.

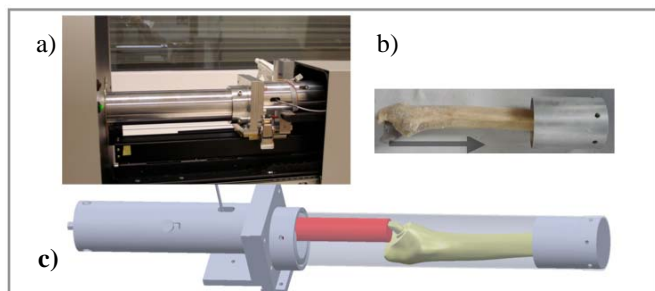


Figure 1: a) Loading device mounted on the μ CT scanner. b) femur cemented to the base of the loading device, arrow indicates direction of load, which is applied on the neck of the implant. c) sketch of the loading device, with the loading piston in red.

For various loading conditions the micromotion of the iron filings was measured with a SkyScan1076 in-vivo micro-CT scanner. We limited the scanning to a section of 20mm in length, at a low resolution mode of $(36\mu\text{m})^3$ of voxel size. The applied load was measured continuously with a calibrated load cell. The duration of one scan was approximately of 20 minutes. The images were reconstructed with Skyscan software and analyzed with Mathematica 7. For all loading cases, the implants were mapped to the initial nonloaded implant position by minimizing the distance between the implant reference points, obtaining thus, the rigid body transformation (RBT)

[5]. The reference points were obtained by measuring the geometric centerline of the implant. The corresponding matching points between scans were those that minimized the residual of RBT minimization method.

RESULTS AND DISCUSSION

In (figure 2.a) a 3D plot of the filings, filtered from the μ CT data, is shown together with the implant centerline. Due to the irregular shapes of the filings, the error of the iron filing's position was estimated of $\pm 50\mu\text{m}$. The filing's motion detected was as high as $200\mu\text{m}$ (figure 2.b). However, a higher resolution is needed to study quantitatively the micromotion along the peri-implant. To resolve the issue, spherical beads will be used instead of filings, as in Roentgen Stereophotogrammetric Analysis, the resolution might surpass the voxel size.

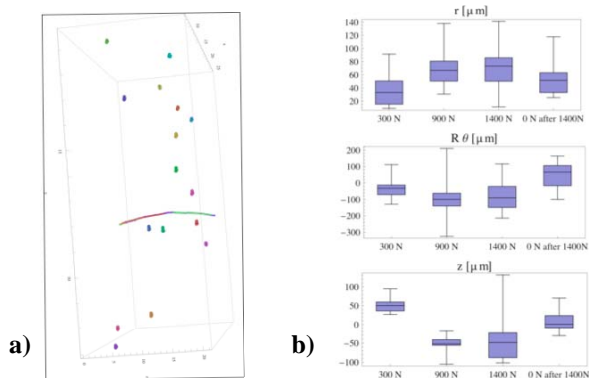


Figure 2: a) 3D plot of mapped implant centerlines and iron filings for different loads. Different colors represent different iron filings. b) Iron filings displacement distribution in the direction of \hat{e}_r , \hat{e}_θ , \hat{e}_z . with \hat{e}_z in the direction of the implant axis. For 300N, 900N, 1400N and 0N after the 1400N load respectively.

CONCLUSIONS

This new technique for measuring μ motion using μ CT imaging, is promising as it enables to measure the displacement of loosely placed and bound particles round the implant in 3D during loading in a non destructive manner. However, for future experiments, a higher resolution will be used for the μ CT imaging, and spherical particles used instead of filings.

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REFERENCES

1. Kobayashi et al. J Bone Joint Surg, **79**:583-9, 1997
2. Soballe et al. J Bone Joint Surg Br, **75**:270-8, 1993
3. Riddle et al. J Orthop Res **27**:143-9, 2009
4. Bergmann et al. J Biomech **34**:859-71, 2001
5. Challis. J Biomech **28**:733-737, 1995