IN-VITRO POST-OPERATIVE STEM STABILITY USING COMPOSITE AND CADAVERIC MODELS

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INTRODUCTION:
Immediate postoperative stability of cementless hip stems is one of the key factors for the long-term success of total hip replacement. Good initial stability promotes early osteointegration between the implant and the host bone, leading to a better fixation over time. The ability to discriminate between stable and unstable stems in the laboratory constitutes a desirable tool that could allow the identification of unsuitable stem designs prior to clinical trials. The use of composite femora for stability investigations is wide spread (Maher et al., 2001 and 2002, Liu et al., 2003) even if their use in this application is yet to be validated. The gross mechanical properties of composite femora are well known and have been found to be comparable to those of cadaveric femora (Cristofolini et al., 1996), however post-operative stem stability is dictated by the type of material directly supporting the stem rather than the mechanical properties of the whole bone. This study aimed at establishing whether Sawbones® composite femora are suitable for the assessment of migration and micromotion of a cementless hip stem.

METHOD:
The stability of six size 7 SL Plus stems (PLUS Endoprothetik AG, CH) implanted into Sawbones® was compared to that of five SL Plus stems implanted into cadaveric femora. Ethical approval was obtained for the harvest and use of cadaveric material. Stability was assessed in terms of micromotion and migration. Micromotion was defined as the recoverable movement of the implant relative to the bone under cyclic loading, a function of the elasticity of the bone-implant construct. Migration was defined as the non-recoverable movement of the implant with respect to the surrounding bone, and reflects the visco-elastic behaviour of bone as well as micro-damage caused by the implant to the material in its immediate surroundings.

The movement of the implant with respect to the surrounding bone was monitored at two different locations on the lateral side of the stem by means of two custom made transducers (Figure 1) based on the concept described by Berzins et al. (1991).

![Figure 1: Transducer positions and local co-ordinate system adopted for this study.](image)

Each femur was tested in two different loading configurations: single leg stance and stair climbing using a pelvic substitute with abductor strap (Tanner et al., 1988). During single leg stance (SLS) the femur, positioned in 11° of adduction and 7° of flexion (Andriacchi et al., 1980) and was subject to a sinuosoidal load cycle oscillating between 0 and 1100N applied through the femoral head. During stair climbing (SC) the femur was positioned in 11° of adduction and 32° of flexion (Andriacchi et al., 1980). In this case the compressive sinusoidal curve oscillated between 0 and 800N. Each test consisted of 200 loading cycles applied at a frequency of 0.5 Hz. The voltage output from each transducer was acquired at a frequency of 50 Hz to avoid aliasing and stored on a personal computer. The captured data was post-processed by a MATLAB routine (The MathWorks Inc, MA) and converted into translations and rotations of the stem with respect to the bone according to the local coordinate system defined in Figure 1. A Fast Fourier transform algorithm was used to evaluate the amplitude of micromotion. Migration was evaluated by a second order polynomial fit through the center point of the oscillations. Statistical analysis was performed using SPSS statistical package (SPSS Inc, IL). Results are expressed as medians (25th – 75th percentiles). Differences between the groups were evaluated with the Mann-Whitney U test, statistical significance was assumed for p<0.05.

![Figure 2: Proximal linear micromotion SLS (left) and rotational micromotion SC (right).](image)

![Figure 3: Proximal linear migration for SLS (left) and SC (right).](image)

RESULTS:
As in both models and loading configurations, distal micromotion and migration were very small, only the results for the proximal migrations are reported. However, this observation indicates that the stems were mainly distally fixed. In the SLS experiments the largest amplitudes of micromotion measured by the proximal transducer were oscillations parallel to the axis of the femur (z in Figure 1). These amounted to 13 μm (8-23) for the cadaveric and 19 μm (16-21) for the Sawbones® models (Figure 2). SLS also induced relevant rotations with respect to the x-axis (X rotation in Figure 1). In the SC experiments the rotations along the x-axis became more predominant (Figure 2). In particular the proximal rotations recorded in sawbones were significantly larger than those measured distally (p=0.009) and larger than those measured proximally in cadaveric hosts but not significantly so. During stair climbing the prevalent linear micromotion movement consisted of oscillations parallel to the x-axis (Figure 1). These were greatest in the proximal part of the implants inserted in sawbones, amounting to 11 μm (7-15). In the case of cadaveric bone oscillation amplitudes along this axis were nearly half: 4 μm (3-11). The non-recoverable movement (migration) of the implants was minimal both in SLS and SC for both hosts. The sawbones models led to underestimating the extent of migration in both loading conditions. In general the proximal part of the implant was affected by the largest migrations, partially reflecting the pattern described in the case of the recoverable movement.

DISCUSSION:
This study has demonstrated that Sawbones® provide an effective model to establish micromotion with oscillation patterns and orders of magnitude similar to cadaveric bone. However migration is not modelled as effectively. The migration is much more dependent on the quality of fit and the internal geometry of the femur and therefore more caution should be placed on interpreting migration data from Sawbones models.

REFERENCES:

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