ABSTRACT INTRODUCTION:

Concerning biomechanical research, human specimens are preferred to achieve conditions that are close to the clinical situation. On the other hand, synthetic femurs are used for biomechanical testing instead of fresh-frozen human femurs, to create standardized and comparable conditions. A new generation of synthetic femurs is currently available aiming to substitute the validated traditional one. The manufacturing process has been changed as well as the geometry and the materials. Structural femoral properties of the new generation have already been validated, yet a biomechanical validation is missing.

The aim of our study was to analyze potential differences in the biomechanical behaviour of two different synthetic femoral designs by measuring the primary rotational stability of a cementless femoral hip stem.

METHODS:
The synthetic femurs were divided into two groups as depicted in figure 1. Group A consists of three femurs (size large, composite bone 2nd generation, Sawbones® Europe, Malmö, Sweden) and group B consists of three femurs (size large, composite bone 4th generation, Sawbones® Europe, Malmö, Sweden). A standardized femoral neck osteotomy was performed at all synthetic femurs followed by reaming and rasping by an experienced surgeon (C. H.) using the original surgical instruments. The cementless SL-PLUS® standard stem (size 6, Smith&Nephew Orthopaedics AG, Rotkreuz, Switzerland) was implanted in both groups. Using a material testing machine (Frank-Universalsprüfmaschine 81816/B, Karl Frank GmbH, Weinheim-Birkenau, Germany), the stems were pressed into the synthetic bones in a stepwise manner by 25 cycles of F1 = 2000N followed by 25 cycles of F2 = 4000N.

The spatial micromotions of the synthetic bones and of the stems were explored at multiple levels under cyclic application of axial torques along the longitudinal stem axis of up to T2 = ±7.0Nm, to enable physiological but non-destructive measurements. To track the spatial motion, six different points along the longitudinal axis (Fig.2) were measured with regard on the Trochanter minor (served as reference (ø 0)). Two points were located ventral on the implanted stem (ø 1: shoulder, ø 2: tip) and the other four lateral on the synthetic bone (ø 3: 3cm below the Trochanter minor, ø 4: 8cm below the Trochanter minor, ø 5: at the same level as ø 2, ø 6: 20cm below the Trochanter minor).

To measure the spatial motion at one point, a cube (edge length: 3.1cm) was rigidly attached to this point via a metal rod. To reach the tip of the stem, a hole, slightly greater than the rod, was drilled through the synthetic bone. The position of the cube was recorded by six linear variable displacement transducers (LVDT, Fa. Mahr, Göttingen, Germany). These LVDTs were attached in a three-two-one configuration. This arrangement allowed to successively track the spatial motion of the selected point in relation to the Trochanter minor as a function of the applied axial torque T2 as previously described1.

RESULTS:

Figure 3 compares the rotational stability of the SL-PLUS® stem in 2nd (black) and 4th (red) generation synthetic femurs. The dashed line presents the motion of the bone and the continuous line the motion of the stem. The relation between absolute motion of the stem and absolute motion of the synthetic femur at one level, resulted as relative motion. These relative motions at the implant-bone-interface allowed identifying the fixation modulus of the stem.

In group A, mean relative micromotions were higher distally (8.42 SD ±1.38 mdeg/Nm) compared to the proximal region (3.63 SD ±1.10 mdeg/Nm). The same behaviour was found in group B with micromotions of 8.40 (SD ±0.39) mdeg/Nm distally and 6.55 (SD ±1.27) mdeg/Nm proximatively. Considering both groups, significant differences were found within the proximal region (#0 p<0.039 and #3 p<0.043). Distally no significant differences could be found (#4 p=0.289 and #5 p=0.983).

DISCUSSION:

Compared to other implant designs, the SL-PLUS® stem resulted in low relative motions regardless the used synthetic femur. Within the two distal measuring levels, no significant differences could be observed. Proximally, at the level of the Trochanter minor, mean relative motions nearly doubled from group A to B. However, the anchorage principle of the SL-PLUS® stem was still similar in both synthetic femurs. Qualitatively, both synthetic femurs revealed a proximal fixation of the stem. Although the values of relative motion slightly differs, 4th generation synthetic femurs are suitable to achieve similar results for measuring the primary stability of cementless femoral hip stems compared to 2nd generation synthetic femurs.

Future measurements with human specimens should validate weather one of the synthetic bone models is closer to the human situation.

SIGNIFICANCE:

Within this study we could show that the new 4th generation synthetic femur designs could quantitatively give comparable results to older synthetic bone models regarding biomechanical tests, like primary stability measurements on cementless hip stems.

REFERENCES:


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