INTRODUCTION

Although the survival rate of total hip arthroplasty with cementless stems is lower than with cemented stems, avoiding the cement remains an advantage for in young patients. For cementless stems, primary stability is crucial for its osteointegration and life span. Until now, the primary stability is only efficiently measured on a limited number of simultaneous sites. Therefore, the goals of this study were: 1) to develop a technique to measure the micromotion in multiple simultaneous sites around the cementless stem; 2) to use this technique to compare the primary stability of an anatomical versus a straight stem.

METHODS

Three anatomical (SPS) and three straight (Harmony) stems were randomly implanted in three pairs of cadaveric femurs without any sign of pathology (92, 88 and 87 year old females). The surgery was achieved according to manufacturer (Symbios Orthopédie SA, Switzerland) recommendations. Before stem implantation, 12 Tantalum beads (stem-markers) were dilled on the stem surface and 500 stainless steel beads (bone-markers) were press-fit on the reamed medullar cavity. After stem implantation, the femoral condyles were resected and the distal end of the femur was cemented into a cylindrical cup. The stem neck was cut with a diamond saw so as to set the loading point at the center of the femoral head. A load was applied at the femoral head center with a piston. This loading device (Fig. 1) was designed to operate within a µCT (1076 Skyscan, Belgium). Four successive scans were performed for all stems: S1) no load, S2) 2000 N load, S3) no load, S4) random displacement of loading device without piston. The centers of all markers were localized using a homemade algorithm [1]. A rigid frame of reference fixed to the stem was defined with stem markers in S1. Micromotion was defined as the displacement of bone markers between S2 and S3. Micromotion was divided into a tangential and perpendicular component relative to the stem surface. Subsidence was defined as the displacement of bone markers between S1 and S3. Error was defined as the displacement of the bone markers between S3 and S4. Micromotion measurements were grouped and analyzed in 4 sides: anterior, posterior, medial and lateral. For each region, the boxplot indicates the median, the first and third quartiles, and the 5th and 95th percentiles. Subsidence of each stem was defined with stem markers in S1.

RESULTS

Measurement error was ± 15µm. In overall, micromotion was below 150 µm, except for the SPS of pair #1 and the SPS of pair #3 (Fig. 2). In pair #1, the subsidence was nearly 5 mm in the SPS, while there was only a slight subsidence in the Harmony. In pair #2, both stems performed very similarly. The micromotion was below the critical limit and there was no difference in subsidence. In pair #3, results micromotion was similar than in pair #2, except in the anterior region, where it was higher for the SPS. In overall, the SPS was less stable for this pair.

DISCUSSION

The initial stability of cementless femoral stem is a key condition for the long-term success of total hip arthroplasty. We propose a new method for measuring micromotion and subsidence. The method was applied to compare two typical stem designs. Overall, the measured micromotion was within a physiological range and below the critical value of 150 µm, except for the SPS of pair #1. Subsidence values were also coherent with typical reported data in cadaveric or clinical studies, except for the same case, which explains its high micromotion. The high subsidence of the SPS stem of pair #1 can be observed in real clinical situations and would require a revision. In pair #2 and #3, micromotion was notably higher in the anterior and medial sides than in the posterior and lateral sides. Limited to pair #2 and #3, the comparison showed that the straight stem was more stable. However, the limited number of samples prevents to conclude that one design is better than the other. Actually, we think that the choice of a stem design should be made according to the shape of the medullary canal. Femurs of pair #2 were indeed more straight shaped, promoting a straight design of the stem, while femurs of pair #3 were more tulip-like shaped, suggesting a better initial stability of an anatomical design.

The strength of this work consists in providing a local, simultaneous and multi-site measure of micromotion. This study was however weakened by the limited number of specimens. Without statistical significance, we can however assume that there is no absolute improvement of using an anatomical stem compared to a straight one. Actually, this study suggests that these different designs should be chosen according to the patient’s femur shape, which supports the idea of a patient specific pre-operating choice.

To conclude, this study reveals the strength the method for analyzing the initial stability of cementless implants. Since the stem fixation is supported by a complex 3D surface of bone, we have showed the importance of measuring these values overall around the stem rather than only in a few points.

REFERENCES


ACKNOWLEDGEMENTS

This project was supported by the Swiss National Science Foundation (#125498), the Inter-Institutional Center for Translational Biomechanics (EPFL-CHUV-DAL), and Symbios Orthopédie SA (Switzerland).