INTRODUCTION

Total hip replacement (THR) is one of the most successful orthopaedic operations in the short term. However, several biological and biomechanical processes contribute to the survivorship of THRs in long term (>15 years) use. One of the most significant geometrical parameters is the abduction angle of the acetabular cup. Generally, the acetabular cup is tried to be oriented at the abduction angle of about 45° and at the anteverision angle of about 15°. However, in clinical data the abduction angles are observed to vary in a wide range: even from 0° to 85° [1]. Orientation of the cup is shown to affect, e.g. the range of motion of the THR, dislocation tendency, osteolysis, the stress distributions and the direction of the wear in the cup [2]. Finite element analysis (FEA) enables the determination of the stress distribution throughout the THR construction. FEA can be used to predict contact pressures, deformation and wear of the acetabular cup in different abduction angles [2].

The purpose of this study was to evaluate the effect of the abduction angle on the performance of the ultra-high molecular weight polyethylene (UHMWPE) cups using a cyclic fatigue testing. In this preliminary test, the aim was to find out the most critical factors, which could be studied further using testing, clinical data and FEA.

METHODS

Two UHMWPE acetabular cup models, Link Modell IP and Link Lubinus Eccentric, so-called snap-lock (Waldemar Link GmbH & Co, Hamburg, Germany), with good clinical record based on Scandinavian hip registers [3, 4] were tested. The main difference between these cup models is the cup design and especially centric/eccentric location of the ball in the cup. Both of the cups are made of crosslinked polyethylene (UHMWPE) cups using a cyclic fatigue testing. In this preliminary test, the aim was to find out the most critical factors, which could be studied further using testing, clinical data and FEA.

Cyclic fatigue testing was carried out using a dynamic fatigue tester Instron 8874 (Instron, Canton, MA, USA) for 12 acetabular cup-femoral head pairs (Fig. 1). The cups were cemented (average thickness of cement mantle was 4 mm) in a stainless steel cup holder using bone cement Palagos® R-40 cum Gentamicin (Schering-Plough Europe, Hamburg, Germany) , with good clinical record based on Scandinavian hip registers, with good clinical record based on Scandinavian hip registers, the cement mantle was 4 mm) in a stainless steel cup holder using bone cement Palagos® R-40 cum Gentamicin (Schering-Plough Europe, Hamburg, Germany) , with good clinical record based on Scandinavian hip registers [3, 4] were tested. The main difference between these cup models is the cup design and especially centric/eccentric location of the ball in the cup. Both of the cups are made of crosslinked polyethylene and fixed with the bone cement.

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RESULTS

The deformation of the cup was significantly higher (p<0.05) for the IP cups than for the Eccentric cups. However, the deformation of the cup was almost significantly higher (p=0.052) for 60° than 45° abduction angle. The rotation of the Eccentric cup increased the deformation in a sideways direction in respect of the load axis. In all the cyclic tests, the cement mantle deformed so that the abduction angle decreased. However, the average rotation of the cup was only 0.07° corresponding to a total shift of about 80 µm at the implant/cement mantle interface. The total subsidence of the cups in the cement mantle was quite low, i.e. 0-60 µm/5 million cycles. The elastic yielding of the complete setup during a single loading cycle decreased in all the tests during the first one million cycles and was then stable; about 100 µm. Additional mechanical testing according to standard ISO 5833 proved that the bone cement fulfilled very well the requirements of the standards.

For the FEA, two 3-D models of the acetabular cups and the heads, as well as the bone cement were reconstructed by using hexahedral elastic elements. The effect of the abduction angle on the contact pressure was investigated with different loading forces. Consequently, the model could be used for the prediction of UHMWPE cup wear, deformation and loosening.

DISCUSSION

Cyclic testing showed that in the reference case (45°) the contact pressure was about the same in the IP cup and in the Eccentric cup. However, the increase of the abduction angle (from 45° to 60°) increased the contact pressure in the IP cup but not in the Eccentric cup. These predictions were consistent with the experimental findings.

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*Vaaninen, T P; *Koistinen, A; **Santavirta, S S; *Korhonen, R K; +*Lappalainen, R
+*University of Kuopio, Kuopio, Finland

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