AN EXPERIMENTAL ANALYSIS OF MICROMOTION OF A CEMENTLESS MODULAR ACETABULAR COMPONENT IN TOTAL HIP ARTHROPLASTY: EVALUATION OF THE BONE AND CUP LINER INTERFACES UNDER PHYSIOLOGIC LOADS

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INTRODUCTION

Basic daily activities, such as walking and climbing stairs produce forces on the acetabular cup that results in shear forces throughout the contacting surface producing acetabular cup micromotion. Minimizing micromotion of the acetabular component is critical to the long term survival of total hip arthroplasty. A typical cementless acetabular component is coated with a porous surface (pore size 100 - 400 microns) that permits osseous ingrowth. Micromotion at the cup bone interface greater than the pore size can preclude ingrowth. Micromotion at the liner cup interface can create abrasive “backside” wear which can be a source of particulate matter. This particulate matter can migrate into the bone cup interface causing osteolysis, degradation of the interface and cup loosening [1-3].

The objective of this paper is to investigate the micromotion that occurs in the bone / cup and cup / liner interfaces, in a cementless THR component under approximate physiologic loads. A comparison of these two types of micromotion will allow an assessment to be made of the contribution of each in the overall acetabular cup micromotion.

METHODS

Two different experiments were designed to measure the micromotion in the two contacting surfaces under loading conditions. Four fresh-frozen cadaver pelvises, from 2 different cadavers, were used to study the micromotion between the acetabulum and the acetabular cup. The specimens were cleaned of all muscles. A cementless acetabular prosthesis was inserted into each pelvis. The pelvis specimen was then potted into a metal box for better fixation with respect to the loading jig. In all cases, the cup was placed with a 2 mm underreaming of the acetabulum in relation to the cup. To apply loads in the cup, a custom loader was designed. After positioning the cup, the liner was inserted in its socket. The loader was connected to the cup attaching it to the liner. Figure 1.

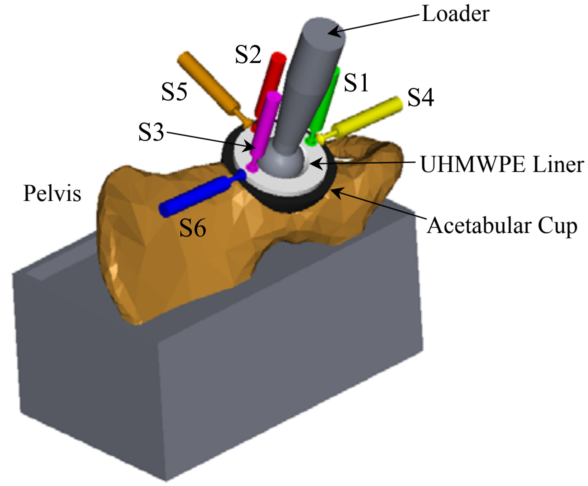

Figure 1. Experiment Scheme for measuring hip micromotion. Disposition of the LVDT sensors and loader over the potted cadaver pelvis.

To obtain the cup-cup micromotion seven UHMWPE liners were tested. The liner specimen was positioned in a custom jig designed to hold the acetabular cup at a constant angle of 45° with respect to the horizontal, simulating a 45° inclination angle (Figure 2). A commercially available femoral head was attached to a customarily designed loader. The femoral head-loader was place in an Instron machine. When the femoral head was perfectly fitted into the liner’s socket the supporting jig was fixed to the based of the Instron machine. At this point the loads were applied.

In both experiments, a fixture supporting six LVDT sensors was attached to the liner. The sensors were positioned in contact with the liner in the same fashion in both experiments. Three of the sensors touch the liner perpendicularly to the outer flat surface (S1, S2, S3), while the other three are in contact with the liner perpendicularly from the side (S4, S5, S6) as shown in Figure 1 and 2. Similar loading profiles were applied in both experiments. The loads ranged form 100 to 2500 N [4, 5], applied over the same coordinate system in both experiments. A comparison of the micromotion obtained in both experiments was made.

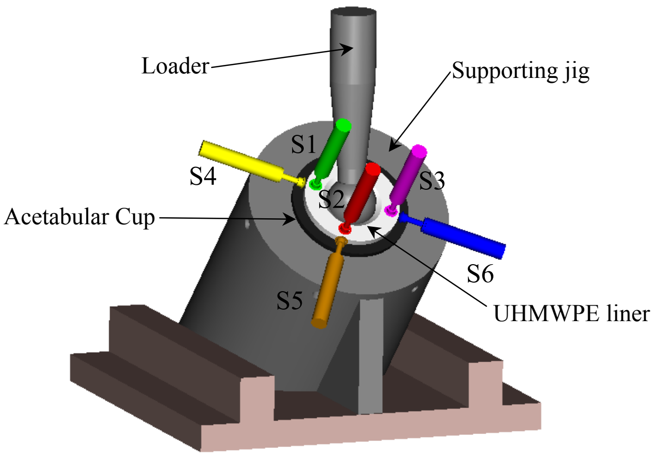

Figure 2. Experiment Scheme for measuring liner micromotion. Disposition of the LVDT sensors and loader over the fixed acetabular cup.

RESULTS

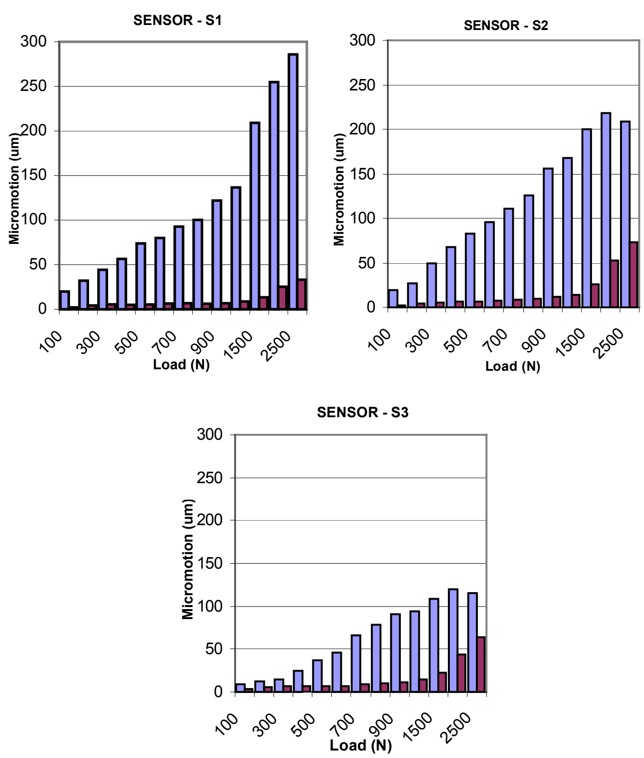

Figure 3. Comparison of the micromotion obtained in both the hip and the liner experiments as function of the load for the sensors S1, S2, and S3. Light and dark colored represent hip and liner micromotion respectively.

Several factors must be considered before interpreting the results obtained. According to the way the experiments in this study have been made, the results represent not only the micromotion of the two contacting surfaces, but also the local deformation of the polyethylene liner. When load is applied over the liner, it moves as a rigid solid and it deforms. The LVDT sensors register both effects.

The readings obtained for the sensors that registered the greater micromotion (S1, S2, S3) are shown in Figure 3. For these three sensors, a linear relation can be observed between the micromotion and the applied load. For S4, S5 and S6, a linear relation micromotion-load can also be observed, but only for loads bellow 1500 N, with micromotion values below 50 µm. Subtracting the micromotion that occurred in the hip and the liner, we would get a better approximation of the micromotion that occurred in the cup-bone interface. For loads smaller than 900 N, all sensors registered micromotion below 100 µm. For a load of 2500 N (worst case scenario) a maximum micromotion value of 252 µm and a minimum value of 51 µm were registered.

SUMMARY

The purpose of this study is twofold: (1) analyze the maximum micromotion achieved in the interfaces bone-cup and cup-liner, in cementless acetabular components and (2) use these values to estimate the influence of each type of micromotion over the overall acetabular cup micromotion. In the specimens tested bone cup micromotion was maintained below 150 microns with loads below 1000 newtons. However, it cannot be assumed that all micromotion of an acetabular liner occurs at the bone cup interface. Measurable micromotion at the cup liner interface can occur but is below 50 microns for loads below 2000 newtons.

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