INTRODUCTION:

Wear debris from polyethylene tibial inserts is thought to be a major factor in aseptic loosening of total knee arthroplasty (TKA). Fractures and delamination of the polyethylene also represent a major problem. The in-vivo measurement of such wear and polyethylene damage would be useful in assisting the quantitative comparison of different types of polyethylene inserts. In this abstract, we report results of a technique designed to measure changes in the thickness of a polyethylene tibial component over time. A hybrid Radiostereometric Analysis (RSA) and single-plane fluoroscopy pose estimation technique [1] was used to dynamically assess the 3D pose of two in-vivo rigid body segments implanted with tantalum markers. The purpose of the study was to determine the accuracy of repeated dynamic proximodistal motion measurements as a function of knee flexion. Related techniques designed to measure changes in polyethylene tibial component thickness over time have centered around the measurement of static [2] and triplicate [3] single-plane fluoroscopy images and CAD-based single-plane [4] and biplanar [5][6] radiographic techniques. Based on evidence reported in the literature, the annual rate of changes in polyethylene tibial component thickness is between 130 [5] and 230 [7] microns.

METHODS:

Five patients were recruited to this study and implanted with tantalum markers in the femoral and tibial bone during TKA with the Profix (OxZr, Smith & Nephew, Memphis TN) implant. The conventional RSA technique [8] was performed six months postoperatively to calculate a spatial model of the implanted markers. A fluoroscopy apparatus capable of acquiring 5 image frames per second (Ultimax, Toshiba, New York NY) was used to export DICOM images of size (1024 x 1024) pixels during a standing, weightbearing, clinical procedure that consisted of slightly flexing and extending the knee between 0-15 degrees. Three-dimensional pose estimates for theibia and femur components were performed using constrained Gauss-Newton (GNC) non-linear based image analysis [1] [9]. Proximodistal motion was performed using the femur as a fixed rigid body segment. The envelope of proximodistal tibiofemoral motion as a function of knee flexion was determined using a second order polynomial. The procedure allowed the attribution of confidence intervals by calculating the standard deviation at half degree flexion intervals. The dynamic examination was performed twice for each patient enrolled in the study.

RESULTS:

We found that the proximodistal tibiofemoral distance varied with knee joint flexion angle as shown in Fig. 1. Each line shown in the figure represents an independent measurement of the distance between markers implanted in the tibia and the femur. The average error between the independent observations shown in Fig. 1 is 27 microns. The proximodistal flexion curve was different for each patient. The average error for the 5 human subjects examined in this series was 134 microns.

DISCUSSION:

The in-vivo measurement of tibial component wear has been previously measured as a decrease in the distance between the femur and tibia components [5][7]. In a knee replacement this is not as easy as in a hip with spherical ball-and-socket joint geometry. This is due to at least two reasons: Firstly, it is almost impossible to obtain exactly the same position of the components at two different examinations. Any difference in anteroposterior (AP) position and flexion of the femur on the tibia will affect the proximodistal measurements. Secondly, the polyethylene will not wear in a circular spot but over the sliding distance of the femoral condyles. We found that articulating the knee under load whilst performing a simple dynamic motion protocol can align the components reproducibly and compensate for various flexion angles.

Figure 1: Example of a double baseline proximodistal motion measurement of a single knee. The error between the two measurements was 27 microns. Error bars indicate ±1 standard deviation.

We also found that the proximodistal motion curves as a function of knee flexion exhibited different shapes for each human subject in this study. This occurred as a result of the different configuration of tantalum markers implanted during TKA. The proximodistal tibiofemoral distance can also exhibit slightly different behavior than shown in Fig. 1, according to the type of kinematic activity performed by the patient. We found that asking the patients to remain stationary in an upright position prior to slowly flexing the knee yielded the most reproducible anteroposterior position on the femoral condyles. Asking the patient to perform a single-step ascent resulted in larger variations in proximodistal motion at full extension than shown in Fig. 1.

The data reported in this study represent baseline proximodistal motion measurements that were performed at a single point in time. The thickness of the polyethylene is expected to decrease over time. The current technique may be used in the future to approximate patterns of change in the thickness of the polyethylene tibial component.

REFERENCES:


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