Wear of a Rotating Hinge Knee Joint

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INTRODUCTION: Hinge knee replacements are used for a number of applications including patients with severe bone and soft tissue loss. In some designs a rotating component is used in order to reproduce rotational knee movement. This means that in knees of this generic design wear can possibly occur either through the bushes associated with the hinge mechanism and through the rotating platform. In this study the wear of a rotating hinge knee joint was investigated as realised in the clinical hinge knee joint. The knee was manufactured by Stanmore Implants and is used clinically for bone tumor applications and revision of failed condylar knees. This knee has three different plastic bearing surfaces from which debris could be generated. The hinge knee joint with plastic bushes dissipates load through a plastic bumper pad located into a cobalt chrome tibial component which is free to rotate on a plastic bearing platform fixed into the tibia. The question we wished to answer was whether wear was as high as with condylar designs and which component of the knee generated the most wear.

MATERIALS AND METHODS: Four rotating hinge knees were tested in a force controlled simulator using force and motion data specified in ISO/TC150/SC4/N189 for testing knee replacements. The femoral component was mounted so that the flexion-extension angle was along the centreline of the axle. The femur was constrained to move around this axis. The tibia was free to move in a horizontal plane and to rotate about a vertical axis. The bottom of the tibial plastic bearing component was mounted with 0° inclination. A general feature of hinge knees is the built in hyperextension stop and so in this test hyperextension of 3.5° was used. The axial load was off-set onto the medial side by 5mm. The knee articulation was lubricated with 30% foetal calf serum. At 1 million cycles and thereafter at every 1 million cycles up to 10 million cycles the following measurements were taken: AP and rotational laxity for the four knees; roughness measurements of the metallic tibial and femoral component bearing surfaces; and weight loss measurements of the UHMWPE plastics (bushes, bumper and tibial bearing) utilising soaked controls measured according to ISO/TC150/SC4/N189. In order to measure the load distribution between the axle and the bumper pad pressure sensitive film (Fuji Film) was inserted between the pad and the femoral component at the start of the test and after 10 million cycles. Load distribution and contact area was measured at 0°, 15°, 30°, 60°, and 90° of flexion.

RESULTS: The forces, internal and external torque, and displacements supplied to the 4 stations at the start of the test and at 10 million cycles were the same. All four knees behaved similarly. As expected for a knee hinge, the anterior-posterior motion is negligible, whilst the internal-external rotation for all 4 knees at the start of the test is around 5°. Whilst on average the magnitude of the rotation does increase over the tests the shape of the curves for all knees at 10 million cycles are different with the knees becoming more rotationally lax (figure 1). The adjusted weight loss of the bumper pads taking into account the soaked controls is shown in figure 2. The average weight loss at 10 million cycles is 6.46mg (4.68mg SD). Photographs of the 4 bumper pads show that wear and deformation occur in the posterior medial and lateral regions of the pad. The wear regions are associated with motion of the femoral component over the entire gait cycle. There was no evidence of delamination wear and visual examination of the bumper pad indicated considerable creep of the plastic, with some wear attributed to adhesive and abrasive mechanisms. The adjusted combined weight loss of the material and lateral plastic bushes taking into account the soaked controls is shown in figure 3. The average gravimetric wear of the bushes on the medial side was 8.11mg (2.2SD) and on the lateral side the wear was almost the same at 12.83mg (2.14 SD). There was no evidence of delamination wear. The adjusted weight loss of the tibial plastic taking into account the soaked controls is shown in figure 4. The average weight loss at 10 million cycles is 50.036mg (13.67 SD). Figure 5 shows a single component (from station 2) coated with a thin layer of gold palladium which shows the extent of the wear track on the tibial plastic. The wear track is seen as a continuous band posterior to the position of the tibial stem with more anterior wear surrounding the stem in the medial and lateral regions. There is evidence of scratches on the surface of the plastic and these are orientated in a radial direction and are due to the rotational motion of the knee. At 10 million cycles the average combined wear of all the plastic components was 77.76mg (SD =6.69) with the tibial component accounting for around 64% of the total wear. It can be seen the load passing through the pad is greater in hyperextension. The calculated load passing through the axle increase in flexion and although variable is often larger than the load passing through the pad. After 10 million cycles there is more load passing through the axle than at the start of the test.

DISCUSSION: This is the first study of wear in a rotating hinge knee joint. The combined average wear for a rotating hinge knee joint is low when compared to the gravimetric wear associated with UHMWPE acetabular cups in hip joint replacements. Wear of this hinge knee joint is low when compared with the wear of condylar knees tested in similar simulators. Although all components contributed to the plastic wear the greatest wear was found on the tibial plastic. This is probably associated with the rotational torque leading to cross over wear. There was an increase in rotational laxity of the knee and this is associated with wear and deformation of the tibial plastic. Similarly there was a redistribution of load transfer through the axle and the pad and this is associated with wear of the pad. Overall this design represents a low wear alternative for patients with severe bone loss around their knee.

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