LARGE FEMORAL HEADS FOR CROSS-LINKED UHMWPE CUPS

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**Introduction:** It is important to re-examine the femoral head size for total hip joint replacements, following on the recent extensive introduction of cross-linked polyethylene materials. Large femoral heads provide large range of motion and reduced incidence of dislocation. The main concern associated with large sized femoral heads has been the increase in the sliding distance and wear for conventional ultra high molecular weight polyethylene (UHMWPE) cups. Therefore, the optimum femoral head diameter has been chosen to be around 28 mm, in order to balance the linear and volumetric wear rates.

However, it should be asked whether the 28 mm diameter cup is the best option for recently introduced cross-linked polyethylene materials. Some preliminary hip simulator studies have suggested that the linear relationship between wear and sliding distance does not apply for this case [1]. From a theoretical point of view, the important tribological parameters governing wear are contact stresses and lubricant thickness between the two articulating surfaces. Contact stresses are directly related to fatigue wear, while the lubricant thickness determines the extent of asperity contacts between the two articulating surfaces and hence should have a large effect on adhesive and abrasive wear. For a given outside diameter of the cup, an increase in the femoral head size increases contact area and consequently decreases contact stresses, but at the same time the cup thickness is decreased, which may lead to a decrease in contact area and an increase in contact stresses. This argument also applies to lubricant film thickness, since the lubricant film thickness is, in general, directly related to the contact area. Therefore, there should exist an optimum femoral head size. The purpose of this study was to determine the optimum femoral head size from both the contact mechanics and lubrication point of view.

**Materials and Methods:** A simple ball-in-socket model was chosen for analyzing both the contact mechanics and lubrication for cross-linked polyethylene cups in articulating with either a metallic or ceramic femoral head. The cup was placed horizontally and fixed on the outside. A vertical load of 2500 N and a horizontal angular velocity of 1 rad/s (representing flexion/extension) were applied to the femoral head. The viscosity for synovial fluid after total joint replacements was assumed to be 0.005 Pas. Three cases were considered. For the nominal case, the radial clearance between the femoral head and the acetabular cup and the elastic modulus for the cross-linked polyethylene were assumed to be 0.1 mm and 1000 MPa respectively. For the second case, the elastic modulus for the cross-linked polyethylene was changed to 250 MPa [2], while for the third case, the radial clearance was changed to 0.2 mm. The outside diameter of the cup was fixed at 50 mm and the femoral head radius was varied between 10 mm to 25 mm.

Both contact mechanics and lubrication were analyzed for the above ball-in-socket model employing cross-linked polyethylene cups. The maximum contact pressure at the articulating surfaces was predicted using the method outlined by Bartel et al [3]. The minimum lubricant thickness was predicted based on the elastohydrodynamic lubrication mechanism [4].

**Results:** Figures 1 and 2 show the predicted maximum contact pressure and the minimum lubricating film thickness respectively against different femoral head radii for the three cases considered in the present study. It is clear that an increase in the femoral head radius leads to a decrease in the predicted maximum contact pressure and an increase in the predicted minimum lubricant film thickness initially, and then this trend is reversed when the femoral head radius is further increased, beyond about 18 mm. It is also noted that a decrease in the elastic modulus or the radial clearance leads to a decrease in the predicted maximum contact pressure and an increase in the predicted minimum lubricant thickness.

**Discussion:** The optimum femoral head radius predicted from the present theoretical analysis is between 18 and 20 mm for the cross-linked polyethylene cups, depending on whether contact stress or lubrication is considered, as well as the specific parameters chosen for both the elastic modulus and the radial clearance. It is however noted that the change of both the maximum contact pressure and the minimum lubricant film thickness is very small near the optimum range of the femoral head radius. An increase in the femoral head radius from 14 mm to 18 mm results in a decrease in the predicted maximum contact pressure by 10 to 25% and an increase in the predicted lubricant film thickness by 20 to 40%. The predicted minimum lubricant film thickness can reach between 0.13 and 0.27 µm, and therefore a cross-linked polyethylene cup with an average surface roughness below 0.05 µm may experience a substantial lubrication effect. Further hip simulator studies are required to confirm these theoretical predictions.

**References:**