The Combined Effect of Head and Cup Centres Mismatch and Different Cup Inclination Angles on the Occurrence and Severity of Edge Loading and Wear in Hip Replacement

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References:

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This study demonstrated how rotational and translational surgical positioning affects the occurrence and severity of edge loading under a set of kinematic conditions. It provides an indication which supports the rationale for aligning the head and cup centres and correcting positioning of the cup inclination angle during total hip joint replacement.

Introduction
Clinically, increased wear and deformation of hip replacement bearings have been associated with edge loading [1] and in vitro testing has demonstrated it can affect the tribological performance [2]. Factors that influence the occurrence of edge loading in total hip replacement include, surgical translational and rotational positioning of the femoral head and the acetabular cup [3], surgical variations such as soft tissue tension, patient’s activity [4, 5] and the cup design.

Aim
To determine how the level of medial-lateral surgical translational mismatch between the head and cup centre under different cup inclination angles for ceramic-on-ceramic bearings, affect the: 1) magnitude of dynamic separation, 2) the magnitude of the forces acting under edge loading, 3) the time during the cycle the head spends on the rim of the cup (duration of edge loading), and 4) component wear.

Method
Illustration of head and cup centre mismatch leading to laxity of the joint

Study 1: A biomechanical test was performed with the following conditions: four different levels of translational surgical mismatch between the head and the cup were applied: 1, 2, 3 and 4 (mm). Each level of mismatch was coupled with a cup inclination angle equivalent in vivo of 45°, 55° and 65° (n=3 for each condition).

Outcomes: 1) magnitude of dynamic separation, 2) magnitude of the forces under edge loading and 3) duration of edge loading.

Study 2: A wear test was performed on selected conditions: a medial-lateral mismatch of 2, 3 and 4 mm with a 45° and 65° cup inclination angle (n=6 for each condition).

Equipment: • Leeds Mark II Physiological Equipment • Gravimetric wear Anatomical Hip Joint Simulator • CMM

Results and Discussion
Larger magnitudes of surgical translational mismatch resulted in a greater level of dynamic separation conditions and hence a more severe edge loading condition (Fig. 1).

Increasing the translational mismatch from 2 to 3 to 4 mm resulted in an increased wear rate for both cup inclination angles (Fig. 2), with the 65° cup inclination angle having significantly higher wear rate than the cup inclination angle of 45° (p<0.02, p=0.00, and p<0.01 respectively).

By evaluating the severity of edge loading (area of load under the curve during separation) a model can be used to predict the wear for different conditions (Fig. 4 and 5).

Surgical variations, such as slope inclination angle, mediatised cups, head offset deficiencies, and stem subsidence can lead to edge loading and increased wear in hip replacement bearings.

Materials

36 mm BIOLOX® delta ceramic-on-ceramic (DePuy Synthes, UK)

Significance
This study demonstrated how rotational and translational surgical positioning affects the occurrence and severity of edge loading under a set of kinematic conditions. It provides an indication which supports the rationale for aligning the head and cup centres and correcting positioning of the cup inclination angle during total hip joint replacement.