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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SAFER

Stratified Approach For Enhanced Reliability (SAFER)

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.

Materials

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

Method

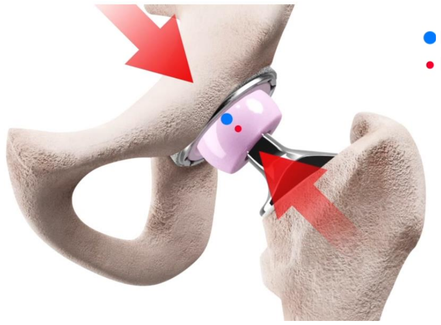
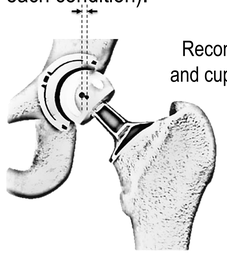
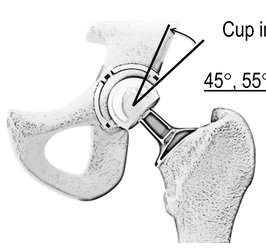


Illustration of head and cup centre mismatch leading to laxity of the joint

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).



Reconstructed head and cup lateral centre mismatch of: 1, 2, 3 and 4 mm



Cup inclination angle of: 45°, 55° and 65°

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).

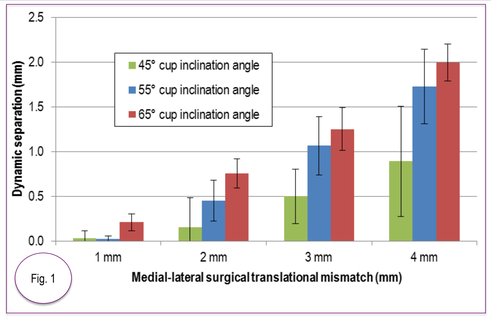
Equipment:
- Leeds Mark II Physiological Anatomical Hip Joint Simulator

Measurements:
- Gravimetric wear
- CMM

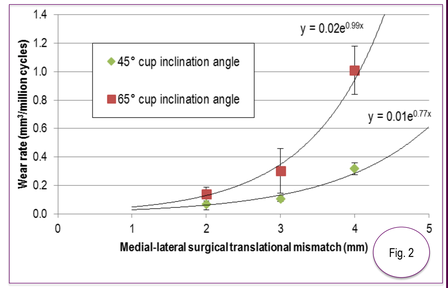
Test conditions:
- Walking gait cycle kinematics
- Lubrication: 25% new-born calf serum + 0.03% sodium azide

Statistical analysis was performed using one way ANOVA (significance at 0.05)

Results and Discussion

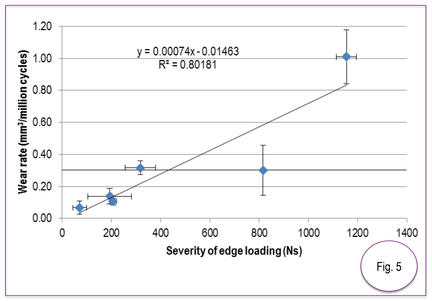


Larger magnitudes of surgical translational mismatch resulted in a greater level of dynamic separation conditions and hence a more severe edge loading condition (Fig. 1).

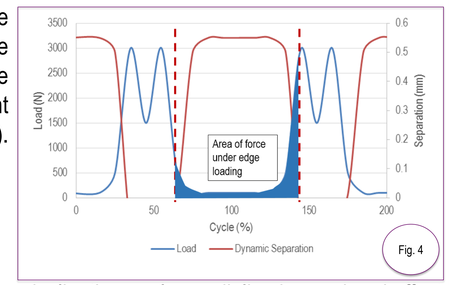


Increasing the translational mismatch from 2 to 3 to 4 mm resulted in an increased wear rate for both cup inclination angles (Fig. 2), with the 65° cup inclination angle having significantly higher wear rate than the cup inclination angle of 45° (p=0.02, p=0.02, and p<0.01 respectively).

This study also showed that cup inclination angle affects the magnitude of dynamic separation for a given surgical translational mismatch, thus leading to severe edge loading and increased wear rates with increased cup inclination angles (Fig. 3).



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 steep inclination angle, medialised cups, head offset deficiencies, and stem subsidence can lead to edge loading and increased wear in hip replacement bearings.

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 correctly positioning the cup inclination angle during total hip joint replacement.

References:

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Disclosure

J. Fisher is an NIHR senior investigator, a paid consultant to DePuy Synthes, Invibio, Tissue Regenix Group plc and a share holder of Tissue Regenix Group plc; E. Ingham is a paid consultant to DePuy Synthes, Stryker, Tissue Regenix Group plc and a share holder of Tissue Regenix Group plc; S. Williams is a paid consultant to DePuy Synthes; Jonathan Thompson and Graham H. Isaac are employees at DePuy Synthes

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