An Investigation into the Dynamic Loading of Ceramic-on-Ceramic Total Hip Replacements and Its Relevance to Squeaking

*Jim Pierrepont - University of Sydney - Sydney, Australia
Hans Feyen - Melbourne Orthopaedic Group - Melbourne, Australia
Jonathan Baré - Melbourne Orthopaedic Group - Melbourne, Australia
David Young - Melbourne Orthopaedic Group - Melbourne, Australia
Brad Miles - Optimized Ortho - Sydney, Australia
Andrew Shimmin - Melbourne Orthopaedic Group - Melbourne, Australia

*Email: jim.pierrepont@gmail.com

Introduction

Acetabular cup orientation has been shown to be a factor in edge-loading of a ceramic-on-ceramic THR bearing. Currently all recommended guidelines for cup orientation are defined from static measurements with the patient positioned supine. The objectives of this study are to investigate functional cup orientation and the incidence of edge-loading in ceramic hips using commercially available, dynamic musculoskeletal modelling software that simulates each patient performing activities associated with edge-loading.

Methodology

Eighteen patients with reproducible squeaking in their ceramic-on-ceramic total hip arthroplasties were recruited from a previous study investigating the incidence of noise in large-diameter ceramic bearings. All 18 patients had a Delta Motion acetabular component, with head sizes ranging from 40 – 48mm. All had a reproducible squeak during a deep flexion activity. A control group of thirty-six patients with Delta Motion bearings who had never experienced a squeak were recruited from the silent cohort of the same original study. They were matched to the squeaking group for implant type, acetabular cup orientation, ligament laxity, maximum hip flexion and BMI. All 54 patients were modelled performing two functional activities using the Optimized Ortho Postoperative Kinematics Simulation software. The software uses standard medical imaging to produce a patient-specific rigid body dynamics analysis of the subject performing a sit-to-stand task and a step-up with the contralateral leg, Fig 1.

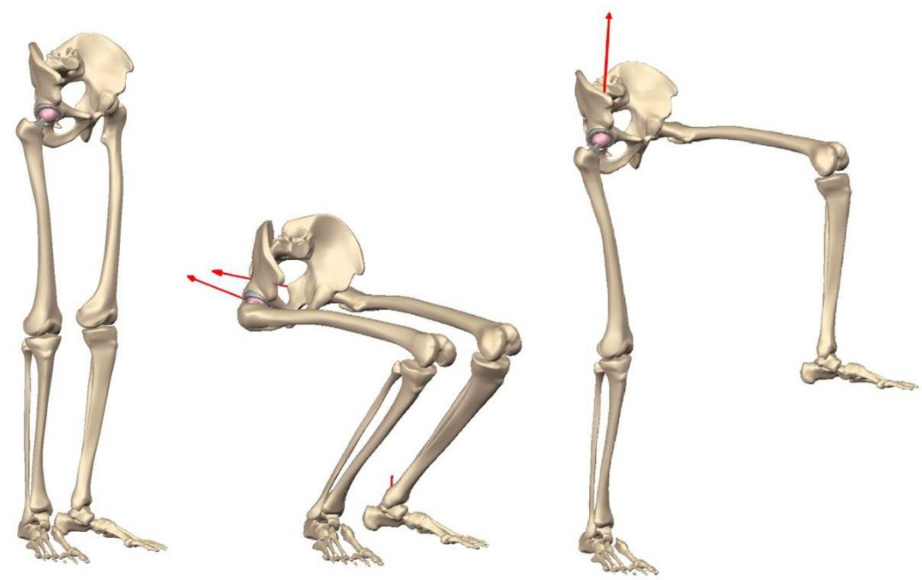

Fig 1. Images from the Optimized Ortho postoperative kinematic simulation software. The software runs a patient specific rigid body dynamics analysis of three functional activities: standing, sit to stand, and stepping up with the contralateral leg.

The software calculates the dynamic force at the replaced hip throughout the two activities and plots the bearing contact patch, using a Hertzian contact algorithm, as it traces across the articulating surface, Fig 2. As all the squeaking hips did so during deep flexion, the minimum posterior Contact Patch to Rim Distance (CPRD) can then be determined by calculating the smallest distance between the edge of the contact patch and the true rim of the ceramic liner, Fig 2. A negative posterior CPRD indicates posterior edge-loading.

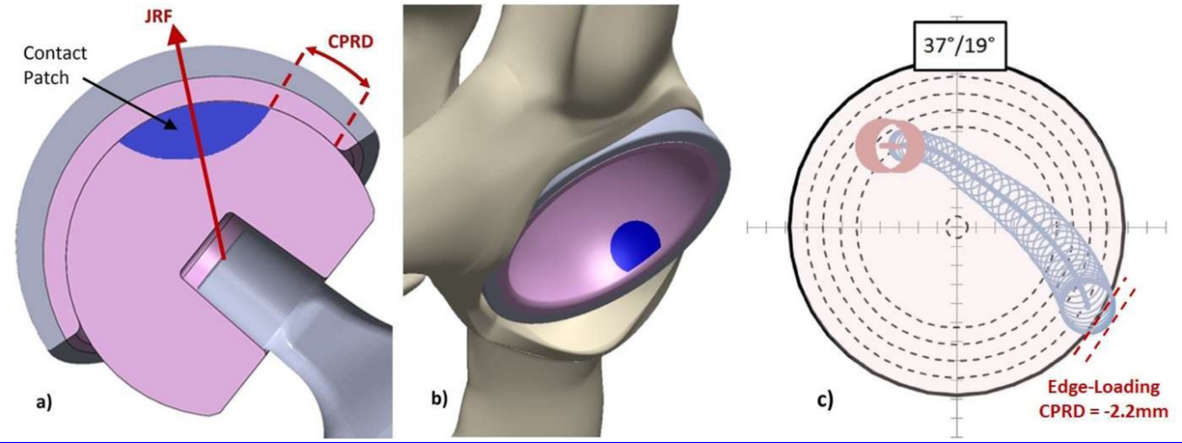

Fig 2. a) Schematic showing the Joint Reaction Force (JRF) at the centre of the contact patch. The contact patch to rim distance (CRPD) is described as the arc length between the edge of the contact patch and the true rim of the liner. b) A negative CPRD implies the contact patch has passed over the true rum of the line and edge loading has occurred. c) An Optimized Ortho polar plot showing the trace of the contact patch across the articulating surface.

Results

The mean CPRD was significantly less in the squeaking group than the control group, -2.5mm and 2.9mm respectively, ($p < 0.001$), Fig 3. The mean pelvic tilt in the flexed seated position was 12.6° (range -13.5° to 30.3°) for the squeaking group and 5.1° (-9.8° to 26.4°) for the control group. Consequently, the mean functional cup anteversion at seat-off was significantly less in the squeaking group than the control group, 8.1° (-10.5° to 36.0°) and 21.1° (-1.9° to 38.4°) respectively ($p < 0.001$), Fig 3. There were 67% (12) of patients in the squeaking group that showed posterior edge-loading in the simulation compared to only 28% (10) in the control group that exhibited posterior edge-loading in the simulation.

Fig 3. Results Table			
	Squeaking Group	Silent Control Group	p value
Standing pelvic tilt ± SD (range)	-1.8° ± 7.4° (-18.0° – 9.4°)	-1.2° ± 7.6° (-14.1° – 12.9°)	NS
Supine pelvic tilt ± SD (range)	2.6° ± 5.2° (-8.8° – 10.4°)	4.9° ± 5.4° (-5.5° – 16.0°)	NS
Flexed seated pelvic tilt ± SD (range)	12.6° ± 13.2° (-13.5° – 30.3°)	5.1° ± 8.9° (-9.8° – 26.4°)	p < 0.05
Pelvic tilt change from supine to stand ± SD (range)	-4.4° ± 4.8° (-13.9° – 4.8°)	-6.2° ± 4.6° (-21.1° – 4.6°)	NS
Pelvic tilt change from stand to flexed seated ± SD (range)	14.4° ± 12.1° (-9.2° – 31.0°)	6.3° ± 10.6° (-18.3° – 27.8°)	p < 0.05
Cup Inclination at "seat-off" ± SD (range)	33.4° ± 6.6° (22.8° – 49.0°)	36.2° ± 6.5° (21.3° – 48.3°)	NS
Cup Anteversion at "seat-off" ± SD (range)	8.1° ± 14.4° (-10.4° – 36.0°)	21.1° ± 9.9° (-1.9 – 38.4°)	p < 0.001
Posterior CPRD (mm)	-2.5 ± 5.6 (-9.4 – 8.7)	2.9 ± 3.9 (-6.5 – 10.5)	p < 0.001

Fig 3

Conclusions

Acetabular cup orientation during activities associated with edge-loading are likely very different from those measured when supine. Patients with large anterior pelvic tilts during deep flexion activities might be more susceptible to posterior edge-loading and squeaking in ceramic-on-ceramic bearings, as a consequence of a significant decrease in cup anteversion. If these patients can be identified preoperatively, cup orientation and bearing choice could be customised accordingly to accommodate these individual motion patterns.