Wear and friction of a multi-bearing acetabular system

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Introduction

Based on the clinical success of large head metal-on-metal (MoM) bearings technologies in the resurfacing arena, a multi-bearing acetabular system, known as R3 system, was developed by Smith & Nephew. The novel R3 system (Fig. 1) utilizes porous coated Ti-6-4 shells in which liners of crosslinked UHMWPE, ceramic, or as-cast CoCr liners can be placed, providing wide advanced bearing options using one acetabular system. The as-cast CoCr metallurgy and microstructure is identical to the clinically successful Birmingham Hip Replacement (BHR) resurfacing system [1, 2]. The bearing surface design and manufacturing aspects such as diametrical clearance, surface roughness, and spherical form are all identical for the BHR and R3 systems. However, the boundary conditions for the R3 and resurfacing systems are different. This is because BHR cup is monolithic as-cast CoCr with HA coated cast-in porous back surface, while the MoM R3 is a modular system consisting of porous coated Ti-6-4 shell and an as-cast CoCr liner.

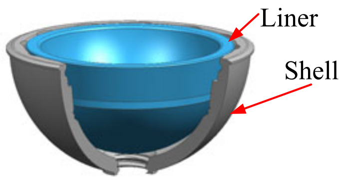

Fig. 1 Schematic of R3 system

Aim

This study was to evaluate the tribological performance of R3 devices as compared to that of standard BHR devices.

Materials and Methods

Five pairs of 46 mm metal-on-metal R3 devices (Smith & Nephew) and three pairs of 48 mm BHR devices (Smith & Nephew) were tested in a ProSim hip wear Simulator. The lubricant was new born calf serum with 0.2% sodium azide diluted with de-ionized water to achieve protein concentration of 20 g/l. The flexion/extension was 30° and 15° and the internal/external rotation was ±10°. The force was Paul-type stance phase loading with a maximum load of 3 kN and a standard ISO swing phase load of 0.3 kN. The frequency was 1 Hz.

One R3 joint and one BHR device were friction tested in a ProSim hip friction simulator at 0, 3 and 5 million cycles (Mc) of wear testing. The test was conducted in new born calf serum with added carboxymethyl cellulose (CMC) to generate viscosities of 0.001 to 0.1 Pa·s. The loading cycle was set at maximum loads of 2 kN and minimum of 0.1 kN. The flexion/extension was 30° and 15°, and the frequency was 1 Hz.

Results and discussions

Friction: The coefficient of friction (COF) of the R3 joint varied from 0.08 to 0.14 depending on the viscosity of the serum and cycles of wear simulation test. Under physiologically relevant lubricant conditions (0.001 to 0.01 Pa·s), the COF for the R3 device tested was comparable to that of the standard BHR device, Table 1.

Table 1 COF (± 95% confident limit) for the R3 and BHR bearings at 0 and 5 million cycles (Mc)

Viscosity (Pa·s)		0.001	0.003	0.010
0 Mc	R3	0.13±0.004	0.14±0.001	0.12±0.006
	BHR	0.13±0.003	0.14±0.001	0.14±0.005
5 Mc	R3	0.12±0.003	0.11±0.005	0.10±0.006
	BHR	0.11±0.002	0.10±0.002	0.09±0.001

Wear: The R3 devices generated typical characteristics of wear as the BHR devices, with a relatively higher wear rate during the initial running in period (0 – 0.5 Mc) followed by a low steady state wear rate after 0.5 Mc. The average wear rate at 0.5 Mc was 1.86 mm^3/Mc for the R3 and 1.80 mm^3/Mc for the BHR devices. The wear rate during the steady state for the R3 and the BHR devices was reduced to 0.09 mm^3/Mc and 0.12 mm^3/Mc respectively. The difference in wear rates between the BHR and R3 devices during the running in and steady states were not statistically significant ($p > 0.05$).

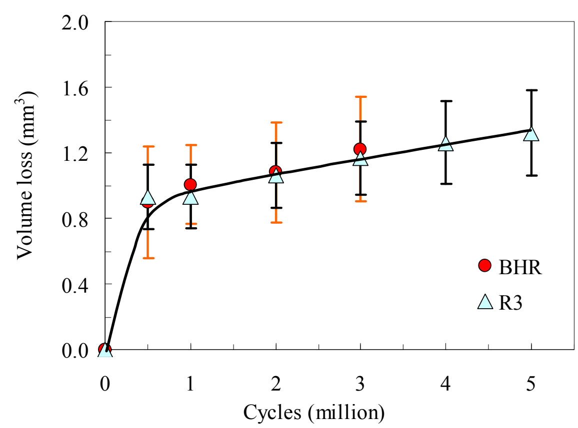

Fig. 2 Volume loss for R3 and BHR devices (Error bar represents 95% confidence limit).

Conclusion

The results presented in this study show that tribological performances of R3 and the BHR devices are comparable.

References

[1] J. Daniel, P. Pynsent and D. McMinn, *JBJS (Br),* Vol. 86-B, 2004, pp.177-184.
[2] D. McMinn, J. Daniel, Proc. ImechE, Part H: J. Engineering in Medicine, Vol.220, 2006, pp.239-251.