WEAR AND FRICTION CHARACTERISTICS OF THE TRI-POLAR ALL CERAMIC HIP PROSTHESIS

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Introduction

There is increasing interest in the use of ceramic on ceramic bearings for hip replacement world wide, due to recognition of their extremely low wear and biocompatibility of the wear debris [1]. Recent developments in ceramic matrix composites and the introduction of Biolox Delta with improved fracture toughness, further reduces the risk of fracture and also extends the design flexibility of the material. A stripe wear morphology has been frequently observed on the femoral head of ceramic-on-ceramic hip prostheses, which is believed to be due to micro-separation of the components and contact of the head on the rim of the cup [2]. The double-mobility polyethylene hip prosthesis has been extensively used in France, this prosthesis provides improved function and stability. However there remain concerns about polyethylene wear and osteolysis. A novel tri-polar all ceramic hip prosthesis, 3Δ™ (CeramConcept L.L.C., USA) has been designed and developed, which combines the functional advantages of the double-mobility hip with the tribological advantages of ceramic bearings [3].

The aim of this study was to evaluate the wear and friction characteristics of this novel tri-polar all ceramic artificial hip joint.

Materials and Methods

The tri-polar hip prosthesis (CeramConcept L.L.C., USA) comprised a 22mm ceramic head, a 22/32 mm mobile ceramic head, a 32mm internal diameter ceramic acetabular insert, and a polyethylene retaining ring. All ceramic components were manufactured from Biolox Delta ceramic matrix composite (CeramTec AG, Germany).

The wear of the tri-polar bearing was compared to a 28 mm ceramic on ceramic (Biolox Delta) bearing couple in the Leeds II Physiological Anatomical hip joint simulator over 5 million cycles, using 25% bovine serum as a lubricant. The test conditions comprised of physiological twin peak time dependent loading with an elliptical wear path. Simulator studies were carried out under these standard ISO conditions, but also under novel micro-separation conditions which replicate head/cup rim contact at heel strike and simulate stripe wear on a conventional ceramic femoral head as found on conventional ceramic on ceramic retrievals [2]. Two or three specimens were studied for each case. Wear was determined gravimetrically.

Friction testing was performed using a pendulum friction simulator (Simulation Solutions, UK). Flexion/extension motion of ±25° was applied to the head and a dynamic loading profile with a 3 kN peak load was used. Three tri-polar bearings were tested. Similar to the wear study, 25% bovine serum was used as the lubricant and the results were compared to a 28 mm Biolox Delta ceramic on ceramic bearing.

Results

The wear rates for the tri-polar and conventional Biolox Delta hip bearings are detailed in Table 1. Under standard conditions the wear of the tri-polar and conventional ceramic on ceramic bearing were very low. The wear of the tri-polar all ceramic hip was less than 0.01 mm^3/ million cycles, the detection limit for wear measurement, while the conventional ceramic on ceramic bearing produced a wear rate of 0.07 mm^3/ million cycles. The difference between these very small wear rates is not clinically significant. Under micro-separation conditions there was a significant difference in the wear performance. For the conventional Biolox Delta ceramic on ceramic bearing, stripe wear was found on the head with a bedding in wear of 0.32mm^3/million cycles and a steady state wear of 0.12mm^3/million cycles, resulting in an overall wear rate of 0.16mm^3/million cycles . The all ceramic tri-polar bearing did not reveal stripe wear on either articulating component and the overall wear could not be detected, being less than 0.01mm^3/million cycles. Wear of the polyethylene ring could also not be detected gravimetrically.

The frictional torque of the tri-polar bearing was lower at 0.7 Nm, compared to 1.8 Nm for the conventional Biolox Delta ceramic on ceramic bearing. This resulted in a 50% reduction in friction coefficient for the tri-polar bearing, as detailed in Table 2.

Discussion

Low wear rates of under 1 mm^3/million cycles for Biolox Delta ceramic on ceramic hip prostheses under both standard conditions and micro-separation has been previously reported [4]. Under standard conditions even lower wear was observed for the tri-polar bearing due to the small head diameter. The majority of the sliding distance in the tri-polar hip occurred at the 22 mm diameter ball head, and since wear is proportional to the sliding distance this resulted in lower wear than a conventional 28 mm ceramic hip.

Under micro-separation conditions the wear of the tri-polar bearing was low due to the absence of edge loading and hence absence of stripe wear. The design of the tri-polar bearing with the mobile ceramic head prevented edge loading of the head on the edge of the cup, so significantly reducing wear under these severe, but clinically relevant micro-separation conditions.

The tri-polar hip also showed improved frictional characteristics with a reduced frictional torque due to articulation at the smaller diameter 22mm inner femoral head.

Previous studies have shown increased stability and range of motion with the tri-polar hip prosthesis design [3, 5, 6].

Table 1 Wear Rates (mm^3/million cycles) ± Standard Error for Tri-polar and Conventional Biolox Delta Ceramic on Ceramic Bearings

	Standard ISO	Micro-Separation
3Δ™ Tri-polar	<0.01	<0.01
Conventional	0.07 ± 0.03	0.16 ± 0.05

Table 2 Coefficient of Friction for Tri-polar and Conventional Biolox Delta Ceramic on Ceramic Bearings

3Δ™ Tri-polar	0.02
Conventional	0.04

Conclusion

The tri-polar all ceramic hip prosthesis examined in this study showed improved wear and friction characteristics in comparison with a conventional Biolox Delta ceramic on ceramic bearing. Most importantly wear could not be detected under micro-separation conditions, and stripe wear was not observed.

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References

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Ceramic-on-ceramic hip prosthesis performance will be reviewed in this chapter (in vitro and in vivo) along with a discussion of the concerns with ceramic-on-ceramic joints that hap pen in a minority of cases such as joint squeaking and component fracture. The majority of articles reviewed discuss the performance of alumina-on-alumina joints.Â Friction tests using different viscosities of carboxy-methyl cellulose (CMC) solution show that these joints operate close to full-fluid film lubrication with very low friction factors (0.002 at physiological viscosities) [6, 12]. These ceramic-on-ceramic joints have been shown to have very low surface roughness values that play a part in this low friction [6]. Tests were also performed using different viscosities of bovine serum [6, 12].