TRIBOLOGY IN TOTAL HIP ARTHROPLASTY: HISTORICAL DEVELOPMENT AND FUTURE TRENDS

C. B. Rieker
Sulzer Orthopedics Ltd., P.O. Box 65, CH - 8404 Winterthur, SWITZERLAND; e-mail: claude.rieker@sulzer.com

Keywords: Arthroplasty, Hip, Wear

INTRODUCTION

Arthritis is a common disease in the elderly population. The most frequent treatment of arthritis is a total joint replacement. Approximately 1.100.000 hip endoprostheses are implanted per year worldwide. This procedure is very successful in more than 90 % of the patients with good results after up to 10-year follow-ups. Unfortunately, due to the body’s reaction against the wear particles, these good results may be jeopardized during an extended time in-vivo, especially in young, male, and active patients. Therefore, there is an urgent need to develop new, low wear rate, articulations.

HISTORIC DEVELOPMENT

The first attempts for hip arthroplasties were made in 1890 using ivory and stainless steel. In the first half of the 20th century, many tests were made with various materials (glass, Bakelite, stainless steel, Plexiglas, etc.). None of these materials were clinically successful. The first modern hip prosthesis was implanted in 1962 by Sir John Charnley, who developed the concept of low friction arthroplasty (cemented stem with a 22.25 mm head in stainless steel combined with a cup made of UHMWPE).

With the use of orthopaedic cement, metal-on-metal articulations (in the 60’s) and alumina-on-alumina articulations (in the 70’s) were also developed. Due to the better short-term results of low friction arthroplasties, these alternative bearings almost disappeared in the 80’s.

ARTICULATIONS WITH POLYETHYLENE

Due to the higher risk of dislocation of low friction arthroplasties with 22.25 mm heads, larger head diameters (mainly made of Co alloys) were developed in the 70’s and the 80’s. Simultaneously, alumina heads were also developed to lower the risk of three-body wear. Currently, the most frequently implanted size in head diameters is 28 mm.

For this diameter, the typical in-vivo wear rates are:
- 200 µm/year for the system metal/UHMWPE
- 100 µm/year for the system alumina/UHMWPE

These wear rates are sufficiently low to assure a stable mechanical function of the hip arthroplasty.

Due to the small size of the UHMWPE wear particles (about 0.5 µm), their number is enormous (about 500.000 per step) and this may overload the lymphatic system, leading in the long term to an aseptic loosening of the components [1], due to particles disease.

This limitation of hip arthroplasty was the stimulus to develop new articulation systems.

LOW WEAR SOLUTIONS

Three main direction were followed to lower the wear of hip arthroplasties:

1. Metal-on-metal articulations
   In the early 80’s, some anecdotic observations of perfect results with metal-on-metal articulations (follow-up time of more than 15 years) were made. These observations were the motivation to develop a new generation of improved metal-on-metal joints. The clearance was found to be the key factor for controlling the wear behaviour of metal-on-metal hip joints [2].
   After the running-in phase, the in-vivo wear rate of a modern metal-on-metal articulation is about 5 µm/year.

2. Alumina-on-alumina articulations
   Due to the better quality of the alumina components, a renewal of alumina-on-alumina articulations was made in the early 90’s. In the in-vivo wear rate is also within the range of 5 µm/year. However, the fracture rate of these alumina-on-alumina articulations is about 1 on 2.000 [3].

3. Highly cross-linked UHMWPEs
   The latest development was made in the late 90’s with the development of highly crosslinked UHMWPEs. These UHMWPEs showed an extreme wear resistance on hip simulators [4] and the first clinical results are currently collected.

FUTURE POSSIBILITIES

There are two main future directions for the tribology of total hip prostheses: the development of coatings (DLC, …) and the development of new, tougher ceramics with lower fracture risk for ceramic-on-ceramic articulations.

REFERENCES