

# TRIBOLOGIC ASPECTS OF TOTAL HIP ARTHROPLASTY

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**INTRODUCTION:** The tribology (science of wear & friction) of artificial joints comprises the wear behaviour of bearing surfaces of implants. With material pairings used today the surrounding tissue and body fluids of an implant are threatened by the generation of particles released from the articulating surfaces as well as by corrosion of metal implant materials. This abstract will highlight the basic mechanisms involved in the wear mechanism and particle generation process. It also contains a number of state-of-the-art methods to assess tribologic factors in total hip arthroplasty (THA) in order to present a methodical approach to unveil a failed total hip reconstruction.

**TRIBOLOGY:** Interacting forces and the relative movement of the pairing play a predominate role in the discussion of any tribologic system. Surface properties of the materials used and thus lubrication characteristics and temperature rise are consequences of the design parameters of the system. Concerning the tribologic situation in total hip arthroplasty, wear particles and their assumptive trigger of osteolysis are the focus of our interest. There are four basic types of wear: adhesive, abrasive, corrosive, and surface-fatigue. The most common type, adhesive wear, arises from strong adhesive forces that are generated at the interface of two solid materials. Abrasive wear occurs when a hard, rough surface slides over a softer one, producing grooves on the latter. It can be caused by loose, abrasive particles rolling between two soft sliding surfaces or by particles embedded in one of the opposing surfaces. Corrosive wear occurs whenever a gas or liquid chemically attacks a surface left exposed by the sliding process. Surface-fatigue wear is produced by repeated high stress attendant on a rolling motion. The stress causes subsurface cracks, which eventually grow and separate larger particles from the surface.

**TOTAL HIP ARTHROPLASTY:** The four major material pairings used in THA today are metal-on-polyethylene, ceramics-on-polyethylene, metal-on-metal and ceramics-on-ceramics. Tribological systems as these produce wear particles of different materials and size. The mechanical input to the system, its lubrication, the materials involved and the design of the prostheses influence the generation rate and size distribution of those particles. Depending on the interacting

forces (mainly the activity of the patient) the wear rate can be increased three times in the beginning of the lifetime of an implant - the so-called running-in period. Examples of different wear characteristics of the bearing surfaces will be discussed including selective corrosion of metal ball heads, abrasive wear patterns in polyethylene cups, crack propagation of ceramics etc. Particles liberated from the surfaces of the bearing partners induce foreign particle reaction of the biological system. They are digested and corrode or capsulated and embedded in the peri-prosthetic tissue depending on size and material composition. Analytical methods of tissue & fluid examination supply the contamination rate by foreign materials.

**METHODS OF INVESTIGATION:** The main techniques involved in the examination of tribological well-functioning of implants are the wear measurement by the dimensional method or the departure of roundness according to ISO standards and the surface examination with optical and scanning electron microscopy (SEM). There are numerous results deriving from the dimensional characterization of the bearing surfaces: the volumetric wear, localization of wear on the surface, the linear wear rate, and the clearance. To describe the type of wear on the surfaces of the femoral ball heads and acetabular inlays they are inspected by optical means and by scanning electron microscopy (SEM). Stereo-imaging and EDX-mapping (energy dispersive x-ray) are commonly used to get impressions of the worn surfaces of the implants, as well as material- and topographic-contrast-imaging with primary electron detection. The application of a standardized retrieval procedure and methods of investigation for the implants and tissues are essential to obtain comparable results. Such standard methods are presented.

**FUTURE ASPECTS:** Whilst the basic tribology in THA is widely understood, description routines for the morphology and size distribution as well as the generation function are still to be defined. A quasi-static equilibrium attunes between the generation of particles and the biological reaction and feedback to the tribologic system. The tissue reaction and its feedback to the tribologic system needs further modelling which could be used in a mathematical description of the feedback loop.