Tribology and Bioscience

Tribology is the science of interacting surfaces in relative motion and is associated with friction, wear and lubrication. Tribology when applied to biological systems is called biotribology. The article provides an overview on biotribology and its applications.

Biotribology is defined as the tribological phenomenon (friction, wear & lubrication) occurring in biological systems or we can say either in human body or in animals. The word biotribology was coined only four decades ago (Dowson & Wright 1973) but the science of biotribology started long way back.

In the earlier 19th century, Young (1809) and Poiseuille (1840) studied the flow properties of blood, essential today for the design of artificial organs. Reynolds likened lubrication of articulated joints to lubrication of machine elements.

Biotribology and implantation of artificial devices in the human body

We all have heard or met people who have undergone total hip replacement surgery. It's quite common in old age. Each year in the US, an estimated 30 000 people undergo a hip replacement procedure.

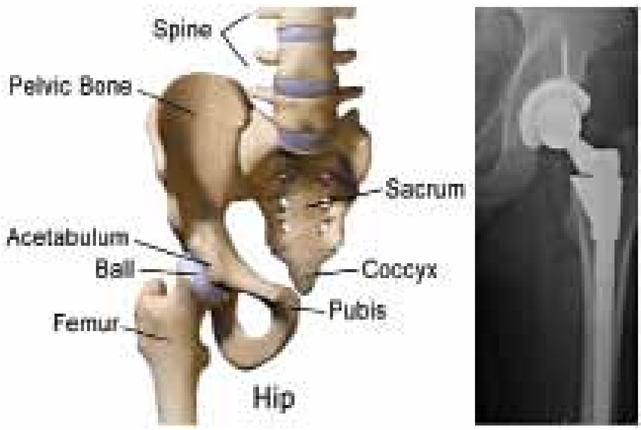

Figure 1: Anatomy of hip joint and hip replacement

The hip joint is one of the largest joint in human body and is of the ball and socket type. The socket is formed by the acetabulum while the ball is the femoral head. A thin tissue called the synovial membrane surrounds the hip joint and provides small amounts of fluid that lubricate the cartilage and eliminate almost all friction during hip movement.

Arthritis (inflammation of the hip joint and the breakdown of the cartilage that normally cushions your hip bones), post-traumatic arthritis (fractures of the hip due to some injury) and childhood hip diseases are some of the common causes of hip pain. Based upon several factors (medical history, physical examination, X-ray, MRI scans and many other tests), an orthopaedic surgeon decides whether the patient should have hip replacement surgery or not.

Metal socket

Total hip joint replacement first involves surgical removal of the damaged ball and socket. The damaged femoral head is then replaced with a metal stem carrying a metal (or ceramic) ball at its head. The socket (acetabulum) is replaced with a metal socket. Screws are sometimes used to hold the socket in place. In order to allow smooth gliding a plastic, ceramic, or metal spacer is inserted between the new ball and the socket.

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After the ball and socket are fixed they are aligned according to the natural hip movement of the patient. The surgery takes a few hours. Physical therapy can help in strengthening your hip and restores movement for walking and other normal daily activities.

Three main classes

Currently, three main classes of materials are being used in hip replacements: ceramics, metals and polymers. The ceramics category includes aluminum oxide ceramics and zirconia-toughened alumina ceramics. The metal category involves Cobalt-chrome-molybdenum alloys (CoCrMo) while the polymer category consists of ultra-high molecular weight polyethylene (PE). These materials can be combined in several ways and are generally classified in hard-soft and hard-hard combinations.

The wear characteristics of these materials should allow a hip joint to last for the entire life of the patient. But in reality these implants last only 12 to15 years in the human body. Replacing them means another major surgery for the patient which would be very distressing for the patient both health wise and cost wise.

Figure 2: Tooth implant

Figure 3: A human eye

The answers

Biotribologists are searching for answers to this problem. A range of biomaterials are now being tested for friction and wear characteristics using simulators. These are used to perform tribological tests on biomaterials so that the quality and efficiency can be checked, prior to implantation in the human body.

Better tribological understanding of hair and skin can help in the development of efficient hair products such as shampoos and conditioners and skin care products such as moisturizers

Experiments can run for several months or even a year in order to reproduce 10 or more years of natural wear. Cross linked polyethylene for sockets can be a possible solution for the problem. Laboratory tests have shown much less wear for cross linked polyethylene.

Another problem with hip replacement surgery is the lubricant "synovial fluid" which provides nourishment to the cartilage, thereby reducing friction and wear of the natural joint. But synovial fluid was developed for lubrication of human tissue and not for lubricating metal joints. Extensive research work is required in order to find a solution to this problem.

Biotribology application into dental science

The teeth are the hardest substance in the human body and can survive for a few decades. Other than chewing, teeth play an important role in speech. Tooth wear is unavoidable and can happen naturally or artificially. Excessive wear may lead to improper contact between teeth and can result in discomfort while chewing.

A better understanding of the wear mechanisms of teeth can help us to find better materials and systems for dental implants. Teeth are made of enamel (white outer part of teeth composed of calcium phosphate, a rock-hard mineral) which shows excellent wear resistance even in the harshest environment found in the mouth such as extreme temperature variations, wide range of loads, reciprocating movement and many others. Current artificial dental implants include ceramics, metals and their alloys, polymers and composites.

Although much progress has been made in achieving quality implants for dental application, biotribologists are working hard to understand the friction and wear characteristics of implants in order to make an implant as tough as a natural tooth. However, the major challenge is simulating natural mouth environment in laboratory for tribological tests.

Biotribology application into ocular science

Tears lubricate our eyes which helps in the free frictionless movement of various parts of the eye. Dry eye syndrome is caused by a lack of sufficient lubrication and moisture on the surface of the eye or a general decrease in the quantity of tears.

Scientists are working hard in order to replicate properties of tears in a lubricant as this can prove to be a cure for the disease. Also the effect of these artificial fluids on compact lenses is a matter of great research.

Biotribology application into dermatology

Tribology founds its application even in human hair and skin. Blow-drying, straightening, use of synthetic styling products, chemical dyeing, or the constant grip of hair extensions contribute towards mechanical and chemical damage of hair fibers which in scientific terms can be considered as wear phenomenon in human hair. On the other hand, combing of hair via a plastic comb and entangling of hair represents friction.

Better tribological understanding of hair and skin can help in the development of efficient hair products such as shampoos and conditioners and skin care products such as moisturizers. Shampoos and conditioners have to be developed in such a fashion that they provide excellent cleaning and repairing functions. This can be accomplished with the help of microscale and nanoscale technologies such as atomic force/friction force microscopies (AFM/FFM) and nano-indentation.

AFM helps in examining the structure of the hair surface and its cross section. Nano-indentation can help in the estimation of nano-mechanical properties such as hardness, elastic modulus, and scratch resistance, of the hair surface before and after conditioner treatment in varied configurations.

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Figure 4: Human hair