Chapter 8
Surface Modifications and Tribological Effect in Orthopedics Implants

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ABSTRACT

In this chapter, the authors illustrate advantages and disadvantages of several surface modification techniques on orthopedics implants. The number of hip and knee replacement procedures per year is one of the highest in medical surgery, and there are many approaches engaged to improve the acceptability of these prosthesis to be suitable for young patients. Surface modification is one of them that has been utilized owing to its potential impacts. A critical review on the major tribological and biological outcomes of these modifications is exclusively described. A few interesting results of recent investigations have been explained for future trends in biotribological effect in orthopedic implants.

1. INTRODUCTION

A successful design and fabrication of modified surface can control the major aspects of tribology such as lubrication, friction coefficient, wear rate and debris. There are many examples of successful applications of engineering and functional surfaces in tribology such as engine cylinder (Ryk & Etsion, 2006), golf ball (Bearman & Harvey, 1975), ball and rolling bearing (Ali, Křupka & Hartl, 2013) and artificial joints (Ito, Kaneda, Yuhta, Nishimura, Yasuda & Matsuno,2000). Similarly, it is not uncommon to find an example of natural surfaces (such as skin) on various living element in order to perform in special circumstances. For example, ribs and grooves are found to be on the shark skin which decrease drag and friction forces effectively; again tree frogs are capable to climb

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smooth surfaces without slipping because of their special microstructure surface profile feet, in that case, the drag and the friction increase (Sawano, Warisawa &Ishihara, 2009). In engineering tribology, comparatively wider options are available changing the interface conditions such as dimension of interface, lubricant or roll/sliding ratios, however, in orthopedic implants; these options are limited to be changed. One of the available modifiable options is surface modification, either in bottom up (coating) or bottom down (texturing, dimple or groove) methods. The required modified surface depends on experimental parameters including expected tribological outcomes, interface conditions (lubrication, temperature, geometry) and bulk material properties. Orthopedics implants are used to the patients for relieving the intolerable pain, and retaining patient's mobility. Unlike engineering bearings, these joints cannot be easily replaceable, thus a lifelong prosthesis is very much desirable. The revision rate of the implanted joints is still high——37% after 20 years, which is a key concern, particularly for the young patients (Tarabolsi, Klassen, Mantwill, Gärtner, Siegel & Schulz, 2013). The failure mechanism reveals that excess wear rate and generated debris are mostly associated to the aseptic loosening—— a major reason of the high revision rate of implanted hip or knee joints (Bozic, Ong Lau, Kurtz, Vail, Rubash &Berry, 2010; Nine, Choudhury, Hee, Mootanah &Osman, 2013). Therefore, plenty of researches have been conducted recently aiming to reduce the wear rate by improving material properties, optimizing geometry (size and shape) and lubrication mechanism, and *surface modification*. Bottom up surface modification improves the mechanical and surface properties such as hardness, wettability, biocompatibility, and corrosion resistance, however, the adhesion problem is still an insolvent issue (Ching, Choudhury,Nine & Osman, 2013; Hauert, Thorwarth &Thorwarth, 2013). On the other hand, surface texture is relatively new technique in orthopedics implants, and their efficiency is under laboratory based research because the relative speed is low but contact pressure is high, and viscosity of synovial fluid is lower than non-Newtonian fluid (Roy, Choudhury,Bin Mamat & Pingguan, 2014). Furthermore, design of surface texture has not been optimized yet because of multidirectional sliding nature of hip joints and variation in lubrication properties of synovial fluid (protein concentration). Durability of dimple profiles is another concern which could be demolished over time and affect severely on the functional ability of implanted joints. Few studies proved the effectiveness of dimple surface in friction reduction experimentally but predicted long term wear properties theoretically (Ito et al., 2000, Sawano et al., 2009). Our earlier study (Roy et al., 2014) proves that the hardness of dimple edge is lower than the bulk material. A precise and mass production of micro texture is also a challenge, particularly to a complex and hard substrate. In this chapter an in-depth discussion of bottom up and bottom down surface modification techniques and their available impact on biotribology are discussed.

2. BACKGROUND: BIO-TRIBOLOGY AND SURFACE MODIFICATION

Bio-tribology deals with a wide range of research topics from artificial joint implants to hair conditioners and soft-tissue friction. In this chapter, we have focused on load-carrying bearings such as hip and knee joints which usually perform well in the presence of a healthy synovial fluid. However, in some cases, their performances can be disrupted due to a change in synovial fluid quality, higher surface roughness and stiffer cartilage. A lot of researches have been carried out to understand the lubrication mechanism in synovial joints, and a number of lubrication mechanisms have been proposed to address them (Ghosh, Choudhury,Das &Pingguan-Murphy, 2014). Recent studies (Ghosh et al., 2014; Vrbka, Krupka,Hartl, Navrat, Gallo,& Galanda'kova,2014) revealed that syno-

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