Chapter 9
Articulating Biomaterials:
Surface Engineering, Tribology, and Biocompatibility

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ABSTRACT

This chapter examines the importance of surface characteristics such as microstructure, composition, crystallographic texture, and surface free energy in achieving desired biocompatibility and tribological properties thereby improving in vivo life of artificial articulating implants. Current implants often fail prematurely due to inadequate mechanical, tribological, biocompatibility, and osseointegration properties, apart from issues related to design and surgical procedures. For long-term in vivo stability, artificial implants intended for articulating joint replacement must exhibit long-term stable articulation surface without stimulating undesirable in vivo effects. Since the implant's surface plays a vital and decisive role in their response to biological environment, and vice versa, surface modification of implants assumes a significant importance. Therefore, overview on important surface modification techniques, their capabilities, properties of modified surfaces/implants are presented in the chapter. The clinical performance of surface modified implants and new surfaces for potential next-generation articulating implant applications are discussed at the end.

1.0 INTRODUCTION

Joints or articulations are important parts of human skeleton which provide mechanical supports and most of the cases provide mobility in rigid skeleton. Joints are the parts where two or more bones come together and may allow one bone to move against other. Joints are classified in two major groups according to structural compositions (type of connective tissues and joint capsule) and functional (degree of movement) behaviour of the joints. These two classifications are interrelated as

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joints' mobility depends on the major connective tissues binding the bones and presence or absence of a joint capsule.

Types of joints:

1. **Structural Classification:** Joints are classified based on the major connective tissues binding the bones and presence or absence of a fluid-filled joint capsule.
   a. **Fibrous Joints:** Bones are joined by fibrous connective tissue, no joint cavity present, and exhibit slight or no movement.
   b. **Cartilaginous Joints:** Bones are united by means of either hyaline cartilage or fibrocartilage, lack of joint cavity, and exhibit little or no movement
   c. **Synovial Joints:** Articulating bones having smooth surfaces (called articular cartilage) and the end of the articulating bones surrounded by a fluid-filled joint cavity. Synovial joints are freely moveable joints. Synovial joints are mostly found in limbs.
2. **Functional Classification:** Depending on movement capability (functionality), joints are broadly classified in three groups:
   a. **Synarthroses:** These joints are immovable in nature. Bones are in almost direct contact and connected by fibrous connective tissue. Example - the joints between the bones of the skull.
   b. **Amphiarthroses:** These joints allow slightly movement. Here bones are connected by cartilage in such a way that only limited movement is permitted. Example - spinal column, rib cage where the ribs connect to the sternum.
   c. **Diarthroses:** These joints are joints that can exhibits free movement, are also called synovial joints. Example – hip joint, knee joint, shoulder joints, elbow joints, etc.

In this chapter only synovial joints (diathroses) are considered in detail due to their complexity in terms of structure and functional performance. Following sections of this chapter provide an overview of structure and function some of the important natural synovial joints and materials used for their replacement. Further, the importance of implants' surface characteristics in achieving desired *in vivo* life via tailoring biocompatibility, corrosion and tribological properties using various surface modification techniques is also highlighted. This is followed by a discussion on performance of these surface modified implants under simulated *in vitro* and *in vivo* conditions. Finally, a brief notes on new surfaces for next-generation articulating implant applications and future directions are presented. The influence of above stated surface characteristics of biomaterials on cellular activities such as cell adhesion, proliferation and differentiation on artificial implants, which strongly effect osseointergration, osteoinduction, osteoconduction and biological fixation, are beyond the scope of present chapter.

1.1 Structure and Characteristics of Natural Synovial Joints

Among different joints, synovial joints are most important joints with large range of movement. These joins experience large ranges of relative motion in multiple directions, exceeding 100 million cycles within a lifetime without failure, and in some cases with peak loads more than six times body weight (Mow & Mak, 1987; Unsworth, 1978). Due to the dynamic loading associated with the normal activities of life, these joints are porn to suffer from injuries or degeneration. Deterioration of these joints causes debilitated pain and loss of mobility for the patient. As a result, biomechanics of different synovial joints has been studied science the early 1900's.

Synovial joints have a characteristic space between articulating bones, called synovial cavity, which is covered in a capsule containing synovial

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