Biomaterials

المحاضرة الأولى

م.م نور ضياء محمد تقي الربيعي

Introduction to Biomaterials

INTRODUCTION

With the evolution of human civilization, the field of biomaterials evolved involving different materials at multiple length scales from nano- to micro- to macro level with a simple focus to extend human life and

Over 1000 years back, silver in different forms was used as an antimicrobial agent to prevent infection. Different types of surgical procedures can also be found during early stages of civilization. However, probably the most significant developments took place in the field of biomaterials over the years 1901–2000.

Artificial joints improved the quality of life for millions of people over the past 60 years, resorbable sutures simplified surgical procedures, and different cardiovascular devices saved millions of lives, just to name a few.

The advent of tissue engineering and organ regeneration is pushing the frontiers of science today to make the years 2001–2100 more exciting in the field of biomaterials. However, to appreciate the benefits, it is not just the design of biomaterials that is important, but sound engineering design and appropriate materials and device characterization are also needed.

Moreover, for a biomedical device to see the commercialization light, it is also important to carry out testing following appropriate standards to get regulatory approval. Overall, benefits of biomaterials research can only be appreciated when these materials are characterized well at both the materials level and the device level following regulatory guidelines.

Considering the multidisciplinary nature of the field, it is also not easy to carry out large variety of experiments using different techniques. Realizing this problem in biomaterials characterization, we have developed this book to offer an insight on various characterization tools focusing on biomaterials and biomedical devices.

BIOMATERIALS AND BIOCOMPATIBILITY

A biomaterial is a material, synthetic or natural, that can be used in medical applications to perform a body function or replace a body part or tissue. A biomaterial is intended to interact at the interface of biological systems. It may also be used as a delivery system for drug or biological factor. Biomaterials are designed based on application needs. Reaching back to the beginnings of civilization, the Romans, Aztecs and Chinese used gold in dental applications.

The Mayans were found to have fashioned dental implants out of sea shells with results indicating actual bone integration. A biomaterial must be biocompatible, i.e., it should be friendly to biological system and not do any harm to the system, whether at the cellular level or at the system level.

A biocompatible material should elicit appropriate host response or able to perform its intended function in a specific application without the presence of adverse reactions.

This is an emerging paradigm that requires and pushes unique multidisciplinary boundaries based on understanding and integration of concepts from various broad fields, but not limited to, chemistry, biology, materials science, mechanical, chemical and electrical engineering as well as medicine.

Biomaterials are used to augment, repair or replace any tissue, organ, or function of the body that has been lost through trauma, disease or injury. Recent practice in medicine often times uses tissue reconstruction using autograft, where tissue graft or organ transplant from one point to another of the same individual takes place.

However, limited availability, donor site morbidity and above all, the need for a second surgery restrict their application. On the other hand, potential alternative is the use of allograft, i.e. tissue graft or organ transplant from a donor of the same species as the recipient.

The other alternative could be xenograft, which is tissue graft or organ transplant from a donor of a different species from the recipient. Both allograft and xenograft use are somewhat restricted due to the immunogenic response and they may impose adverse biocompatibility in patients' body.

These reasons draw our attention to the biomaterials that are available from other sources, which could be synthetic or natural. It was not until the turn of the twentieth century, modern biomaterials and their potential applications began to take shape. These first-generation modern biomaterials are mainly focused on basic functionality and biocompatibility.

Since early 1900s, metal plates were used to stabilize long bone fractures with the hopes of faster and more functional healing. By the 1930s, full joint replacement surgeries were being performed with varying degrees of success.

The invention and widespread use of synthetic plastics created a boom in the biomaterials industry resulting in devices such as synthetic heart valve (metal cage surrounding a silicone elastomer ball) and total hip arthroplasty systems (ultrahigh molecular weight polyethylene).

Some other important inventions in this era include the intraocular lenses (poly(methyl methacrylate)dPMMA) and the desk-sized pacemaker.

Further understanding of the complexities of biology ushered in the next generation of biomaterials beginning in the 1960s.

Scientists and engineers began to design materials specifically for use in biomedical applications. The focus began to shift from materials that were simply biocompatible to technologies that took into consideration the specific needs of the specific biology.

Many bioresorbable materials, those biomaterials resorbed in biological system, were also created during this time. Some of the major advances in materials came in the form of synthetic polymers such as Teflon, which is still widely used today in various vascular grafting and surgical applications. Hydrogels lead to the invention of the soft contact lenses.

Poly(lactic–glycolic acid) (PLGA) was developed for resorbable sutures. Plastic materials were not the only advances made during this time period. Ceramics such as calcium phosphate synthetic bone analogs were also developed. Today, these synthetic materials are used more often than autografts (bone taken from another source on the patient’s body) or allografts (processed cadaver bones). Titanium alloys with better biocompatibility were developed as a lighter alternative to traditional stainless steel orthopedic implants.