BIOMATERIALS IN MEDICINE

Patitapabana Parida[1], Subash Chandra Mishra[2]

[1.] University Dept. of Pharmaceutical Science, Utkal University, Bhubaneswar, Odisha, India,
[2.] Dept. of Metallurgical and Materials Engineering, National Institute of Technology, Rourkela, Odisha, India.

Introduction

The performance of materials in the body can be classified in many ways. Biomaterial is used to make devices to replace a part or a function of the body in a safe, reliable, economic, and physiologically acceptable manner [hench and erthridge, 1982]. A Variety of devices and materials presently used in the treatment of disease or injury include such commonplace items as sutures, needles, catheters, plates, tooth fillings, etc. Over the years, a biomaterial can be simply defined as a synthetic material used to replace part of a living system or to function in intimate contact with living tissue. The Clemson University Advisory Board for Biomaterials has formally defined a biomaterial to be "a systemically and pharmacologically inert substance designed for implantation within or incorporation with living systems". It is also defined as "a nonviable material used in a medical device, intended to interact with biological systems" [Black, 1992]. Other definitions have included "materials of synthetic as well as of natural origin in contact with tissue, blood, and biological fluids, and intended for use for prosthetic, diagnostic, therapeutic, and storage applications without adversely affecting the living organism and its components" [Bruck, 1980] and "any substance (other than drugs) or combination of substances, synthetic or natural in origin, which can be used for any period of time, as a whole or as a part of a system which treats, augments, or replaces any tissue, organ, or function of the body" [Williams, 1987]. By contrast, a biological material is a material such as skin or artery, produced by a biological system. According to these definitions one must possess knowledge in a number of different disciplines or collaborate with individuals from a wide variety of different specialties in order to properly develop and use biomaterials in medicine and provides some examples of the uses of biomaterials, which include replacement of a body part that has lost function due to disease or trauma, to assist in healing, to improve performance, and to correct abnormalities. The role of biomaterials has been influenced considerably by advances in many areas of biotechnology and science. For example, with the advent of antibiotics, infectious disease is less of a threat than in former times, so that degenerative diseases assume a greater importance. Moreover, advances in surgical technique and instruments have permitted materials to be used in ways that were not possible previously [1].

History

The use of biomaterials did not become practical until the advent of an aseptic surgical technique developed. Earlier surgical procedures, whether biomaterials were generally unsuccessful as a result of infection occurs. Problems of infection tend to be exacerbated in the presence of biomaterials, since the implant can provide a region inaccessible to the body's immunologically competent cells. The earliest successful implants, as well as a large fraction of modern ones, were in the skeletal system. Bone plates were introduced in the early 1900s to aid in the fixation of long bone fractures. Many of these early plates broke as a result of unsophisticated mechanical design; they were too thin and had stress concentrating corners. Also, materials such as vanadium steel, which was chosen for its good mechanical properties, corroded rapidly in the body and caused adverse effects on the healing processes. Better designs and materials soon followed. Following the introduction of stainless steels and cobalt chromium alloys in the 1930s, greater success was achieved in fracture fixation, and the first joint replacement surgeries were performed. As for polymers, it was found that warplane pilots in World War II who were injured by fragments of plastic (polymethyl methacrylate) aircraft canopy did not suffer adverse chronic reactions from the presence of the fragments in the body. Polymethyl methacrylate became widely used after that time for corneal replacement and for replacements of sections of damaged skull bones. Following further advances in materials and in surgical technique, blood vessel replacements were tried in the 1950s and heart valve replacements and cemented joint replacements in the 1960s. Recent years have seen many further advances [2].

Application & uses of Biomaterials

Table 1. Uses of Biomaterials

Problem Area	Examples
Replacement of diseased or damaged part	Artificial hip joint, kidney dialysis machine
Assist in healing	Sutures, bone plates, and screws
Improve function	Cardiac pacemaker, intraocular lens
Correct functional abnormality	Cardiac pacemaker
Correct cosmetic problem	Augmentation mammoplasty
Aid to diagnosis	Probes and catheters
Aid to treatment	Catheters, drains

Table 2. Biomaterials in Organs

Organ	Examples
Heart	Cardiac pacemaker, artificial heart valve, total artificial heart, blood vessels
Lung	Oxygenator machine
Eye	Contact lens, intraocular lens
Ear	Artificial stapes, cochlea implant
Bone	Bone plate, intramedullary rod
Kidney	Catheters, stent, Kidney dialysis machine
Bladder	Catheter and stent

Table 3. Biomaterials in Body Systems

System	Examples

Skeletal	Bone plate, total joint replacements
Muscular	Sutures, muscle stimulator
Nervous	Hydrocephalus drain, cardiac pacemaker, nerve stimulator
Endocrine	Microencapsulated pancreatic islet cells
Reproductive	Augmentation mammoplasty, other cosmetic replacements

1. Metallic Biomaterials

The first metal alloy developed specifically for human use was the “vanadium steel” which was used to manufacture bone fracture plates (Sherman plates) and screws. Most metals such as iron (Fe), chromium (Cr), cobalt (Co), nickel (Ni), titanium (Ti), tantalum (Ta), niobium (Nb), molybdenum (Mo), and tungsten (W) that were used to make alloys for manufacturing implants can only be tolerated by the body in minute amounts. Sometimes those metallic elements, in naturally occurring forms, are essential in red blood cell functions (Fe) or synthesis of a vitamin B-12 (Co), but cannot be tolerated in large amounts in the body [Black, 1992]. The biocompatibility of the metallic implant is of considerable concern because these implants can corrode in an in vivo environment [Williams, 1982]. The consequences of corrosion are the disintegration of the implant material per se, which will weaken the implant, and the harmful effect of corrosion products on the surrounding tissues and organs [3].

2. Ceramic Biomaterials

The most important properties like; 1. Should be non-toxic, 2. Should be non-carcinogenic, 3. Should be non-allergic, 4. Should be non-inflammatory, 5. Should be biocompatible, 6. Should be biofunctional for its lifetime in the host. Ceramics are generally hard; in fact, the measurement of hardness is calibrated against ceramic materials & are focused on a general overview of the relatively bioinert, bioactive or surface reactive ceramics, and biodegradable or resorbable bioceramics. Ceramics used in fabricating implants can be classified as nonabsorbable (relatively inert), bioactive or surface reactive (semi-inert) [Hench, 1991, 1993], and biodegradable or resorbable (non-inert) [Hentrich et al., 1971; Graves et al., 1972]. Alumina, zirconia, silicone nitrides, and carbons are inert bioceramics. Certain glass ceramics and dense hydroxyapatites are semi-inert (bioreactive), and calcium phosphates and calcium aluminates are resorbable ceramics [Park and Lakes, 1992] [4]

3. Polymeric Biomaterials

Synthetic polymeric materials have been widely used in medical disposable supplies, prosthetic materials, dental materials, implants, dressings, extracorporeal devices, encapsulants, polymeric drug delivery systems, tissue engineered products, and orthodoses like those of metal and ceramics substituents. The main advantages of the polymeric biomaterials compared to metal or ceramic materials are ease of manufacturability to produce various shapes (latex, film, sheet, fibers, etc.), ease of secondary processability, reasonable cost, and availability with desired mechanical and physical properties. The required properties of polymeric biomaterials are similar to other biomaterials, that is, biocompatibility, sterilizability, adequate mechanical and physical properties, and manufacturability [5].

Table 4. Biomedical Application of Polymeric Biomaterials

Synthetic Polymers	Applications
Polyvinylchloride	Blood and solution bag, surgical packaging, IV sets, dialysis devices,catheter bottles, connectors, and cannulae
Polyethylene	Pharmaceutical bottle, nonwoven fabric, catheter, pouch, flexible container, and orthopedic implants
Polypropylene	Disposable syringes, blood oxygenator membrane, suture, nonwoven fabric, and artificial vascular grafts
Polymethylmetacrylate	Blood pump and reservoirs, membrane for blood dialyzer, implantable ocular lens, and bone cement
Polystyrene	Tissue culture flasks, roller bottles, and filterwares
Polyethylenterephthalate	Implantable suture, mesh, artificial vascular grafts, and heart valve
Polytetrafluoroethylene	Catheter and artificial vascular grafts
Polyamide	Packaging film, catheters, sutures, and mold parts

4. Composite Biomaterials

The term “composite” is usually reserved for those materials in which the distinct phases are separated on a scale larger than the atomic, and in which properties such as the elastic modulus are significantly altered in comparison with those of a homogeneous material. Accordingly, reinforced plastics such as fiberglass as well as natural materials such as bone are viewed as composite materials, but alloys such as brass are not. Foam is a composite in which one phase is empty space. Natural composites include bone, wood, dentin, cartilage, and skin. Natural foams include lung, cancellous bone, and wood. Natural composites often exhibit hierarchical structures in which particulate, porous, and fibrous structural features are seen on different micro-scales [Lakes, 1993]. In biomaterials, it is important that each constituent of the composite be biocompatible. Moreover, the interface between constituents should not be degraded by the body environment. Some applications of composites in biomaterial applications are: (1) dental filling composites, (2) reinforced methyl methacrylate bone cement and ultra-high-molecular-weight polyethylene, and (3) orthopedic implants with porous surfaces. Moisture absorption by polymer constituents also causes swelling. Such swelling can be beneficial in dental composites since it offsets some of the shrinkage due to polymerization. Flexible composite bone plates are effective in promoting healing [Jockish, 1992], but particulate debris from composite bone plates gives rise to a foreign body reaction similar to that caused by ultra-highmolecular- weight polyethylene[6].

5. Biodegradable Polymeric Biomaterials:

The term biodegradation is loosely associated with materials that could be broken down by nature either through hydrolytic mechanisms without the help of enzymes and/or enzymatic mechanism. Other terms such as absorbable , erodible , and resorbable have also been used in the literature to indicate biodegradation. Interest in biodegradable polymeric biomaterials for biomedical engineering use has increased dramatically during the past decade. This is because this class of biomaterials has two major advantages that non-biodegradable biomaterials do not have. First, they do not elicit permanent chronic foreign-body reactions due to the fact that they are gradually absorbed by the human body and do not permanently leave traces of residual in the implantation sites. Second, some of them have recently been found to be able to regenerate tissues, so-called tissue engineering, through the interaction of their biodegradation with immunologic cells like macrophages. Hence, surgical implants made from biodegradable biomaterials could be used as a temporary scaffold for tissue regeneration. This approach toward the reconstruction of injured, diseased, or aged tissues is one of the most promising fields in the 21st century. While aromatic polyesters are almost totally resistant to microbial attack, most aliphatic polyesters are biodegradable due to their potentially hydrolysable ester bonds: Naturally Produced: Polyhydroxyalkanoates like the poly-3-hydroxybutyrate (PHB), polyhydroxyvalerate & polyhydroxyhexanoate; Renewable Resource: Polylactic acid; Synthetic: Polybutylene succinate , polycaprolactone , Polyanhydrides, Polyvinyl alcohol, Most of the starch derivatives, Cellulose esters like cellulose, acetate and nitrocellulose and their derivatives (celluloid) are recently used [7].

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