IMPLANTABLE MATERIALS (8)

The science of biomedical materials involves a study of the composition and properties of materials and the way in which they interact with the environment in which they are placed. The most common classes of materials used as biomedical materials are metals, polymers, ceramics, and composite. These four classes are used singly and in combination to form most of the implantation devices available today.

A. *Metals and Alloys:*

Metals have been used almost exclusively for loadbearing implants, such as hip and knee prostheses and fracture fixation wires, pins, screws, and plates. Although pure metals are sometimes used, alloys frequently provide improvement in material properties, such as strength and corrosion resistance. Three material groups dominate biomedical metals: Stainless steel, cobalt-chromium- molybdenum alloy, and titanium and titanium alloys.

The main considerations in selecting metals and alloys for biomedical applications are their excellent electrical and thermal conductivity, biocompatibility, appropriate mechanical properties, corrosion resistance, and reasonable cost. It is very important to know the physical and chemical properties of the different metallic materials used in any surgery as well as their interaction with the host tissue of the human body.

Stainless Steel:

Stainless steel was first used successfully as an important material in the surgical field. Stainless steel is the generic name for a number of different steels used primarily because of their resistance to a wide range of corrosive agents [10, 15]. Stainless steel has been used for wide range of application due to easy availability, lower cost, excellent fabrication properties, accepted biocompatibility and great strength.

TABLE 3 MECHANICAL PROPERTIES OF METALLIC BIOMATERIALS [31]

Material	Young's Modulus, E (GPa)	Yield Strength, (MPa)	Tensile Strength, UTS (MPa)	Fatigue Limit, (MPa)
Stainless steel	**190**	**221-1,213**	**586-1,351**	**241-820**
Co-Cr alloys	**210-253**	**448-1,606**	**655-1,896**	**207-950**
Titanium (Ti)	**110**	**485**	**760**	**300**
Ti-6Al-4V	**116**	**896-1,034**	**965-1,103**	**620**
Cortical bone	**15-30**	**30-70**	**70-150**	

TABLE 4 APPLICATION OF METALS AS IMPLANTS USED IN HUMAN BODY

Types of Materials	Applications
Stainless steel	**Joint replacements (hip, knee), Bone plate for fracture fixation, Dental implant for tooth fixation, Heart valve, Spinal Instruments, Surgical Instruments, Screws, dental root Implant, pacer, fracture plates, hip nails, Shoulder prosthesis**
Cobalt-chromium alloy	**Bone plate for fracture fixation, Screws, dental root implant, pacer, and Suture, dentistry, orthopedic prosthesis, Mini plates, Surgical tools, Bone and Joint replacements (hip, knee), dental implants**
Titanium and its Alloys	**Cochlear replacement, Bone and Joint Replacements (hip, knee),Dental Implants for tooth fixation, Screws, Suture, parts for orthodontic surgery, bone fixation devices like nails, screws and plates, artificial heart valves and surgical instruments, heart pacemakers, artificial heart valves**

Cobalt-Chrome:

Cobalt chromium alloys can be basically categorized into two types; one is The CoCrMo alloy [Cr (27-30%), Mo (5-7%), Ni (2.5%)] has been used for many decades in dentistry, and in making artificial joints and the second one The CoNiCrMo alloy [Cr (19-21%), Ni (33-37%), and Mo (9-11%)] has been used for making the stems of prostheses for heavily loaded joints, such as knee and hip [15]. Cobalt- based alloys are highly resistant to corrosion even in chloride environment due to spontaneous formation of passive oxide layer within the human body environment [10, 15, 16, 26, 27]. The thermal treatments used to Co-Cr- Mo alloys modify the microstructure of the alloy and alters the electrochemical and mechanical properties of the biomaterial [26]. The corrosion products of Co-Cr-Mo are more toxic than those of stainless steel 316L.

Titanium and its Alloys:

There are three structural types of titanium alloys: Alpha (a), Alpha-Beta (a-P) or metastable p and Beta (P).The p phase in Ti alloys tends to exhibit a much lower modulus than a phase, and also it satisfies most of the other necessities or requirements for orthopedic application [28, 29]. Ti alloys due to the combination of its excellent characteristics such as high strength, low density, high specific strength, good resistance to corrosion, complete inertness to body environment, enhanced biocompatibility, moderate elastic modulus of approximately 110 GPa are a suitable choice for implantation. Long-term performance of titanium and its alloys mainly Ti64 has raised some concerns because of releasing aluminum and vanadium

[9, 10]. Both Al and V ions are associated with long term health problems, like Alzheimer disease and neuropathy. Furthermore when titanium is rubbed between itself or between other metals, it suffers from severe wear [30].

The mechanical properties of materials are of great importance when designing load-bearing orthopedic and dental implants. Some mechanical properties of metallic biomaterials are listed in Table 3. The mechanical properties of a specific implant depend not only on the type of metal but also on the processes used to fabricate the material and device. The elastic moduli of the metals listed in Table 3 are at least seven times greater than that of natural bone.