Biomaterials

First Course

Third Stage

By

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Lecture No. (7)

Bio-metallic Materials

Introduction of Bio-metallic Materials:

In modern history, the metals and their alloys are widely used as biomedical materials. On one hand, metallic biomaterials cannot be replaced by ceramics or polymers at present. Because mechanical strength and toughness are the most important safety requirements for a biomaterial under load-bearing conditions, also their excellent electrical and thermal conductivity and mechanical properties. On the other hand, metallic materials sometimes show toxicity and are fractured because of their corrosion resistance is inadequate in vivo environment and mechanical damages as shown in (Figure 1), therefore no longer used as implants.

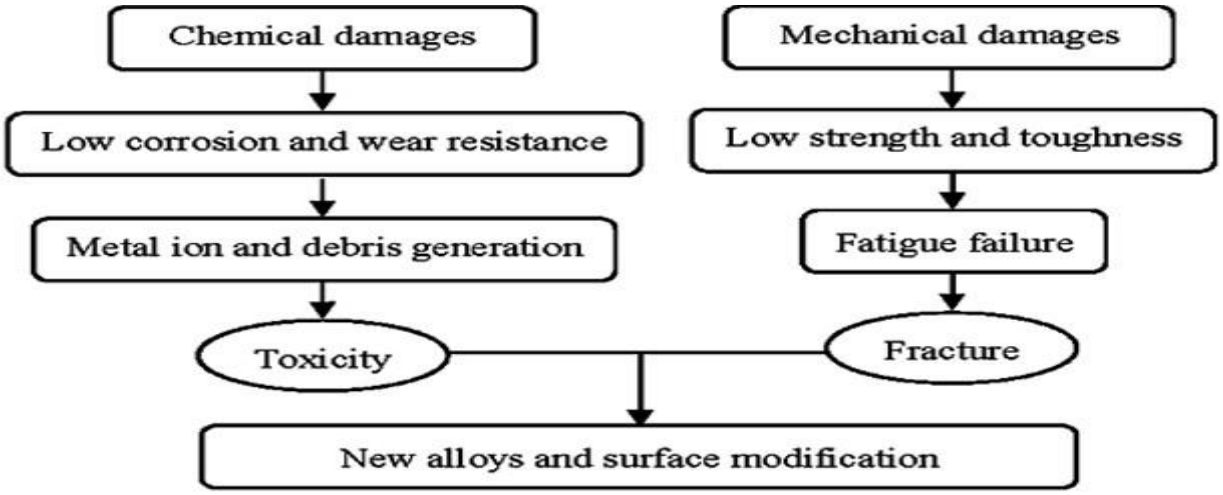

Figure (1): Degradation of metallic materials.

Therefore, development of new alloys is continuously trialed. Purposes of the development are as follows:

1- To remove toxic elements.

2- To decrease the elastic modulus to avoid stress shield effect in bone fixation.

3- To improve tissue and blood compatibility.

4- To miniaturize medical devices.

Advantages of Bio-metallic Materials

1- High strength.
2- High hardness.
3- Fatigue and impact resistance.
4- Wear resistance.
5- Easy fabrication.
6- Easy to sterilize.
7- Shape memory.

Disadvantages of Bio-metallic Materials

1- High modulus.
2- High corrosion.
3- Metal ions sensitivity and toxicity.
4- High density.

In general, metallic biomaterials can be grouped in the following categories:

1. Stainless steels.
2. Cobalt-based alloys.
3. Titanium-based alloys.
4. Specialty metallic alloys.

Some metals are used as passive substitutes because of their excellent mechanical properties, and corrosion resistance for:

1. Hard tissue replacement such as total hip and knee joints.
2. Hard tissue for fracture healing aids as bone plates.
3. Screws.
4. Spinal fixation devices.
5. Dental implants.

Some metallic alloys are used for more active roles in devices such as:

1. Vascular stents.
2. Orthodontic wires.
3. Catheter guide wires.

4. Cochlear implants.

Figure (2) illustrate the general used of bio-metallic materials in human body, and Table (1) summarized the type of metals generally used for different implants division.

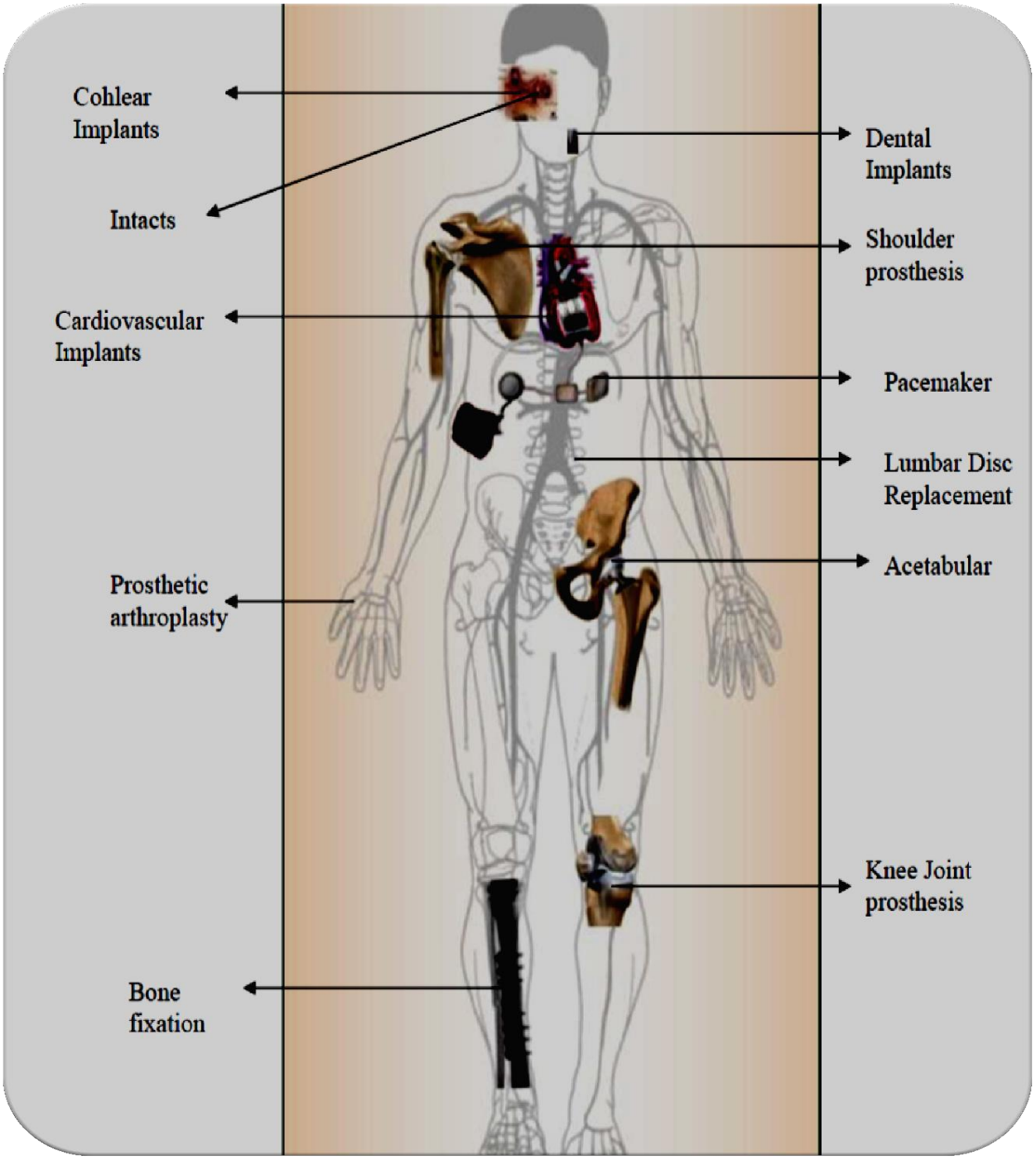

Figure (2): The General Applications of Bio-metallic Materials in Human Body.

Table (1): Implants Division and Type of Metals Used.

Division	Example of implants	Type of metal
Cardiovascular	Stent Artificial valve	316L SS; CoCrMo; Ti Ti6Al4V
Orthopedics	Bone fixation (plate, screw, pin) Artificial joints	316L SS; Ti; Ti6Al4V CoCrMo; Ti6Al4V; Ti6Al7Nb
Dentistry	Orthodontic wire Filling	316L SS; CoCrMo; TiNi; TiMo AgSn (Cu) amalgam, Au
Craniofacial	Plate and screw	316L SS; CoCrMo; Ti; Ti6Al4V
Otorhinology	Artificial eardrum	316L SS

Stainless Steels

Stainless steel is an iron (Fe) based alloy with at least 11 wt. % chromium (Cr). It may also contain several other alloying elements, such as nickel (Ni), molybdenum (Mo), and manganese (Mn). High corrosion resistance, in combination with good mechanical properties, is the main reason for its wide use specially in relatively aggressive environments, such as sea water, or food, or the human body. Even though the corrosion resistance is high for a given grade, but the low levels of metals can be released from the stainless steel surface in contact with different fluids that causes metal ions sensitivity and toxicity.

Stainless steel was first used successfully as an important material in the surgical field. A wide range of properties exists depending on the heat treatment (annealing to obtain softer materials) or cold working (for greater strength and hardness), and has many types which include:

I- Type 302 & 304 stainless steel was introduced, which is stronger and more resistant to corrosion than the vanadium steel.

II- Type 316 stainless steel was introduced, which contains a small percentage of molybdenum to improve the corrosion resistance in chloride solution (salt water).

III- Type 316L stainless steel. The carbon content was reduced from 0.08 to a maximum amount of 0.03% for better corrosion resistance to chloride solution

and to minimize the sensitization.

The inclusion of molybdenum enhances resistance to pitting corrosion in salt water. The 316L stainless steels may corrode in the body under certain circumstances in highly stressed and oxygen depleted region, such as the contacts under the screws of the bone fracture plate. Thus, these stainless steels are suitable to use only in temporary implant devices, such as bone fracture plates, screws, hip and nails.

The advantages of stainless steels, especially type **316** and **316L** over other grades of steel:

1. Biocompatible.
2. These can be hardened by cold-working.
3. This group of stainless steels is nonmagnetic and possesses better corrosion resistance.
4. The inclusion of molybdenum enhances resistance to pitting corrosion in salt water.
5. Cheaper than other metals.
6. Has high strength, ductility and toughness.
7. Easy machining.

While, in general the disadvantages of stainless steel:

1- Can be corrosion problem.
2- Can be less bone bonding than other metals.
3- May create nickel ion sensitivity.

Co Cr Alloys

There are basically two types of cobalt-chromium alloys:

(1) The Co Cr Mo alloy [Cr (27-30%), Mo (5-7%), Ni (2.5%)]:

Which has been used for many years in dentistry, and relatively recently, in making artificial joints.

The basic elements of the Co Cr Mo alloys form a solid solution of up to 65% Co.

(2) The Co Ni Cr Mo alloy [Cr (19-21%), Mo (9- 11%), and Ni (33-37%)]:

Which has been used for making the stems of prostheses for heavily loaded joints such as the knee and hip. This alloy contains approximately 35% Co and Ni each. This alloy is highly corrosion resistant to seawater (containing chloride ions) under stress.

The molybdenum is added to produce finer grains after casting, which results in higher strengths after casting or forging. The chromium enhances corrosion resistance, as well as solid solution strengthening of the alloy. The corrosion products of Co Ni Cr Mo alloy are more toxic than those of stainless steel 316L, due to may produce cobalt or chromium ion sensitivity/toxicity.

The superior tensile strength of the Co Ni Cr Mo alloy makes it suitable for the applications which require long service life without fracture. While the modulus of elasticity for the Co Cr alloys does not change a values range about (220 to 234) GPa., which are higher than other materials such as stainless steels. While, the changes in their ultimate tensile strength.

The advantages and disadvantage of Co Cr Mo:

1- Cast alloy forms have lower cost than wrought or forged forms.

2- Cast alloys forms have higher elastic modulus than wrought or forged forms.

3- Wrought or forged forms has the highest strength/wear resistance.

4- Hardest to fabricate.

5- May produce cobalt or chromium ion sensitivity/toxicity.