UNIT IV BIOMATERIALS

Biomaterials

Biomaterials are used to make devices to replace a part or a function of the body in safe, reliably economically, and physiologically acceptable manner. A variety of devices and materials are used in the treatment of disease or injury. Commonplace examples include suture needles, plates, teeth fillings, etc.

Biomaterial: A synthetic material used to make devices to replace part of a living system or to function in intimate contact with living tissue.

Biological Material: A material that is produced by a biological system.

Bio-compatibility: Acceptance of an artificial implant by the surrounding tissues and by the body as a whole.

1) Polymeric biomaterials
2) Bioceramics
3) Metallic biomaterials
4) Biocomposite
5) Biologically based (derived) biomaterials

Polymerization

a) Condensation: A reaction occurs between two molecules to form a larger molecule with the elimination of a smaller molecule.
b) Addition: A reaction occurs between two molecules to form a larger molecule without the elimination of a smaller molecule.

Bioceramics

1) Alumina
2) Zirconia (partially stabilized)
3) Silicate glass
4) Calcium phosphate (apatite)
5) Calcium carbonate

Metallic biomaterials

1) Stainless steel (316L)
2) Co-Cr alloys
3) Ti_6Al_4V

4) Au-Ag-Cu-Pd alloys
5) Amalgam (AgSnCuZnHg)
6) Ni-Ti
7) Titanium

Surface modification (treatment)

Physical and mechanical treatment

Chemical treatment

Biological treatment

Surface Properties of Materials

1) Contact angle (Hydrophilic & Hydrophobic)
2) ESCA & SIMS (surface chemical analysis)
3) SEM (Surface morphology)

Deterioration of Biomaterials

1) Corrossion
2) Degradation
3) Calcification
4) Mechanical loading
5) Combined

General Criteria for materials selection

1) Mechanical and chemicals properties
2) No undersirable biological effects
    a) carcinogenic, toxic, allergenic or immunogenic
3) Possible to process, fabricate and sterilize with a godd reproducibility
4) Acceptable cost/benefit ratio

Cell/tissue reaction to implant

1) Soft tissue
2) Hard tissue
3) Blood cells

METALLIC IMPLANT MATERIALS

1) Stainless steel
2) Cobalt-chromium alloys

3) Titanium alloys

a) Must be corrosion resistant
b) Good fatigue properties
c) Other compatible issues

Metallic implants are used for two primary purposes.

To replace a portion of the body such as joints, long bones and skull plates.

Fixation devices are used to stabilize broken bones

a) less chromium content should be utilized (because Cr is a highly reactive metal)
b) Make use of austenite type steel (less magnetic properties)
c) Lowered carbon content
d) Inclusion of molybdenum helps corrosion resistance
e) Electroplating technique (increases corrosion resistance)

COBALT CHROMIUM ALLOYS

Cobalt based alloys are used in one of three forms

a) Cast; as prepared
b) Wrought (fine structure with low carbon contents ; pure forms)
c) Forged

Cobalt based alloys are better than stainless steel devices because of low corrosion resistance

Polymers

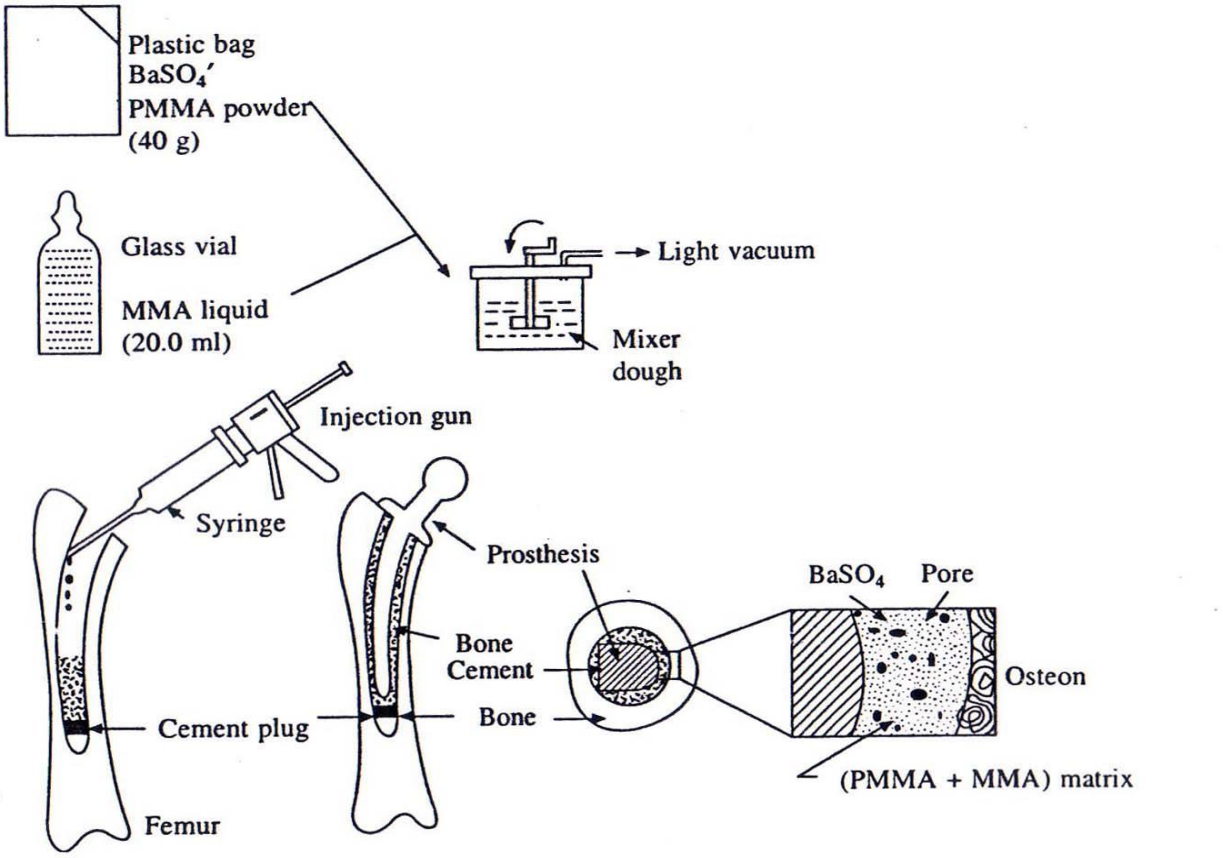
Polyethylene and Polypropylene

a) Suture materials of monofilament polypropylene (Prolene are used clinically.
b) Compared with metal wire, catgut, silk, and polyglycolic acid sutures, propylene product exhibits least fibroblastic response and silk the most in the nerve tissues of rabbits.

ACRYLIC RESINS

a) Simple acrylates have relatively high toughness and strength.
b) The most widely used polyacrylate is poly(methyl methacrylate,PMMA).
c) The features of acrylic polymers are brittle in comparison with other polymers
d) excellent light transparency
e) high index of refraction.

BONE CEMENT MIXING AND INJECTION



HYDROGELS

a) Hydrogels find their name from their affinity for water and incorporation of water into their structure.

b) The concentration of water in the hydrogel can affect the interfacial free energy of the hydrogel,as well as the biocompatibility.

c) Hydrogels have inherently weak mechanical properties.

d) Hence for some applications they are often attached to tougher materials such as silicone rubber, polyurethane or PMMA.

POLYAMIDES

a) Since the hydrogen bonds play a major role in determining properties, the number and distribution of amide bonds are important factors.

b) Nylon tubes find applications in catheters.

c) The coated nylon sutures find wide biomedical applications.

d) Nylon is also utilized fabrication of hypodermic syringes

Soft Tissue Implants

a) Attempts have been made to replace or augment most of the soft tissues in the body
    a) Connective tissues: skin, ligament, tendon, cartilage
    b) Vascular tissue: blood vessels, heart valves
    c) Organs: heart, pancreas, kidney
    d) Other: eye, ear, breast
b) Most soft tissue implants are constructed from synthetic polymers
    a) Possible to choose and control the physical and mechanical properties
    b) Flexibility in manufacturing
c) "Soft tissue implants" can also be designed for soft tissue repair

Sutures

a) Used to repair incisions and lacerations
b) **Important characteristics for sutures::**
c) Tensile strength
d) Flexibility
e) Non-irritating

Tissue Adhesives

a) Used for repair of fragile, non-suturable tissues
    a) Examples: Liver, kidney, lung
b) The bond strength for adhesive closed tissues is not as strong after 14 days as for suture closed tissues

Percutaneous Implants

a) Refers to implants that cross the skin barrier
    a) In contact with both the outside environment and the biological environment
b) Used for connection of the vascular system to external "organs"
    a) Dialysis
    b) Artifical heart
    c) Cardiac bypass
c) Also used for long term delivery of medication or nutrition (IV)
d) Main Problems:
    a) Attachment of skin (dermis) to implant difficult to maintain through ingrowth due to rapid turnover of cells

b) Implant can be extruded or invaginated due to growth of skin around the implant
c) Openings can also allow for the entrance of bacteria, which may lead to infection

Artifical Skin

a) Is actually a percutaneous implant -- contacts both external and biological environments
b) No current materials available for permanent skin replacement
c) Design ideas:
    a) Graft should be flexible enough to conform to wound bed and move with body
    b) Should not be so fluid-permeable as to allow the underlying tissue to become dehydrated but should not retain so much moisture that edema (fluid accumulation) develops under the graft
d) Polymeric or collagen-based membrane
    a) Some are too brittle and toxic for use in burn victims
    b) Flexibility, moisture flux rate, and porosity can be controlled
e) Fabrics and sponges designed to promote tissue ingrowth
    a) Have not been successful
f) Immersion of patients in fluid bath or silicone fluid to prevent early fluid loss, minimize breakdown of remaining skin, and reduce pain
g) Culturing cells *in vitro* and using these to create a living skin graft
    a) Does not require removal of significant portions of skin

Maxillofacial implants

a) Designed to replace or enhance hard or soft tissue in the jaw and face
b) Intraoral prosthetics (implanted) are used to reconstruct areas that are missing or defective due to surgical intervention, trauma, or congenital condition
c) Must meet all biocompatibility requirements
d) Metals such as tantalum, titanium, and Co-Cr alloys can be used to replace bony defects
e) Polymers are generally used for soft tissue augmentation
    a) Gums, chin, cheeks, lips, etc.
f) Injectable silicone had been examined for use in correcting facial deformities; however, it has been found to cause severe tissue reactions in some patients and can migrate
g) Extraoral prosthetics (external attachment) should:
    a) Match the patients skin in color and texture
    b) Be chemically and mechanically stable

c) Not creep, change colors, or irritate skin
d) Be easily fabricated

h) Have been fabricated out of numerous polymers

Biomaterials for organ replacement

Artificial limb

An artificial limb is a type of prosthesis that replaces a missing extremity, such as arms or legs. The type of artificial limb used is determined largely by the extent of an amputation or loss and location of the missing extremity. Artificial limbs may be needed for a variety of reasons, including disease, accidents, and congenital defects.

Design challenges of heart valve prostheses

a) A replaceable model of Cardiac Biological Valve Prosthesis.
b) Thrombogenesis / haemocompatibility
    a) Mechanisms:
        i) Forward and backward flow shear
        ii) Static leakage shear
        iii) Presence of foreign material (i.e. intrinsic coagulation cascade)
        iv) Cellular maceration
c) Valve-tissue interaction
d) Wear
e) Blockage
f) Getting stuck
g) Dynamic responsiveness
h) Failure safety
i) Valve orifice to anatomical orifice ratio
j) Trans-valvular pressure gradient
k) Minimal leakages
l) Replaceable Models of Biological Valves

Lower Limb Prosthesis

a) Components of the Prosthesis
b) Socket- Forms the connection between the residual limb and the prosthesis.
c) Sleeve- Provides suction suspension for prosthesis.
d) Shank (pylon)- Transfers weight from socket to the foot-ankle.
e) Foot-ankle- Absorbs shock and impact and provides stability.

Dental implant

A dental implant is an artificial tooth root replacement and is used in prosthetic dentistry to support restorations that resemble a tooth or group of teeth. There are several types of dental implants. The major classifications are divided into osseointegrated implant and the fibrointegrated implant. Earlier implants, such as the subperiosteal implant and the blade implant were usually fibrointegrated

Biosensors

a) Promising approach to medical diagnostics by patients or in doctors offices
b) Other important applications: pathogens, disease biomarkers, DNA, peroxide, etc.
c) Method of choice for blood glucose in diabetics
d) Rapid diagnostics may lead to more timely and effective treatment