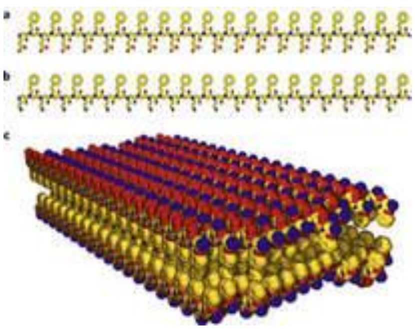


Chapter three

Biopolymers

Biopolymers

There are a large number of polymeric materials that have been used as implants or

part of implant or part of implant systems. The polymeric systems include acrylics polyamides (Nylon), polyesters, polyethylene, polysiloxanes, polyurethane, and a number of reprocessed biological materials.

polymers have little or no competition from other types of materials. Their unique properties are:
1- Flexibility;
2- Resistance to biochemical attack;
3- Good biocompatibility;
4- Light weight
5- Available in a wide variety of compositions with adequate physical and mechanical properties;
6- Can be easily manufactured into products with the desired shape.

Applications in biomedical field as:
1- Tissue engineering;
2- Implantation of medical devices and artificial organs due to its inert nature;
3- Prostheses;
4- Dentistry;
5- Bone repair;
6- Drug delivery and targeting into sites of inflammation or tumors;
7- Plastic tubing for intra-venous infusion;
8- Bags for the transport of blood plasma;
9- Catheter.

major classes

- (PTFE) Polytetrafluoroethylene is a fluorocarbon–based polymer.

Commercially, the material is best known as Teflon. It is made by free-radical polymerization of tetrafluoroethylene and has a carbon backbone chain, where each carbon has two fluorine atoms attached to it.

Properties of PTFE

1-Hydrophobic (Water hating)

2- Biologically inert*: The chemical inertness (stability) of PTFE is related to the strength of the fluorine-carbon bond. This is why nothing sticks to this polymer

3- Non-biodegradable

4- Has low friction characteristics

5- Excellent "Slipperiness"

6- Relatively lower wear resistance.

7- Highly crystalline (94%)

8- Very high density (2.2 $kg.m^{-3}$)

9- Low modulus of elasticity (0.5MPa)

10- Low tensile strength (14MPa)

PTFE has many medical uses, including:

1- Arterial grafts (artificial vascular graft);

2- Catheters;

3- Sutures;

4- Uses in reconstructive and cosmetic facial surgery.

PTFE can be fabricated in many forms, such as:

1- Can be woven into a porous fabric like mesh. When implanted in the body, this mesh allows tissue to grow into its pores, making it ideal for medical devices, such as vascular grafts;

2- Pastes;

3- Tubes;

4- Strands;

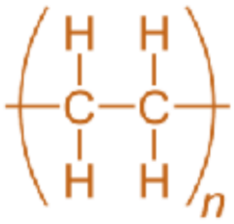
5- Sheets.

Disadvantages of PTFE

PTFE has relatively low wear resistance. Under compression or in solutions where rubbing or abrasion can occur, it can produce wear particles. These can result in a chronic inflammatory reaction, an undesirable outcome.

- **Polyethylene, (PE)**

It is chemically the simplest of all polymers and as a homochain polymer.



It is essentially:

1- Stable and suitable for long-time implantation under many circumstances;

2- Relatively inexpensive;

3- Has good general mechanical properties.

So that it has become a versatile biomedical polymer with applications ranging from catheters to joint-replacement.

- **Polypropylene, (PP)**

Polypropylene is widely used in medical devices ranging from sutures to finger joints and oxy generators.

- **Poly (methyl methacrylate), PMMA**

It is a hard brittle polymer that appears to be unsuitable for most clinical applications, but it does have several important characteristics.

(a) It can be prepared under ambient conditions so that it can be manipulated in the operating theater or dental clinic, explaining its use in dentures and bone cement.

(b) The relative success of many joint prostheses is dependent on the performance of the PMMA cement, which is prepared intraoperatively by mixing powdered polymer with monomeric methylmethacrylate, which forms a dough that can be placed in the bone, where it then sets.

The disadvantages of PMMA

(a) The exotherm of polymerization;

(b) The toxicity of the volatile methylmethacrylate;

(c) The poor fracture toughness.

(But no better material has been developed to date)

- **Polyesters**
- **Polyurathanes**

Denture Base Resins

Although individual denture bases may be formed from metals or metal alloys, most denture bases are fabricated using common polymers. Such polymers are chose based on:

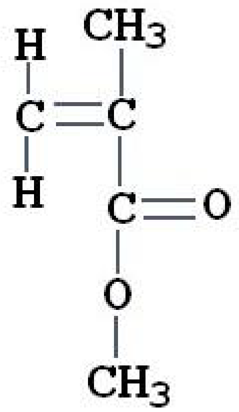
(a) Availability;
(b) Dimensional stability;
(c) Handling characteristics;
(d) Color;
(e) Compatibility with oral tissues.

General Techniques

Several processing techniques are available for the fabrication of denture bases. Each technique is available for the fabrication of an accurate impression of the edentulous arch. Using this impression, a dental cast is generated. In turn, a resin recorded base is fabricated on the cast. Wax is added to the record base and the teeth are positioned in the wax.

Acrylic Resins

Most denture bases have been fabricated using Poly (methyl methacrylate) resins. Such resins are resilient plastics formed by joining multiple methylmethacrylate molecules (PMMA).



Pure PMMA is a colorless transparent solid.

To facilitate its use in dental applications, the polymer may be tinted to provide almost any shade and degree of transparency. Its color and optical properties remain stable under normal intraoral conditions, and its physical properties have proved adequate for dental applications. One decided advantage of PMMA as a denture base material is the relative ease with which it may be processed. PMMA denture base material usually is supplied as a powder-liquid system.

The liquid contains un polymerized MMA, and the powder contains propolymerized PMMA resin in the form of small beads. When the liquid and powder are mixed in the correct proportions, a workable mass is formed. Subsequently,the material is introduced into a mold cavity of the desired shape and polymerized.

Properties of Denture Base Resin

When, methyl methacrylate monomer is polymerized, to form Poly (methyl methacrylate), the density of the mass changes from 0.94 to 1.19gm/cm^3. This change in density results in a volumetric shrinkage of 7%. Based on projected volumetric shrinkage of 7%, an acrylic resin denture base should exhibit a linear shrinkage of approximately 2%.

PMMA absorbs relatively small amounts of water when placed in an aqueous environment. Nevertheless, this water exerts significant effect on the mechanical and dimensional properties of the polymer. PMMA exhibits a water sorption value of 0.69mg/cm^2. Although this amount of water may seem inconsequential, it exerts significant effect on the dimensions of polymerized denture base. Laboratory trials indicate a linear expansion caused by water absorption is approximately equal to the thermal shrinkage encountered as a result of the polymerization process. Hence these processes almost offset one another.

Although denture base resins are soluble in a variety of solvents and a small amount of monomer may be leached, they are virtually insoluble in the fluids commonly encountered in the oral cavity.

The strength of an individual denture base resin is dependent on several factors. These factors include:

(a) Composition of the resin;

(b) Processing technique;

(c) Conditions presented by the oral environment.

the most important determinant of overall resin strength is the degree of polymerization exhibited by the material. As the degree of polymerization increases the strength of the resin also increases.

Resin Teeth for Prosthodentic Applications

PMMA resins used in the fabrication of prosthetic teeth are similar to those used in denture base construction. Nevertheless, the degree of crosslinking within prosthetic teeth is somewhat greater than that within polymerized denture bases. This increase is achieved by elevating the amount of cross-linking agent in the denture base liquid, that is, the monomer. The resultant polymer displays enhanced stability and improved clinical properties.

Despite the current emphasis on resin teeth, prosthetic teeth also may be fabricated using dental porcelain. Hence a comparison of resin and porcelain teeth is provided that:

(a) Resin teeth display greater fracture toughness than porcelain teeth. As a result, resin teeth are less likely to chip or fracture on impact, such as when a denture is dropped;

(b) Resin teeth are easier to adjust and display greater resistance to thermal shock;

(c) Porcelain teeth display better dimensional stability and increasing wear resistance;

(d) Porcelain teeth, especially when contacting surfaces have been roughened often cause significant wear of opposing enamel and gold surfaces. As a result, porcelain teeth should not oppose such surfaces, and if they are used, they should be polished periodically to reduce such abrasive damage;

(e) As a final note, resin teeth are capable of chemical bonding with commonly used denture base resins. Porcelain teeth do not form chemical bonds with denture resins

Materials in Maxillofacial Prosthetic

Despite improvements in surgical and restorative techniques, the materials used in maxillofacial prosthetics are far from ideal. An ideal material should be inexpensive, biocompatible, strong, and stable. In addition, the material should be skin-like in color and texture. Maxillofacial materials must exhibit resistance to tearing and should be able to withstand moderate thermal and chemical challenges. Currently, no material fulfills all of these requirements. A brief description of maxillofacial materials is included in the following :

Latexes

Latexes are soft, synthetic latex is a tripolymer of butylacrylate, methyl methacrylate, and methyl metharylamide. This material is nearly transparent, but has limited applications.

Vinyl Plastisols

They are plasticized vinyl resin sometimes are used in maxillofacial applications. Plastsols are thick liquids comprising small vinyl particles dispersed in a plasticizer. Colorants are added to these materials to match individual skin tones. Unfortunately, vinyl plastisols harden with age because plasticizer loss. Ultraviolet light also has an adverse effect on these materials.
For these reasons, the use of vinyl is limited.

Silicone Rubbers

Both heat-vulcanizing and room temperature vulcanizing silicones are in use today and both exhibit advantages and disadvantages. Room temperature vulcanizing silicones are supplied as single- paste systems. These silicones are not as strong as the heat-vulcanized silicones and generally are monochromatic.
Heat-vulcanizing silicone is supplied as a semi-solid material that requires milling, packing under pressure, and 30-minute heat treatment application cycle at 180_{o}C. Heat vulcanizing silicone displays better strength and color than room temperature vulcanizing silicone.

Polyurethane polymers

Polyurethane is the most recent of the materials used in maxillofacial prosthetics. Fabrication of a polyurethane prosthesis requires accurate proportioning of three materials. The material is placed in a stone or metal mold and allowed to polymerize at room temperature. Although a polyurethane prosthesis has a natural feel and appearance, it is susceptible to rapid deterioration.
The loss of natural teeth, through disease or trauma, has for many years been compensated by the provision of artificial teeth in the form of bridges and dentures.

Natural Polymers

Natural polymers, or polymers, derived from living creatures, are of great interest in the biomaterials field. In the area of tissue-engineering, for example, scientists and engineers look for scaffold on which one may successfully grow cells to replace damaged tissue.
Typically, it is desirable for these scaffolds to be:
(1) Biodegradable;
(2) Non-toxic/ non-inflammatory;

(3) Mechanically similar to the tissue to be replaced;
(4) Highly porous;
(5) Encouraging of cell attachments and growth;
(6) Easy and cheap to manufacture;
(7) Capable of attachment with other molecules (to potentially increase scaffold interaction with normal tissue)

Normal polymers often easily fulfill these expectations, as they are naturally engineered to work well within the living beings from which they come.
Three examples of natural polymers that have been previously studied for use as biomaterials are: collagen, chitosan, and alginate.

Collagen is the most widely found protein in mammals (25% of our protein mass) and is the major provider of strength to tissue. A typical collagen molecule consists of three interwined protein chains that form a helical structure similar to a typical staircase). These molecules polymerize together to form collagen fibers of varying length, thickness and interweaving pattern (some collagen molecules will form ropelike structures, while others will form meshesor networks). There are actually at least 15 different types of collagen, differing in their structure, function, location, and other characteristics. The predominant form used in biomedical applications, however, is type I collagen, which is a "rope-forming" collagen and can be found almost everywhere in the body, including skin and bone.
Collagen can be resorbed into the body, is non-toxic produces only a minimal immune response, and is excellent for attachment and biological interaction with cell. Collagen may also be processed into a variety of formats, including porous sponges, gels and sheets, and can be cross-linked with chemicals to make it stronger or to alter its degradation rate. The number of biomedical applications in which collagen has been utilized is too high to count here, it not only explored for use in various types of surgery, cosmetics, and drug delivery, but in bio-prosthetic implants and tissue engineering of multiple organs as well. Cells grown in collagen often come close to behaving as they do within the body, which is why collagen is so promising when one is trying to duplicate natural tissue function and healing.
However, some disadvantages to using collagen as a cell substrate do exist. Depending on how it is processed, collagen can potentially cause alteration of cell behavior (e.g. changes in growth or movement), have inappropriate mechanical properties, or undergo contraction (shrinkage). Because cells interact so easily with collagen, cells can actually pull and reorganize collagen fibers, causing scaffolds to lose their shape if

they are not properly stabilized by cross-linking or mixing with another less "vulnerable material".
Fortunately, collagen can be easily combined with other biological or synthetic materials, to improve its mechanical properties or change the way cells behave when grown upon it.

Chitosan

It is derived from chitin, a type of polysaccharide (sugar) that is present in the hard exoskeletons of shellfish like shrimp and crab. Chitin has sparked interest in the tissue-engineering field due to several desirable properties:
1- Minimal foreign body reaction;
2- Mild processing conditions (synthetic polymers often need to be dissolved in harsh chemicals; chitosan will dissolve in water based on pH);
3- Controllable mechanical/biodegradation properties (such as scaffold porosity);
4- Availability of chemical side groups for attachment to other molecules.
Chitosan has already been investigated for use in the engineering of cartilage, nerve and liver tissues. Chitosan has also been studied for use in wound healing and drug delivery. Current difficulties with using chitosan as a polymer scaffold in tissue-engineering, however, include low strength and inconsistent behavior with seeded cells. Fortunately, chitosan may be easily combined with other materials in order to increase its strength and cellattachment potential. Mixtures with synthetic polymers such as poly (vinyl alcohol) and poly (ethylene glycol) or natural polymers such as collagen have already been produced.

Alginate

It is a polysaccharide derived from brown seaweed. Like chitosan, alginate can be processed easily in water and has been found to be fairly nontoxic and non-inflammatory enough, so that it has been approved in some countries for wound dressing and for use in food products. Alginate is biodegradable, has controllable porosity, and may be linked to other biologically active molecules. Interestingly, encapsulation of certain cell types into alginate beads may actually enhance cell survival and growth. In addition, alginate has been explored for use in liver, nerve, heart, and cartilage tissue-engineering.
Unfortunately, some drawbacks of alginate include mechanical weakness and poor cell adhesion. Again, to overcome these limitations, the strength and cell behavior of alginate have been enhanced by mixing with other materials, including the natural polymers agarose and chitosan