**Synthetic Non-Biodegradable Polymers:**

Synthetic polymers have been widely used in making various medical devices, such as disposable supplies, implants, drug delivery systems and tissue engineering scaffolds. The advantages of using polymers, as biomaterials, are their *manufacturability*. Polymers are easy to fabricate into various sizes and shapes compared to metals and ceramics. They are also *light in weight* and with a *wide range of mechanical properties* for different applications.

1. **Polyethylene:**

There are three type of polyethylene: linear high-density polyethylene

(HDPE), branched low density polyethylene (LDPE) and ultrahigh molecular weight polyethylene (UHMWPE). HDPE and UHMWPE are frequently used as biomaterials.

* 1. **High Density Polyethylene:**

High-density polyethylene (HDPE) is a very inert material with very low tissue reactivity. It has been used as bone and cartilage substitutes since 1940s. More than 30 years of follow-up results showed favorable response to these HDPE implants. Therefore, HDPE has become a standard reference material for biocompatibility testing. Histological examination of HD implants reveals a lack of minimal inflammatory and foreign body reactions.

When HDPE was fabricated into porous scaffolds, it has the added advantages of allowing fibrous tissue ingrowth into the implant. The ingrowth of the fibrous tissue will provide adequate stabilization in a non-load-bearing environment. MedPor is a porous HDPE product fabricated by sintering HDPE microbeads in a mold to create implants with interconnected porous structure. The average pore size in this material is greater than 100 µm and the pore volume is in the 50% range. These materials are readily available in a variety of preformed shapes and can be customized with a scalpel easily.

The pore size and porosity is very important for tissue ingrowth. Studies have shown that pore size larger than 100 µm encourages tissue ingrowth. The tissue ingrowth results in firm attachment and integration of the implant to the surrounding tissue leading to decreased migration of the implant, thus obviating the need for screw or suture fixation in some cases.

Porous HDPE has been successfully used for cranioacial applications, such as chin, malar area, nasal reconstruction, ear reconstruction, orbital reconstruction, and the correction of craniofacial contour deformities.

* 1. **Ultrahigh Molecular Weight Polyethylene:**

UHMWPE is produced as powder and must be consolidated under elevated temperatures and pressures because of its high melt viscosity—the result of ultra-high molecular weight. As already discussed previously, as the molecular weight increase, the molecular chain of PE start to entangle each other, so UHMWPE does not flow like lower molecular weight polyethylene when raised above its melting temperature. For this reason, many thermoplastic processing techniques, such as injection molding, screw extrusion, or blow molding, cannot be used for UHMWPE fabrication. Therefore, compression molding is a common method to produce finished or semi-finished UHMWPE.

UHMWPE possesses many attractive properties, notably high abrasion resistance, low friction, high impact strength, excellent toughness, low density, ease of fabrication, biocompatibility, and biostability. These properties make it very attractive for use in fabricating bearing surfaces in arthroplasties. In fact, UHMWPE is the sole material currently used for the manufacture of the liner of the aceabular cup in total hip arthroplasties (THAs) and the tibial insert and patellar component in total knee arthroplasties. In these cases, the clinical performance of the components is considered to be very good except for the concern about their wear.

Hip replacement is one of the world's most common operations, with approximately half a million diseased or damaged joints replaced annually worldwide. The number of procedures is growing with a commensurate increase in revisions. After a number of failed attempts with fluorocarbons, success was achieved in the early 1960s in the production of total joint replacements (TJRs) with UHMWPE. This remains the preferred material because of its exceptional mechanical properties, chemical inertness, impact resistance, and low coefficient of friction.

The problem with the use of UHMWPE is the wear debris that will evoke a series of undesirable effects. It has been hypothesized that these particles are phagocytosed, resulting in many "reactions": formation of grannulamatous lesions, osteolysis, and bone resorption.

**2-Poly(methyl methacrylate):**

In 1943, a protocol for the chemical production of bone cement was established in the companies of Degussa and Kulzer. A lot of research and development work has been done since then. In 1958, Sir John Charnley first succeeded in femoral prosthesis in the femur with self-polymerizing PMMA. Since then, the PMMA bone cement (now known simply as bone cement) emerged as one of the premier synthetic biomaterials in contemporary orthopedics. It is currently the only material used for cemented arthroplasties to the contiguous bones.

A typical PMMA bone cement consists of two parts, a solid part in a packet and a liquid part in a vial (See Table 11. 2). When the two parts are mixed before use, the viscosity of mixture will gradually increase and become the dough in a few minutes. The dough will harden in another few minutes. This process actually involves a MMA polymerization process. Polymer PMMA is used to minimize the shrinkage and the heat release caused by the polymerization of monomer MMA, because the pure MMA will exhibit a shrinkage of about 21% due to the change of density and the heat release which can cause the temperature to increase to over 100°C.



Heat stable antibiotics, such as gentamycin, tobramycin, erythromycin, vancomycin, cephalosporin, can be added in a powder form to the powder part. Antibiotics can be slowly release to eliminate possible infections of the surgery.

**3-Polyester:**

Polyester is a family of polymers which have ester linkage connecting the polymers.



Among the polyester family, poly(ethylene terephthalate) (PET) is the world leading synthetic fibers and films. The typical synthetic reaction of PET uses dimethyl terephathalate and ethylene glycol.



The synthesis of PET is a two-step process. First, dimethyl terephthalate is heated with ethylene glycol to obtain low molecular weight oligomers of PET. Then the mixture is heated to a higher temperature of 250°C under vacuum to further promote the condensation reaction. The byproduct methanol is removed using vacuum and heat.

PET is considered to be biocompatible. It has very good mechanical properties. Therefore, PET fibers and the structures made from fibers, such as woven, knitted, felted and braided structures, are used as sutures, internal patches, pledgets, ligamentous prosthesis, artificial blood vessels, heart valve sewing cuffs, etc.

**4- Polycarbonate:**

Polycarbonate family polymers have carbonate linkages in their polymer chains.



Polycarbonate can be synthesized by the reaction of phosgene with bisphenol A [2,2-bis(4-hydroxyphenyl) propane]. The obtained PC is a tough and transparent plastic commercially available.

Polycarbonate is used to make components for oxygenator for open heart surgery, venous reservoir, and arterial filter due to its sterilizability, ease of processing, biocompatibility, and clarity.



**5- Poly amides:**

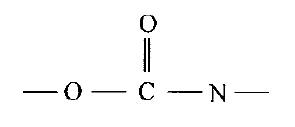
 Polyamide polymers (nylon) have amide linkages in their polymer chains.

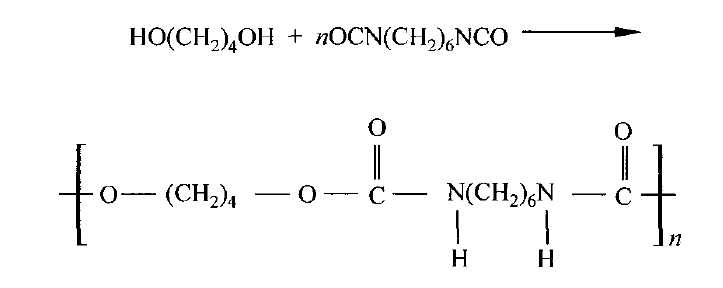
The first polyamide synthesized was Nylon-66. It was synthesized through the polycondensation of hexamethylenediamine and adipic acid . Nylon has been used as surgical sutures.



**6- Polyurethane:**

Polyurethanes are a class of polymer with urethane linkage:



Typically, polyurethane is synthesized by the reaction of dihydric alcohols and diisocyanates. For example, a crystalline polymer can be prepared by the reaction of 1, 4-butanediol and hexamethylene diisocyanate as shown below .

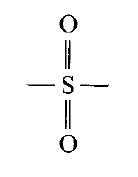
Polyurethane elastomers are frequently used as biomaterials due to their excellent fatigue resistant properties and biocompatibility, good blood compatibility, low toxicity, good thermal and oxidative stability, low modulus, and anti-adhesive nature.

The biodegradation of polyurethane has been extensively studied. It has been found that several factors, such as chemical agents, stress, metal ions, physiological fluids, cells and enzymes are closely related to the polyurethane degradation *in vivo*.

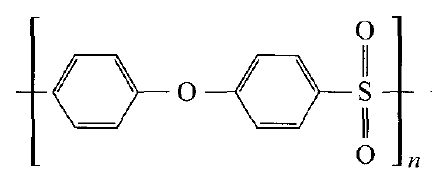
Polyester urethanes are generally hydrolytically unstable when implanted in the human body, and therefore, their use is limited. Poly ( ester urethanes) have been used as catheters and gastric balloons which only need to be used for a short period of time. These poly( ester-urethanes) are especially unstable in acidic environments. The acid-catalyzed hydrolysis of the ester linkage promotes further degradation of the poly( ester urethanes) by cleaving the ure­thane linkage. On the other hand, poly( ether urethanes) are hydrolytically sta­ble. But they undergo *in vivo* degradation via different mechanisms, such as auto-oxidation, metal ion oxidation and environmental stress cracking.

Because of their excellent mechanical properties and biocompatibility, segmented polyurethanes have been frequently used in the medical devices in the past two decades as blood contacting materials, such as totally implantable artificial hearts and left ventricular assist devices ( VADs) . Poly ( ether ure­thanes) were introduced as pacemaker lead insulators due to their hydrolytic stability.

**7-Polysulfones:**

Polysulfons are a family of polymers, which have sulfone linkages in their backbones.

Polysulfones have excellent mechanical properties and chemical resis­tance. One of the important polysulfones is poly( aryl sulfones) .



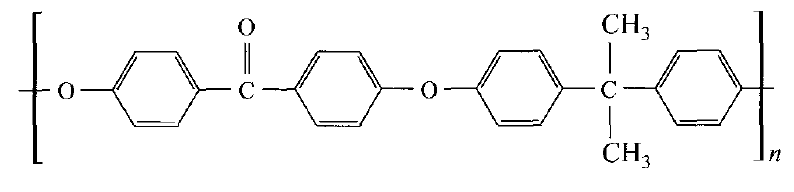
Some of the characteristics of polysulfones are:

1. Heat resistant: Heat deflection temperature ( HDT) 174°C;
2. Excellent hydrolytic stability to hot water and steam sterilization;
3. Excellent chemical resistance to inorganic acids & bases;
4. Food, water and medical contact compliance.

They are used as membranes for hemodialysis. Polysulfones have been used as orthopeadic biomaterials due to their excellent mechanical properties ( tensile modulus – 2. 4 GPa). To improve their bone-bonding properties, polysulfones were used to make composites with bioactive glass.

**8-Poly( ether ether ketone):**

The structure of Poly( ether ether ketone) (PEEK) :



PEEK is a crystalline polymer with a glass transition temperature of 145°C. The most common form of PEEK is the one shown, derived from Bisphenol A, although limitless variations are possible, and a few are commercially pro­duced. PEEK is a remarkable material, highly crystalline, thermally stable, resistant to many chemicals, and very tough. It can be melt-processed at very high temperatures ( >300°C), and is useful for special applications like pipes in oil refineries and chemical plants, and parts for scientific instruments, aero­space and biomedical devices where high price is not a limitation.